

Lifting the Level of Awareness on Pigeonpea – A Global Perspective



MG Mula and KB Saxena

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Lifting the Level of Awareness on Pigeonpea – A Global Perspective

MG Mula and KB Saxena



International Crops Research Institute
for the Semi-Arid Tropics

Patancheru 502 324, AP, India

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About this book

Lifting the Level of Awareness on Pigeonpea - A Global Perspective is an extensive research publication based on secondary materials written primarily to provide comprehensive information on pigeonpea to popularize it as a major legume crop. This book will serve as a reference for all stakeholders involved in the production of this crop, particularly farmers, traders, policymakers and scientists. The book focuses mainly on the crop's production system, research and development (R&D) efforts, economic significance and recommendations with information on geographical background and agricultural system of each country where the crop is grown.

In the concluding chapter, readers will find the authors' recommendations on the environmental and economic significance of this crop, and its commercial viability.

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Foreword



Agriculture is increasingly becoming vulnerable and sensitive to limiting factors such as land availability, climate change effects and the growing frequency of extreme events. Increasing population and rising per capita incomes are fuelling growth in demand for food and feed. Diversification is an option that is waiting to be explored.

Lifting the Level of Awareness on Pigeonpea – A Global Perspective is the result of extensive research based on secondary materials, written primarily to provide comprehensive information on pigeonpea.

Pigeonpea is a crop with huge potential that makes a significant contribution to the food and nutritional security of people. It can be consumed raw, roasted, boiled and further processed as flour and decorticated grain. Being a legume, it contributes towards improving soil fertility by fixing nitrogen in the soil, saving on external application of fertilizer and enhancing the sustainability of agricultural production systems. Given the crop's versatile nature, it could substantially contribute to people and the environment. While some domains have been exploited, there are yet some others waiting to be explored.

The book dwells on the geographical coverage, farming system, commercialization, and economic value of the crop. It is anticipated that this synthesis of information will popularize the legume by providing a reference source accessible to various types of interest groups.

The book is a must read since it provides a synopsis of specific areas needing further research. It also allows households, nutritionists, those in the food industry, and others to know and maximize the crop's uses. Ultimately, the objective is to enhance awareness that will lead to the adoption of pigeonpea cultivation.

A handwritten signature in black ink, appearing to read "William D. Dar".

William D Dar

Director General, ICRISAT

Introduction

The seed of the pigeonpea [*Cajanus cajan* (L.) Mills.] plant is not really a pea as its name implies but it is actually a grain legume (pulse). Small-scale farmers of rainfed agriculture in the arid and semi-arid tropics (SAT) cultivate this legume as backyard plant, grow them on the field bunds or use them as intercrop or mixed crop. This crop is unique as it is both a legume and a woody shrub. It has an inherent ability to withstand environmental stress, specifically short periods of drought. Considered as a traditional food crop, it is a major income generator in many households (Areke 2004). Farmers mostly grow the local pigeonpea types that mature in about a year (9-11 months). The green pods are used for various vegetable dishes. Recently, its use as a fodder crop has increased primarily because of its ability to increase milk in livestock and meat in poultry (Duke 1981).

Today, pigeonpea is an important food grain legume in Asia, South America and in southern and eastern Africa. In these parts of the world, pigeonpeas are grown either for canning or split pulse (*dal*). Since the crop is widely cultivated in small plots or in the backyards, it is difficult to estimate its true production. In the Caribbean region, the fresh green seeds are a popular vegetable. Fresh green seeds are exported to the Dominican Republic, Jamaica, Kenya and Uganda while dry seeds are imported by India from Myanmar. Otherwise, almost all pigeonpeas are consumed locally in the countries of production (foodnet@iitaesarc.co.ug).

Initiatives to improve pigeonpea first took place in India in the 1920s. Since then, many lines have been developed and released through the selections from landraces. The action of the Consultative Group on International Agricultural Research (CGIAR) giving global importance to pigeonpea has opened an important window for research and development towards the improvement in productivity of this crop. Moreover, since its inception in 1972, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) was given the mandate to serve as the world's center for the improvement of pigeonpea because of its importance to sustainable agriculture and to people who survive mainly on a vegetarian diet.

Basic knowledge about the crop's anatomy and physiology has been studied and disease-resistant and pest-tolerant cultivars have been produced.

Collaborative research has been focused on identifying high yielding cultivars and hybrids for short, medium, and long duration lines in suitable agronomic environment and prospects.

On the whole, this book provides relevant information on the pigeonpea production system in major and minor producing countries. Data were collected from literature focusing on the description of pigeonpea farming systems as well as its socio-economic trends. It is hoped that with the presentation of a global perspective on the production, consumption and marketing of this crop, all stakeholders will be provided with a better road map on this subject.

CHAPTER I

A Historical Perspective: The Origin, Taxonomy, Domestication, Vernacular and Regional Genetic Improvement of Pigeonpea

Origin

There has been a major dispute among historians on the origin of pigeonpea. Van Rheede (1686) considered pigeonpea a native of East Indies while Rumphius (1747) claimed that pigeonpea is a native of Malaya. Some authorities however claimed that it originated in Africa. De Condolle (1886) wrote that the early Africans grew pigeonpea from the coast of Guinea to Zanzibar up to the Nile valley. The presence of pigeonpea seeds in the Egyptian tombs of the Seventh Dynasty, including the discovery of a wild species (*Cajanus kerstingii*) and a single endemic species *Cajanus kerstingii* Harms in West Africa (Purseglove 1968, Rachie and Roberts 1974, Brouk 1975 and Brucher 1977), support this claim. However, Watt (1908) reported that early wild species were also prevalent in China and Indochina. On the other hand, De (1974) believes that *Cajanus* species, together with the closely related *Atylosia* were first established in Northern India and on the Deccan Plateau 3,500 years ago. Of these claims, historians agree that the true origin of pigeonpea is India particularly in the Eastern Ghats (Vavilov 1951, De 1974, Royes 1976, van der Maesen 1980, 1991). Excavations in the Maharashtra State in India turned up pigeonpea seeds dating back from the 2nd century BC to the 3rd century BC (Kajale 1974). Moreover, the presence of several wild relatives of this seed in India, the large diversity of the crop's gene pool thereat, a few archaeological remains and ample linguistic evidence, such as its wide usage in the daily cuisine (van der Maesen 1983) supported the conclusion arrived at. Furthermore, the early Asiatic name of the species *Cajanus cajanifolius* 'kayan', which is believed to be of Indian origin (Vavilov 1951) all the more convinced historians that pigeonpea indeed originated in India. Besides, India and Myanmar account for 16 related wild species among which is the *Cajanus cajanifolius* (Haines) considered as the probable progenitor of pigeonpea (De 1974). This same species has been found at three locations in India 3,000 years ago. As to any links to Australia as the origin of pigeonpea, this has been ruled out since the island continent

was separated from Asia in the upper Cretaceous and was limited in the Pleistocene era through the Indonesian archipelago (van der Maesen 1991). Also, Australia has 15 wild relatives of pigeonpea of which 13 are endemic. *Cajanus* progenitors must have evolved along different lines in Australia and Asia because no species are common in these two continents.

As regards Africa, it has only one close wild relative of pigeonpea - the *C. kerstingii* Harms (van der Maesen 1979). In Southeast Asia, a few species appeared including the *Cajanus volubilis* (Blanco), a species related to *C. crassus* (Prain ex King), which is restricted in the drier parts of the islands of Indonesia and the Philippines (van der Maesen 1979).

Taxonomy

Pigeonpea is the only cultivated food crop of *Cajaninae* subtribe of the economically and most important leguminous tribe *Phaseoleae*, which contains many bean species consumed by human beings. Within the tribe *Phaseoleae*, the subtribe *Cajaninae* is well distinguished by the presence of vesicular glands on the leaves, calyx and pods. The cultivated pigeonpea stands alone as a crop species in the subtribe to which most species outside the cultivated pigeonpea gene pool or at most in its tertiary gene pool belong while several *Cajanus* species can be placed in the secondary gene pool (Harlan and de Wet 1971). The subspecies classification of Harlan and de Wet was not followed in *Cajanus* but their concept of gene pools was useful in classifying the genetic materials (Table 1). Lackey (1977, 1978 and 1981) reviewed the *Phaseoleae* as a group and realigned Bentham's classical classification (Bentham 1837, Bentham and Hooker 1865) taking into account the genera described since the last century. Baudet's (1978) classification differs from that of Lackey in minor detail.

In 1986, van der Maesen revised the taxonomy of *Cajanus* DC. Its nearest relatives, earlier commonly classified in *Atylosia* W. and A, do not differ sufficiently from *Cajanus* to warrant genetic status (Table 1). Morphological, cytological, chemical and hybridisation data support this merger even if the needed taxonomic changes are inopportune. The scientific classification of pigeonpea is kingdom (Plantae), division (Magnoliophyta), class (Magnoliopsida), order (Fabales), family (Fabaceae), genus (*Cajanus*), species (*C. cajan*) and the binomial name is *Cajanus cajanifolius* (Linnaeus) Millspaugh.

Table 1. Gene pools of pigeonpea.

Gene pool	Species
Primary	<i>Cultivar: Cajanus cajan</i>
Secondary	<i>Cajanus acutifolius, C. albicans, C. cajanifolius, C. lanceolatus, C. latisepalus, C. lineatus, C. reticulatus, C. sericeus, C. scarabaeoides var. scarabaeoides, C. trinervius</i>
Tertiary	<i>C. goensis, C. heynei, C. kerstingii, C. mollis, C. platycarpus, C. rugosus, C. volubilis, other Cajaninae (eg, Rhynchosia, Dunbaria, Eriosema), other Cajanus spp,</i>

Domestication

Despite the contrasting opinions about the domestication of pigeonpea, ancient Sanskrit sources clarified the early travels of this crop. Historians believed that the crop traveled from India to Malaysia, then to East Africa, then up the Nile Valley to West Africa, then traveled to Zaire or Angola prior to the main slave trade. When Columbus discovered America, the people of African origin were taken as slaves and pigeonpeas traveled to the new world with the slaves. This was the time when pigeonpea started gaining popularity and it was cultivated widely. The crop has maintained its reputation since then, and even now it is being widely demanded (CRNIndia.com 2008).

History of Pigeonpea's Vernacular

The Latin name *Cajanus cajan* came from a Malay word *cachang*, which in turn was a corrupt form of the Telugu word *kandi*. The Telugu word has its origin in the Sanskrit word *kaand* (a stem), a reference to the long stem of the pigeonpea plant (Royes 1976). The name pigeonpea was first reported in Barbados where the seeds were once considered as pigeon feed (Plukenet 1692).

In India, the oldest Sanskrit word for pigeonpea seems to be *adhaki*. Both Charaka (c. 700 BC) and Susruta (c. 400 BC) have used the term *adhaki*

(Krishnamurthy 1991, Vidyalankar 1994). The same name, *adhaki*, appears in Buddhist and Jain literature (200 BC–300 AD) and in subsequent writings until the 16th century. The word *adhaki* originated most likely from the word *ardha*, meaning ‘one-half’ or ‘split into two parts’. Dry whole pigeonpea seed is rarely consumed; only the *dal* is commonly eaten. In the Indian subcontinent, one of the two common names used for pigeonpea is *arhar*. It is logical to assume that *arhar* is a corrupt form of *adhaki*. The second common name for pigeonpea is *tuvara*. In Sanskrit, *tuvara* or *tubara* means astringent. The green seed, which is being consumed in Gujarat for centuries, has an astringent taste. This might have led to the word *tuvara* and its variants, *tuvarika*, *turri*, *tur*, etc. It is interesting to note that the word *arhar* is common in northern India, and *tuvara* (with variants) in southern India. The Sangam literature of the Tamil people (100 BC–300 AD) does not mention pigeonpea, indicating that this plant found a place in Tamil kitchens in the later centuries (Achaya 1998).

The names of pigeonpea in the American hemisphere are derived from African and European vernacular. The Portuguese ‘guandu’, Spanish ‘gandul’ and Egyptian ‘gandoles’ may have been derived from the Indian Telugu word ‘kandulu (van der Maesen 1986), or have African roots, such as Gabonese Fioffe ‘oando’. Guando or Guandul is a corruption of *cajan*, the name pigeonpea took from the Malay *Cachang*. However, the names Angola pea, Congo pea, Kachang bali, Ads Sudani, Cajan des Indes, Puerto Rican pea, Lentille du Soudan and Indischcher Bohnenstrauchall point to origins where most of the names are of European languages like the term pigeonpea itself, which was not framed earlier than the 16th century. According to van der Maesen (1986), there are about 350 recorded names of pigeonpea, however, to this writing, a total of 792 vernacular names were recorded covering 140 countries (Appendix 1).

Regional Genetic Improvement of Pigeonpea

Pigeonpea landraces (Figure 1) of cultivated types and their wild relatives (Figures 2, 3, 4, 5, 6, 7) offer a unique gene pool, which plays an important role in the genetic improvement of crop plants. Breeders turn their attention to the wild relatives of crops after an unsuccessful search for some unique trait in the cultivated germplasm. The wild relatives of cultivated species are important sources of genetic agronomic traits, including resistance to various biotic and abiotic stresses and seed quality. According to Dundas



*Figure 1a. Pigeonpea landrace
in the Philippines.
(Photo: M Palaje)*



*Figure 1b. Pods of landrace.
(Photo: M Palaje)*



*Figure 1c. Pigeonpea green
seeds and pods sold
in the Philippines.
(Photo: F Sugui)*

Figure 2. C. albicans.
(Photo: ICRISAT)

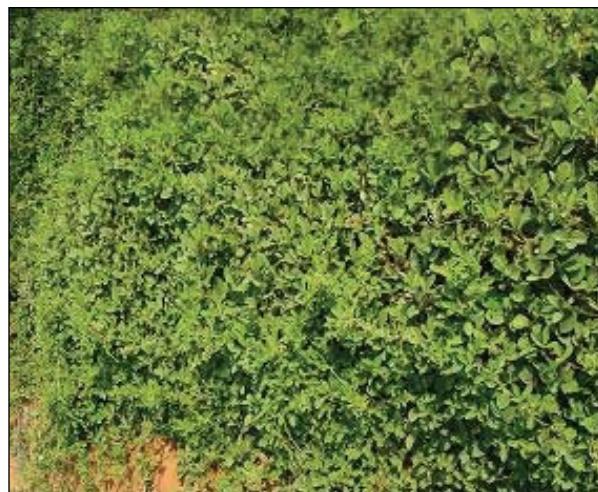


Figure 3. C. scarabaeoides.
(Photo: ICRISAT)

Figure 4. C. sericeus.
(Photo: ICRISAT)





Figure 5. C. cajanifolius.
(Photo: ICRISAT)



Figure 6. C. lineatus. (Photo: ICRISAT)



Figure 7. *C. acutifolius*. (Photo: ICRISAT)

(1990), the utilization of wild species in pigeonpea improvement comes from the secondary gene pool in view of the fact that the normal chromosome recombination helps in the transfer of useful genes to cultivars. Therefore, enrichment of the gene pool should be a continuous process for the long-term benefit of the crop improvement programs.

As mentioned earlier, there are 32 species of genus *Cajanus* and India embraces 18 species (van der Maesen 1986). ICRISAT has the global responsibility of collection, maintenance and evaluation of germplasm of the

wild relatives of pigeonpea. At present, a total of 13,632 accessions from 74 countries are stored at the gene bank (Upadhyaya 2007). Of this, 13,077 accessions belong to the primary gene pool (Harlan and de Wet 1971) with vast genetic variation (Table 2) for important agronomic traits (Remanandan 1990). Saxena (2000) revealed that pigeonpea breeders have effectively utilized both inter and intra accession variability of the primary gene pool in developing high yielding varieties and useful genetic stocks.

Table 2. Phenotypic variation for important economic traits in pigeonpea germplasm at ICRISAT genebank.

Trait	Range	
	Minimum	Maximum
Days to 50% flowering	55.0	237.0
Days to 25% maturity	97.0	299.0
Plant height (cm)	39.0	385.0
Primary branches (no.)	2.0	66.0
Secondary branches (no.)	0.3	145.0
Racemes (no.)	6.0	915.0
Seeds per pod (no.)	1.6	7.6
100 – seed mass (grams)	2.8	25.8
Harvest index (%)	0.6	62.7
Shelling ratio (%)	5.7	87.5
Seed protein (%)	12.4	29.6

Asia

India's pigeonpea research and development (R&D) program is very extensive compared to other countries where it is grown because the crop is regarded as one of India's staple foods. The first documented research effort was conducted by Mahata and Dave in 1931 who identified a few elite early and late maturing high yielding types of pigeonpea. But the first scientific breeding effort was established by Shaw (1933) who described the morphological and agronomic traits of 86 elite field collections in which some accessions were found to have high levels of resistance to *Fusarium* wilt disease. Crop improvement involving field collections and their evaluation

continued for more than two decades without any significant impact on productivity.

The Indian Council of Agricultural Research (ICAR) embarked on an all-Indian coordinated mega pigeonpea crop improvement project in 1965 involving thirty one research centers in diverse agro ecological zones (Ramanujam and Singh 1981). The focus of the project was to assemble pigeonpea germplasm, identify sources of disease and insect resistance and develop high yielding varieties of early, medium and long maturity groups. As part of this project, sixty-four pure line varieties were released from selections of pure line germplasm. Among these lines, twenty-nine were selections from germplasm collected from farmers' fields, thirty varieties were bred from single or double crosses and five were mutants (Singh et al. 2005). The impact of these breeding efforts paved the way for an increase in area (56%) and subsequently increase in total grain production by 54% but failed to improve productivity of the crop.

In 1991, the world's first pigeonpea hybrid, ICPH 8, based on Genetic-Male Sterility (GMS) system was released by ICRISAT and ICAR. Despite demonstrating high yields, the crop cannot be upscaled because of high costs and the inherent constraints associated with seed multiplication of female parents, which was a hindrance in large scale hybrid seed production. To overcome the constraints of this unacceptable technology, scientists from ICRISAT developed hybrids through the cytoplasmic male-sterility (CMS) system, the most widely accepted means of producing commercial hybrids in a number of field crops. In 2005, the first breakthrough of this technology was achieved by crossing *Cajanus cajanifolius* (a wild species) and a cultivated line. This CMS system is stable across diverse environments and has an excellent fertility restoration system (ICRISAT 2009). Among medium duration hybrids, ICPH 2671, which matures in 170-180 days produced 41.6% greater yield than control Maruti in 21 trials conducted from 2005 to 2007 (Saxena 2007). After the development of a stable CMS system, several experimental hybrids were produced and evaluated.

In Myanmar, generally, local landraces of pigeonpea are grown and selections from these have also been released for cultivation exclusively for export. In 1998, pigeonpea was included as one of the seven crops planned for multiplication and evaluation by the Seed Bank of the Central Agriculture Research Institute, Yezin. Forty pigeonpea accessions were

planted for characterization and preliminary evaluation at the Tropical Crops Research Farm, Nyaung-U. Among these, four accessions belong to local collection and the rest were introduced from ICRISAT (Kyi et al. 2001). ICPL 87, ICP 7035 and a local five-seeded pigeonpea were added as checks for short-, medium-, and long-duration, respectively. The earliest accession was ICPL 85010 with a minimum of 145 days to 75% maturity when compared with the three checks. ICPL 87 (short duration) matured in 174 days, ICP 7035 (medium duration) in 199 days and the local five-seeded variety (long duration) in 217 days. With continuous collaboration, ICRISAT supplied a total of 3,000 pigeonpea lines to the Food Legumes Division for testing and from this material, four pigeonpea varieties: Yezin-1 (HPA-1), Yezin-2 (BR-172), Yezin-3 (ICPL 87), and Yezin-4 (ICPL 93003) have been released for commercial cultivation (www.icrisat.org 2004).

In Nepal, pigeonpea breeding programs are based on selections from landraces and those introduced from ICRISAT lines. Long-duration varieties such as Bahar, Rampur and Rahar are commonly planted. In the Philippines, the long-duration types are grown as a backyard crop for vegetable purpose. A recent development is the adoption of early-maturing variety from ICRISAT ICPL 88039 after rice in the rainfed areas of North Luzon (Saxena 2008a). In Sri Lanka, pigeonpea was promoted on a large scale in the 1950s with the introduction of 'T64' and 'T85' indeterminate varieties but this failed due to *Helicoverpa armigera* infestation. In 1970, 'MI 10' (short-stature variety) was developed with yield as high as 1.3 tons/hectare in 1974. But again, the pod borer *Maruca testulatis* brought pigeonpea cultivation to an inoperative state. Although no longer grown as a field crop, long duration and perennial pigeonpea 'Gujerat' cultivar can still be found in home gardens and backyards in Sri Lanka. 'Tur 5' and 'Tenkasi' are also extensively grown (Duke 1981).

According to Zhoujie (1997), the introduction of pigeonpea in China goes back 1,500 years. The landraces have been preserved and are still grown in various provinces of southern China. These provinces include Yunnan, Guizhou, Hainan and Guangxi where large extent of pigeonpea was cultivated until 1989 for lac production and fuel wood (Zhenghong et al. 1997). The crop spread to some areas in Guangdong, Jiangxi, Sichuan, Fujian and Hunan provinces. In these nine provinces, pigeonpea is maintained in hilly forests and in the backyards of some farmers. These landraces contain significant variation for different traits, however, there is no systematic effort put in place to collect, evaluate and preserve this wealth of germplasm. The

first pigeonpea collection mission was undertaken as early as 1960 in some areas of Yunan province. About 20 landraces were collected, but there is no record of availability of this material at the Institute of Insect Resources, Chinese Academy of Forestry, Kunming. The second collection mission was undertaken sometime in 1980s. In this mission 28 landraces were collected and the documentation record of some of their agronomic characters is available. During 1996-98, the third pigeonpea collection mission was undertaken and 76 landraces were collected from Lincang, Cuxiong, Simao and other states. Through these initiatives, researchers listed six wild relatives of pigeonpea following the detailed description of these species with respect to their distribution and morphology as identified by van der Maesen (1986) in his monograph. These are *Cajanus crassus* (Prain ex King) van der Maesen; *Cajanus goensis* Dalz.; *Cajanus grandiflorus* (Benth. ex Bak.) van der Maesen comb. nov.; *Cajanus mollis* (Benth.) van der Maesen comb. nov.; *Cajanus niveus* (Benth.) van der Maesen comb. nov.; and *Cajanus scarabaeoides* (L.) Thouars (Saxena et al. 2001).

These germplasm lines contain significant genetic variability for seed color, seed shape, flower color and pod color. In Yunnan Province, the landraces having a life span of 5-10 years have been cultivated for a long time and are similar in maturity. The variation among the landraces for color of flower, pod and seed was significant. The flower color was red, yellow, or mixed while the seed color included white, cream, grey, dark brown and variegated. In Guizhou Province, pigeonpea germplasm was collected in 1987 from the adjoining areas of Guizhou and Guangxi provinces which represented 10 counties located in the Nanpan river valley. Although the record of the genetic variation in the collection is available, the number of collections was not recorded. The materials gathered had large variation for important aspects of the plant, such as, flower and pod color, plant height, maturity, seed size, seed color and seed shape. The plant height in the germplasm varied between 3 m and 6 m when perennial (1-4 years old) plants were measured. Plants with both red and yellow flower colors were found. The mature pod colors observed were brown, yellowish brown and dark brown while the seed colors were cream, brown, or dark brown. The 100-seed mass was 8-10 g. Analysis of nutritional contents of whole seed samples showed that the protein content was 16-19%, lipid content 1.5% and starch content 38.8 to 45.6%. The local landraces were commonly distributed in river valleys with elevation ranging from 380 m to 700 m. Most of the landraces were found growing in the hills and forests (Feijie et al. 1991, Julin and Xunsheng 1991).

In Hainan Province, 25 pigeonpea landraces were collected during a national crop germplasm collection mission. The collections were classified into two groups: yellow-flowered pigeonpea and double color-flowered pigeonpea. Most of the yellow-flowered pigeonpeas were short in height and early in maturity and the dorsal and ventral surfaces of the flowers were yellow. Matured pods were small, yellow-brown in color and have 2-3 seeds. The seed color was cream with dark speckles. Most perennial pigeonpea landraces had mixed flower color. This group was characterized by high vigor, large plant size, late maturity and yellow flower color with red stripes. The pods were brown or dark brown when mature with 4-5 seeds per pod, which were round or oval and black or light grey. The plant height was 1.5-3.5 m. Pigeonpea landraces in Hainan Province were found in marginal lands or in backyard gardens (Xuxiao et al. 2001).

ICRISAT's collaboration with China on pigeonpea research started in 1997. The introduction of 18 ICRISAT advanced breeding lines was initiated by the Institute of Crop Germplasm Resources (ICGR) of the Chinese Academy of Agricultural Sciences (CAAS) for evaluation in Nanning (Guangxi Province), Ganzhou (Jiangxi Province) and Haikou (Hainan Province). In Nanning and Ganzhou, the crop performed well with seed yield of 1-2 t/ha while in Hainan Island it failed due to severe insect damage. In this province, the local pigeonpea, which is characterized by very late maturity and small unacceptable seed size, is still grown by farmers for soil conservation and as a hedge crop. Since ICRISAT lines were found not adaptable in Hainan, the testing program was continued only in Guangxi and Jiangxi provinces.

In 1998, pigeonpea research was started in the southern hills of Yunnan province. During this year up to 1999, superior varieties were identified and the concept of utilizing pigeonpea for fodder and soil conservation in the dry areas of these provinces was likewise developed. It has a great potential as a fodder crop in the rainfed dry hills where the availability of quality fodder for the animals is the main cause of concern in the promotion of animal husbandry. In these areas also where soil erosion is a very serious issue and the establishment of forest trees for soil protection takes a long time (5-10 years) growing pigeonpea will be a welcome solution. In 2000, pigeonpea promotion activities were extended in Yunnan (2,000 ha), Guangxi (670 ha) and Jiangxi (500 ha) provinces with a seed backup program that included a number of breeding lines and germplasm. The evaluation of 42 pigeonpea lines was undertaken with the purpose of identifying which germplasm would provide fresh vegetable and what genotype would survive the sub-

zero temperature and regenerate the next spring. For vegetable purpose and seed production, ICPL 151, MN 1, MN 8, ICPL 85010 and ICPL 87091 have shown good results. In Guizhou province, ICPL 87091 and ICPL 87119 are being evaluated for fodder production (Xuxiao et al. 2001a). In 2009, Chinese scientists in Yunan and Guangxi provinces have started producing CMS-based hybrid pigeonpea seeds for export to India (Saxena 2008a).

Africa

The first pigeonpea breeding program started in 1968 at the Makerere University in Uganda to breed short maturity grain type varieties (Khan and Rachie 1972). Around 5,400 germplasm from India, Philippines and the Caribbean were evaluated to identify promising single plants for head-to-row selection. The progenies were primarily grouped on the basis of plant type and spreading, then compact types were selected for low and high density cropping systems, respectively. During this period, the cultivars developed were CIVE1, UC948, UC2288, UC3035 and UC16. These are considered “spray types” since their secondary branches are almost as long as the main stem. There were also a few cultivars identified with tertiary branches considered as “bush types” (Duke 1981) namely, UC1377 and UC959. However, from 1973 up to 1986 the pigeonpea research program was stopped due to the adverse effect of civil conflict.

In 1975, the University of Nairobi in Kenya initiated the pigeonpea research followed by the National Dryland Farming Centre, Katumani in 1979. The breeding program centered on the collection, evaluation and selection of germplasm. The first early variety developed through hybridization and released in Kenya was NPP670. Scientists in Kenya also initiated some research on population improvement by using partially out-crossing nature of the crop with moderate success.

The *Cajanus kerstingii* grows in the drier belts of Senegal, Ghana, Togo and Nigeria. In Tanzania, Ethiopia, Rwanda, Sudan, Somalia and Burundi, the pigeonpea improvement program started with germplasm introduced by ICRISAT and neighbouring countries. Pure lines such as NPP610, RK101 and TRT201 were identified for cultivation (Onim 1981).

In a new development, ICRISAT started a regional pigeonpea improvement program with the assistance of the African Development Bank and NARS.

The focus of the program was to breed long duration varieties that were high yielding and disease resistant for deep soils and short maturing types for drought prone areas. Under this program a total of nine varieties were released in Malawi (4 varieties), Kenya (3 varieties), Tanzania (3 varieties), Uganda (2 varieties) and Mozambique (1 variety). The first early maturing variety ICPL 87091 was simultaneously released in Kenya, Malawi, Uganda and Tanzania. In eastern Kenya, about 20% of the farmers have adopted new pigeonpea varieties. Farmers have also started adopting new medium maturing pigeonpea varieties like ICEAP 00554 and 00557 both for grain as well as green vegetable purposes. In Tanzania, about 50% of the farmers in Babati district adopted new varieties that expanded to its neighboring districts Karatu and Mbulu. In some areas, farmers adopted through maize intercropping system the ICEAP 00053, a long duration compact growth habit variety; in northern and central Tanzania, Kenya and Malawi, what was favored was the ICEAP 00040, a long duration variety that is resistant to Fusarium wilt and preferred by the consumer/market. This resulted in increased grain yields and lower production costs compared to the local genotypes. These initiatives have been very effective as shown by the 133% increase in area (0.24 M ha to 0.56 M ha) of cultivation and 178% increase in production (0.14 Mt to 0.3 Mt) (Saxena 2008a) in southern and eastern Africa from 1976 to 2006.

ICRISAT likewise expanded its coverage by conducting studies in 1998-1999 using its improved pigeonpea cultivars from India and Kenya under rainfed conditions in Mpumalanga Province in South Africa. The objective of the research was to evaluate the performance of improved pigeonpea cultivars for possible inclusion in the dryland farming systems in Lowveld areas. Sixteen cultivars with varying maturity periods were evaluated. The farmers, during their field visit, took preference over the ICEAP 00040 and ICEAP 00053 cultivars based on their observations of the growth habit of the plants and pods. The results clearly showed the possibility of successfully growing pigeonpea in the Lowveld areas of Mpumalanga to increase profitability of local farmers (Mathews et al. 2001).

Americas and the Caribbean

Pigeonpea research program in the Caribbean started in 1934 at the Imperial College of Tropical Agriculture where the main focus was to breed high yielding varieties with resistance to rust and *jassids*. The first early

maturing variety with determinate growth habit released from this program is 'Prensado'. This variety, however, did not become popular among farmers (Ariyanayagam and Spence 1978). Subsequently, three more varieties were released. These are the 'Tobago', St. Augustine' and 'Lasiba', which are similar to the traditional types in their phenology and are still grown by farmers. In the mid-sixties, selections from breeding populations were also made, which produced varieties with good quality grains and high yield under intercrop situations (Ariyanayagam and Spence 1978). Besides routine research on diseases, insects and some agronomic aspects, the Caribbean region also aimed to develop varieties that could provide year-round fresh pods for marketing. Spence and Williams (1972) developed a technology of sowing pigeonpea around the shortest day of the year that not only induced agronomic dwarfing and early flowering but also ensured availability of fresh pod for extended periods. In spite of these extensive researches conducted in the Caribbean, the prominent commercial cultivars are still those developed in 1934 and 1956 (Ariyanayagam 1975).

The growth of pigeonpea cultivation in Dominican Republic is encouraged by the canning plants in Puerto Rico. It is the smallholder farmers who predominantly grow pigeonpea and about 80% of their annual harvest is exported in the form of canned or frozen green peas. According to Mansfield (1981), a mixture of varieties such as 'Kaki' and 'Saragateado' have been used for canning in Puerto Rico for a long time. In general, four pigeonpea varieties are recognized in the Dominican Republic, namely, 'Kaki', 'Pinto Villalba', 'UASD', and 'Year-round'. All these varieties are long podded, large and white seeded. In 2005, the 'Navideño' variety was released (Saxena 2008a).

As earlier stated, pigeonpea is cultivated in Puerto Rico primarily for canning purposes and for local fresh pod market. The annual farm value of the crop is over \$3 million. The main breeding objectives are to develop high yielding varieties with different maturities and suitable dwarf lines for mechanical harvesting (Abrams et al. 1978). The pigeonpea breeding programs in Puerto Rico made good progress with the release of vegetable type varieties such as the 'Kaki', 'Panameno', 'Amarillo', 'Saragateado' and 'Totiempo' (Rivas and Rivas 1975). 'Kaki' is the most popular pigeonpea variety (Aponte 1963). In 2000, the 'Guerrero' and 'Cortada' varieties were also released in Puerto Rico (Saxena 2008a).

In Guadeloupe, several lines were introduced and suitable lines identified (Derieux 1971). In Venezuela, the breeding program resulted in the release of vegetable varieties of pigeonpea, such as the 'Panameno', 'Amarillo', 'Kaki', 'Saragateado' and 'Totiempo' (Rivas and Rivas 1975).

In the USA, a cultivar called 'Norman', which is an introduction from Pakistan, was cultivated initially in North Carolina, then later in Florida (Killinger 1968). This was followed by the release in 1920 of the cultivar named 'New Era' by the University of Hawaii under its program to breed varieties for fodder purposes. In 1927, local interest in pigeonpea waned due to the introduction of a new forage legume and the expansion of the area under sugarcane cultivation. In Florida, the day-neutral 'Amarillo' was grown and harvested at different times throughout the year. Other good cultivars planted are 'Morgan Congo', 'Cuban Congo' and 'No-eye Pea' (Duke 1981). In Minnesota (45°N), the three early maturing determinate pigeonpea varieties MN1, MN5 and MN8 were bred during the short warm season (Davis et al. 1995). These lines were selected from the breeding materials supplied by ICRISAT. These varieties were not in use in the country but they served as source of earliness in the breeding program at ICRISAT. Recently, in El Reno, Oklahoma, interest in pigeonpea was revived for fodder purposes. In fact, considerable research is being carried out to grow the crop as a summer legume that will produce excellent fodder (Rao and Coleman 2000, Rao et al. 2002 and 2003).

Oceania

In North Australia a group of endemic *Atylosias* species are grown (Duke 1981). Pigeonpea research started in early seventies to be used as a fodder crop (Akinola and Whiteman 1975, Bell 1978). Researchers found that pigeonpea was a good annual fodder but not as a perennial crop due to considerable plant mortality. In 1978, research for the grain product was initiated at the University of Queensland, Brisbane. The research program resulted in the release of four pigeonpea varieties, particularly 'Royes', 'Hunt', 'Quantum' and 'Quest'. However, not one of these varieties is in cultivation due to their high susceptibility to pod borers. In Fiji, where long duration pigeonpea are traditionally grown, an ICRISAT germplasm (ICP 7035) was released as 'Kamika', which became popular for vegetable and dry seed production (Saxena 2008a).

CHAPTER II

Potential of Pigeonpea: The Crop, Ecology, Utilization, Importance in Cropping Systems and Nutritional Quality

The legume that has been revolutionized in recent years is the pigeonpea. For years, the plant was considered as a poor man's crop such that it became useful only in very dry areas where farmers planted it to scratch a living. But now breeders and institutes like ICRISAT have transformed this subsistence crop of the semi-arid tropics into a versatile and high yielding crop that is resistant to major diseases and can be grown in high as well as low rainfall areas. For rural people, pigeonpea does not only provide food, fuel and forage but it is also used to enrich soil fertility. Moreover, it is now exported as a whole range of products thus providing extensive benefits to smallholder farmers and consumers.

The Crop

Pigeonpea (*Cajanus cajan* (L.) Millspaugh) is an important grain legume crop that is commonly grown in tropical and subtropical regions. It is a perennial shrub that can survive for a period of 3-5 years but it is normally cultivated as an annual crop. Traditional varieties are highly sensitive to photoperiod (McPherson et al. 1985) and they take about 175 to 280 days to reach maturity. In recent years, early, medium and long maturing lines of pigeonpea were developed at ICRISAT. These new lines are relatively photoperiod insensitive and mature in about 90-140 days (short duration), 177-205 days (medium duration), and more than 207 days (long duration) (Saxena et al. 2007).

Although pigeonpea ranks sixth in area and production in comparison to other grain legumes such as beans, peas and chickpeas, it is used in more diverse ways than any other legume. Besides its primary use as food, it can also be used as forage, fodder, fuel and medicine. Recent findings further show its importance in soil conservation along highways and mountain slopes particularly against soil erosion caused by wind and water (Morton 1976, Sheldrake and Narayanan 1979, Nene and Sheila 1990, Ong and Daniel 1990, Saxena 2000).

As food, the pods whether consumed as green pea or dry grain consists of 20-22% protein, which plays a vital role in meeting the protein needs of a vegetarian population (Singh et al. 1990, Saxena 2009). Most parts of Asia and Middle-eastern countries are the major market for good-quality pigeonpeas for human consumption. As forage and fodder, the leaves and dry pods can be utilized for said purpose although the cracked and pinched grain and by-products may be incorporated into animal feeds (Whiteman and Norton 1981). Recently, it was shown that grain from early maturing line GA-2 could be used as a protein supplement for livestock (Philips and Rao 2001). Other valuable uses of this plant are endless. Its woody stems can be utilized as shelter, wood fuel, thatch and fence while the plant in general is also used to culture the lac-producing insect (*Kerria lacca* Kerr). Because of these unique characteristics of pigeonpea, it is recognized as an important crop for subsistence agriculture especially so due to its drought tolerance and ability to recover from the losses caused by various biotic and abiotic stresses.

Pigeonpea is known to produce more nitrogen per unit of plant biomass than most other legumes and can nodulate in most soils although it produces fewer nodules than any other legumes (Onim 1987). It is also considered to be tolerant to low and high temperatures. Aside from being a nitrogen fixing plant, its roots go as deep as 2–5 meters thereby using water and micronutrients up in the organic system to meet its needs. The deep root system allows for optimum moisture and nutrient utilization. Its root system has the ability to break the plough pans, thus improving soil structure. The nodule and leaves are an important source of organic matter adding as much as 40 kg/ha nitrogen to the soil (Kumar Rao et al. 1981). Its ability to enrich soils further adds to the value of the crop, thus it finds an important place in the farming systems adopted by small-farm holders in developing countries (Saxena 2006).

Pigeonpea can adapt to a wide range of soil types from gravelly stones to heavy clay loams of close texture and high moisture content provided there is no standing water on the soil surface or excessive soil salinity. In Hawaii, it was planted in wastelands and infertile soils. It grows on acidic sands in the Sahel and alkali clays in India. Extensive ground cover of pigeonpea prevents soil erosion, serves as windbreak hedge, encourages filtration, minimizes sedimentation and smothers weeds.

Description

Pigeonpea (Figure 8) is an annual or short-term perennial shrub that is usually 1–2 meters in height, but may reach up to 4–5 meters. It is woody at the base and usually erect but with variable growth habit. It has a deep and quick growing tap root and angular stem resulting from three ribs starting from the base of each petiole. It has pubescent trifoliate leaves alternately set in a spiral along the stem and oblong lanceolate leaflets about 5–10 cm long and 2–4 cm wide. Its lateral petioles measure about 2–3 mm and the terminal ones reach 10–20 mm while the stipules linear are 2–3 mm and stipulets filiform are 1–2 mm long. The flowers of this plant are usually yellow but they may also be striped with purple streaks or plain red. The corolla is

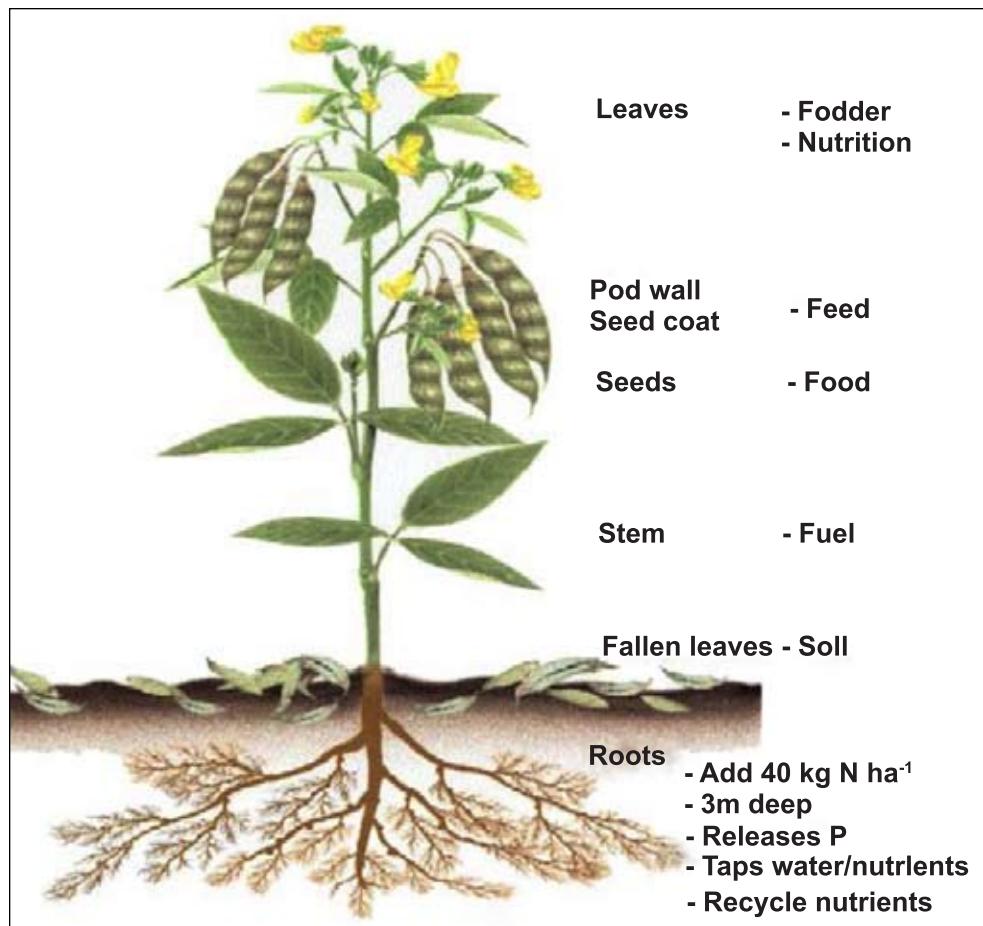


Figure 8. The Pigeonpea Plant.

about 20–25 mm with flag 18–20 mm wide and the calyx is 10–12 mm long with 5 linear teeth. The plant's inflorescence is composed of racemes with 5–10 flowers on top of an axillary and slightly divided peduncle. The pods are about 5–9 cm long x 12–13 mm wide, flat, of variable color, pubescent, acuminate tip and contain 2–9 seeds in shades of brown, white, red or black. The husks bear deep, oblique furrows underlining the septa between the seeds. It has a life span of up to 5 years and its reproduction system is 60% autogamous, mostly diploid with some tetraploid (Pathak 1948, Pathak and Yadava 1951, Saxena et al. 1982) and hexaploids (Pathak and Yadava 1951). Its somatic chromosome number is $2n=22$ as reported by Naithani (1941) on Indian varieties of pigeonpea. This report is strengthened by the findings of Akinola et al. (1972) under the 95 global accessions.

Ecology

As a crop, pigeonpea is very resistant since it can grow in dry areas with less than 650 mm annual rainfall or during dry season exceeding 6 months and it can even produce seed profusely under this condition. However, the most suitable condition for its growth is an annual precipitation of 600-1000 mm with moist conditions for the first two growing months, drier conditions during flowering and at 18-30°C during harvest time.

This crop is less suited in the humid tropics due to its poor tolerance to wet soils or flooding. Under humid conditions, pigeonpea tends to produce ample vegetative growth. However, rain during flowering stage causes poor pod set and permits the attack of pod borers. On the other hand, the growth of pigeonpea at high altitude with low temperature is slow and the plant is sensitive (susceptible) to water logging and frost.

Pigeonpea can grow in a wide range of soil types and textures such as sand, gravelly soils (Figures 9, 10) to heavy clay loams of close texture, but it grows best on well-drained medium heavy loams. The plant prefers pH of 5–7, but it can tolerate pH of 4.5–8.4 (Duke 1981). The plant though is sensitive to high salinity (Chauhan 1987).

The sensitivity of pigeonpea to photoperiod has played an important role in determining its growth and development. The phenological responses of this crop are influenced by photoperiod and temperature that have played a major role in the evolution of the various crop production systems that



Figure 9. Pigeonpea on gravel soil in India. (Photo: RV Kumar)



Figure 10. Pigeonpea sown on rocky mountain slopes in China. (Photo: KB Saxena)

have been established. The photoperiod sensitive reaction of pigeonpea germplasm is not only linked to flowering but also to the amount of biomass produced (Wallis et al. 1981). The traditional pigeonpea cultivars and landraces are highly sensitive to photoperiod, which limits their adaptation up to 30°N and S. Sowing of photoperiod sensitive types near the shortest day of the year generally leads to physiological dwarfing of plants (Spence and Williams 1972). In early maturing genetic materials under natural day lengths at Patancheru (17°N), up to four seed-to-seed generations can be achieved within a calendar year (Saxena 1996). This is in contrast with late maturing types that would require use of an environment controlled facility to provide extended day lengths and high temperatures in achieving a similar rapid generation turnover.

Turnbull (1986) studied the influence of temperature and photoperiod on the floral development of pigeonpea. Under an eight hour photoperiod at 24/16°C, the floral initiation to flower opening (rate of floral primordial development) took 40 days while it took 22 days under sixteen hour

photoperiod at 32/34°C. Saxena (1981) reported that under extended photoperiod of 16 hours, three major genes, particularly the PS₁, PS₂ and PS₃ control flowering in a sensitive parent MS₄A and hierarchically, PS₃ overrides the expression of PS₂ and PS₂ overrides PS₁. These studies suggest that there is a need to fully understand the influences of photoperiod and temperature on flowering in the genotypes of different maturity groups. This might help breeders to manipulate flowering of the sensitive types by adjusting pre- and post-floral initiation temperatures and photoperiod conditions.

Utilization

Food

Pigeonpea is a versatile crop grown primarily as a vegetable in the Caribbean and South America and as a multi-use grain crop (*da*) in India and some regions of Africa. Vegetable products include immature pods (Figure 11a,b), fresh leaves and seeds that have just reached physiological



Figure 11a. Green podded landrace vegetable type pigeonpea. (Photo: F Sugui)

Figure 11b. Red podded pigeonpea of ICP 7035 (vegetable type). (Photo: ICRISAT)



maturity before the green color is lost. The matured dry seeds are dehulled and split as *dal*, then boiled and eaten as a pulse just like any other similar edible dried beans. Dehulling greatly reduces cooking time and improves the appearance, texture, palatability, digestibility and nutritional quality of the seeds (Faris and Singh 1990).

Pigeonpea is also used in the production of noodles (Figure 12) (Singh et al. 1989) and as flour additive to increase the nutritional value of pasta or baked products (Figure 13) without affecting their sensory properties (Torres et al. 2007). In China, pigeonpea is mixed with wheat flour to improve the protein level of baked products and noodles. Millet/pigeonpea biscuits are reportedly highly nutritious and they provide a cheaper alternative to wheat imports in Nigeria (Eneche 1999).

In the Caribbean region, there is a persistent demand for vegetable pods whether canned (Figure 14) or frozen green peas (Figure 15) because this pea is usually combined with rice or served in a soup (Figure 16). In India, it may be ground and used in a variety of meat (Figure 17) and vegetable dishes (Figures 18, 19). In Africa, it is usually served as a stew (www.gracefoods.com/site/gungopeas). Dry seeds of pigeonpea also have other uses, such as in the preparation of *tempe*, a traditional Indonesian food prepared by fermenting the legume seeds with *Rhizopus* and ketchup; snacks (Figure 20), as finger foods (Figure 21) and to produce wine (Figure 22).



Figure 12. Noodles made from pigeonpea starch in China. (Photo: KB Saxena)



Figure 13. Baked pigeonpea cake in the Philippines. (Photo: F Sugui)

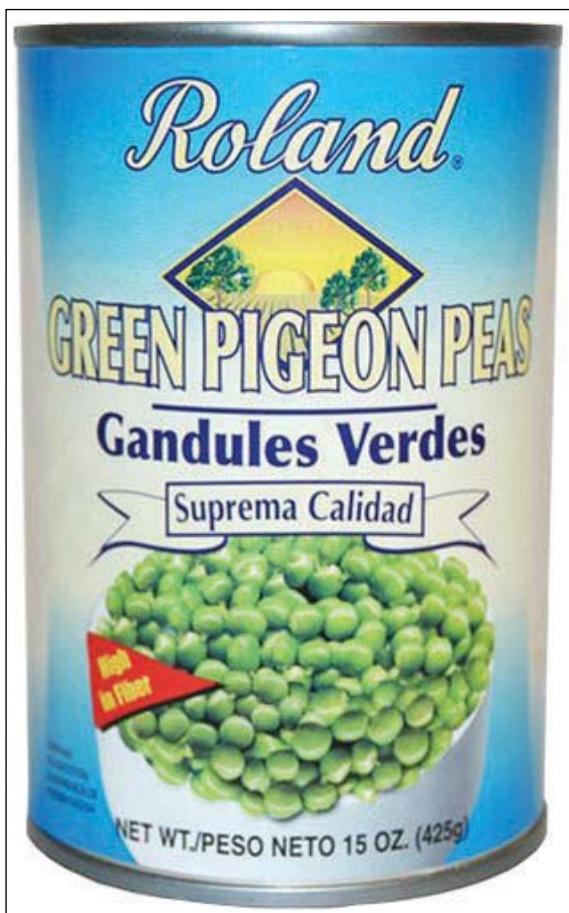


Figure 14. Canned pigeonpea. (Photo: RV Kumar)

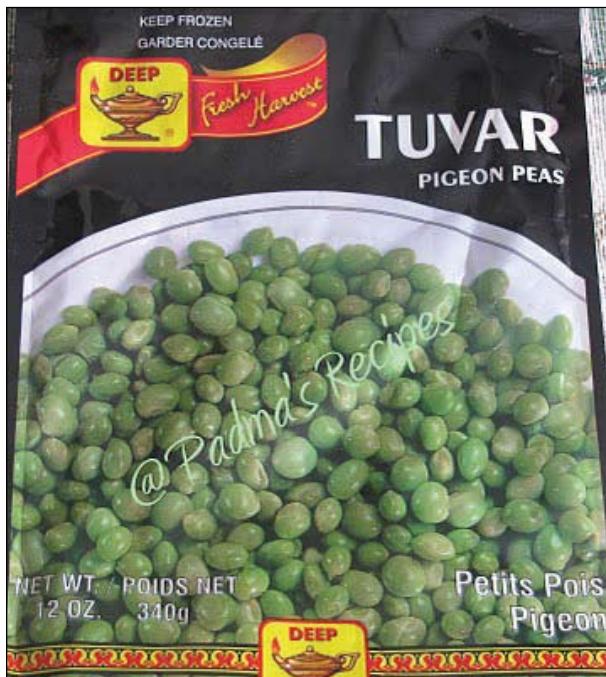


Figure 15. Frozen pigeonpea. (Photo: RV Kumar)



Figure 16. Pigeonpea soup. (Photo: F Sugui)



Figure 17. Pigeonpea with meat. (Photo: ICRISAT)



Figure 18. Vegetable dish with green pigeonpea.
(Photo: F Sugui)



Figure 19. Different pigeonpea dishes in China.
(Photo: KB Saxena)



Figure 20. Pigeonpea as snacks.
(Photo: ICRISAT)



Figure 21. Pigeonpea as finger food.
(Photo: ICRISAT)



Figure 22. Pigeonpea wine in China.
(Photo: KB Saxena)

Animal feed, fodder and forage

The need to substitute fishmeal in animal feed has necessitated the use of plant derived feedstuffs. Legumes such as pigeonpea, which are widely distributed, have been highly favored because they are rich in protein, carbohydrates and minerals. Pigeonpea produces forage quickly and can be used as a short-lived perennial forage crop. The leaves and young pods can be fed to the animals fresh or they can be harvested and conserved (Figure 23a,b). The dried husks, cracked seeds, leaves and trash of the plant have been found to be palatable to livestock. While the protein content of this material maybe low, the inclusion of trash at rates of up to 500 g/kg of the ration improves overall digestibility and intake of accompanying low-quality hays (Quirk 1979). Under good grazing management, pigeonpea can survive up to five years and with intensive management, forage yields can exceed 50 t/ha/annum. Regeneration of foliage is moderate when the plant is younger but it becomes poorer as the plant becomes woodier near the end of its life. The crop cannot tolerate frequent or severe cutting or heavy defoliation through continuous grazing, although regrowth occurs even when ratooned as low as 15 cm. In addition, the leaves of this plant can also be used as food for the silkworm (Duke 1981) and it can also be a substitute for alfalfa in animal feed formulations.

The present high cost of animal sourced protein in feeds makes pigeonpea ideal as a good plant protein substitute as it is less expensive. Singh and Eggum (1984) reviewed the nutritional quality of pigeonpea and Draper



Figure 23a. Fresh cut leaves and young pods of pigeonpea as fodder for livestock in China.
(Photo: KB Saxena)



Figure 23b. Chopped pigeonpea fodder as forage for livestock in China. (Photo: KB Saxena)

(1944) and Springhall et al. (1974) reported some research into feeding poultry pigeonpea-based diets. They indicated that pigeonpea meal (21% crude protein, 9.2% crude fiber) could be included at levels of up to 30% in broiler chick diets with no significant depression in liveweight gains. In another study conducted by George and Elliott (1986), raw pigeonpea seeds can be included at rates of up to 400 g/kg in a commercial layer diet without affecting egg production performance and health and feed intake of the birds. The results of these experiments suggest that raw, ground pigeonpea can be a valuable energy and protein source in poultry diets and can be included at rates of up to 450 g/kg of the dietary dry matter without adversely affecting the health and productivity of the bird.

Likewise, there are a few studies reported on the use of pigeonpea in pig nutrition (Figure 24) by Falvey and Visitpanich in 1979 and 1980. The results of their studies showed that the inclusion of pigeonpea seed in a ration for pigs made up of chopped banana stalk, rice, bran, corn and (unsaleable) red kidney beans improved liveweight gains. However, pigeonpea meal at 30% of the diet resulted in a lower dressing percentage and growth rate and feed conversion were inferior on a carcass basis with the other diets. Moreover, pigs fed diets, which include autoclaved meal, had higher growth rates and



Figure 24. Pigeonpea as feed for pigs. (Photo: KB Saxena)

improved feed conversion ratios. This data suggests that pigeonpea meal is suitable for inclusion in compound rations for growing pigs if autoclaved for 15 minutes at 110°C. While the use of pigeonpea meal in animal diets appears to be technically feasible, in practice its use will depend on the price of the product in relation to alternative protein and energy sources.

Equally important is the optimum utilisation of pigeonpea meal in fish production (Figures 25, 26). According to Ogunji et al. (2005), soaking of pigeonpea seeds for 16 hours enhanced best the fish weight gain and haematological values of African catfish.

From reports of grazing trials, it is clear that high levels of animal production are possible from pigeonpea forage for cattle (Figure 27) at 6.2 kg/ha/day (Akinola et al. 1975) and for goats (Figure 28) at 3.34 kg/ha/day (Bint and Norton 1982). But, there appear to be limits of intake and to liveweight gain when pigeonpea forage is the sole source of feed. The high protein content of pigeonpea leaves suggests that the optimum use of the crop for forage may be as a supplement protein source in compound diets to low quality forage (rice or wheat straw). The perennial habit of the crop makes it valuable as a standover high-protein fodder for those times of the year when protein



Figure 25. Pigeonpea for aquaculture in China. (Photo: KB Saxena)



Figure 26. Pigeonpea grown around a fish pond in Philippines. (Photo: R Navarro)



Figure 27. Cattle grazing pigeonpea in India. (Photo: ICRISAT)



Figure 28. Goat grazing pigeonpea in India. (Photo: ICRISAT)

shortage is the major limit to production (Figures 29, 30, 31). Wijnberg (1983) reviewed the forage quality of pigeonpea and concluded that its leaf nitrogen level is consistently high having an average of 2.9% probably due to the perennial habit and reduced leaf senescence of the crop.

Fuel wood

Since pigeonpea has strong woody stems that grow up to 4m tall and branch freely, its spindly stalks are extensively used as a cooking fuel in energy-short villages of several African countries and in India, Nepal and Sri Lanka (Figure 32). Historically, the stalks were employed to make the charcoal used in gunpowder. Farmers in Africa grow pigeonpea for its wood instead of its grain. Its productivity levels more than make up for the comparatively poor fuel characteristics but the heat value is about $\frac{1}{2}$ that of the same weight of coal.

In the lac growing areas of China (Figure 33), after harvesting the lac resin, pigeonpea plants are chopped and dried for fuel use. The crop produces



Figure 29. Pigeonpea as fodder for rabbits. (Photo: KB Saxena)



Figure 30. Pigeonpea as fodder for goats. (Photo: KB Saxena)



Figure 31. Pigeonpea as fodder for buffalo in China. (Photo: RV Kumar)



Figure 32. Pigeonpea as fuel wood in Nepal. (Photo: RV Kumar)



Figure 33. Pigeonpea for lac production in China. (Photo: KB Saxena)

about 6 t/ha of fuel wood (Zhenghong and Fuji 1997). Moreover, in the low mountain range of China, the farmers cultivate pigeonpea on wastelands and field bunds providing relief from the energy shortage and likewise help in arresting deforestation. The quality of fuel wood has been estimated to be excellent yielding energy at the rate of 4,350 K Cal/kg (Yude et al. 1993).

Soil ameliorants

In addition to food uses, pigeonpea has outstanding soil amelioration (Figure 34) and conservation properties. The growth habit facilitates soil protection (Figure 35) as the canopy continues to expand for 4 months after other crops are harvested. For more than 100 years, the legume symbiosis as shown by pigeonpea was known to be the most efficient way of transforming atmospheric nitrogen into plant nutrients (Alam and Manzoor 2005). Leaf fall at maturity adds to the organic matter in the soil and provides additional nitrogen. The root system is reported to break plough pans, thus improving soil structure, encouraging infiltration, minimizing sedimentation and smothering weeds. The crop nodulates with wide ranges of *Rhizobium* and consistently fixes 20 to 140 kgs ha of N in fertile soil (Anderson et al. 2001).

Pigeonpea produces more nitrogen from plant biomass per unit area of land than many other legumes. The plant can fix atmospheric nitrogen of about 70 kg/ha per season by symbiosis until the mid-pod-fill stage. This is around 88% of the total nitrogen content of the plant at that stage of growth. In



Figure 34. Pigeonpea as soil ameliorant. (Photo: RV Kumar)



Figure 35. Pigeonpea used for soil conservation. (Photo: MG Mula)

northern India the long-duration pigeonpea can fix up to 200 kg N/ha over a 40-week period. The residual effect can be as much as 40 kg N ha (Nene 1987). Rarely does the plant need to be inoculated because it nodulates on *Rhizobium*, which is naturally present in most soils (Faris 1983).

Pigeonpea offers the benefits of improving long-term soil quality and fertility when used as green manure (Onim et al. 1990), cover crop (Bodner et al. 2007), or alley crop (Mapa and Gunasena 1995). The legume also has the ability to reduce the level of root-knot nematodes in the succeeding crop when used as green manure (Daniel and Ong 1990). Pigeonpea has been used successfully in coffee plantations as a cover crop to improve soil properties, reduce weed competition as well as act as a food source for predators (Venzon et al. 2006). Maize yields have been increased by 32.1% in West Africa by using pigeonpea as a cover crop (Sogbedji et al. 2006). Pigeonpea is used in alley cropping, and being perennial, it can be ratooned (Sharma et al. 1978) successfully for subsequent crops in no till production systems (Lal et al. 1978).

Pigeonpea grows well in soils with low phosphorus level. It seems to have special mechanisms to extract phosphorus from black Vertisols. Pigeonpea root exudates have an unusual ability to solubilize ironbound phosphorous, which increases total phosphorous availability in soils with low available phosphorous. The weak response of pigeonpea to phosphorous application in an Alfisol field suggested that pigeonpea was able to efficiently utilize ironbound phosphorous (Iron-Phosphorous) (Ae et al. 1990). Pigeonpea was later shown to exude significant amounts of malonic and oxalic acids along with piscidic acid. Those acids seem to release phosphorous from Iron-Phosphorous and Aluminum-Phosphorous in soils of low phosphorous fertility. Likewise, pigeonpea showed a higher phosphorous uptake from an Andisol of high humic substances than other crops (Otani and Ae 1996). In calcareous soils (alkaline soils with high calcium content), this acid breaks up insoluble calcium phosphate. Normally, this release would only occur if the pH of the soil were low. The crop is deep-rooted, so their ability to release more phosphates means that valuable nutrients are being brought up from the deeper soil layers. The release of phosphorous benefits not only the crop, but also the subsequent crops grown in the same field (Ae et al. 1990, IAD 1992).

Folk medicines

According to Morton (1976), Duke (1981) and van der Maesen (2006), pigeonpea finds wide application in traditional medicine. Diarrhea, gonorrhea, measles, burns, eye infections, earache, sore throat, sore gums, toothache, anemia, intestinal worms, dizziness and epilepsy are treated with leaf preparations. Root preparations are taken to treat cough, stomach problems and syphilis. Stem ash is applied on wounds, and stalks and roots are chewed against toothache. Powdered seeds serve as a poultice on swellings. In Madagascar, the leaves are used to clean teeth. In India and Java, the young leaves are applied to sores. Indochinese claim that powdered leaves help expel bladder stones. Salted leaf juice is taken for jaundice. Leaves are also used for toothache, mouthwash, sore gums, child-delivery and dysentery. Scorched seed, added to coffee, are said to alleviate headache and vertigo. In Argentina the leaf decoction is prized for genital and other skin irritations, especially in females. Floral decoctions are used for bronchitis, coughs and pneumonia. Chinese shops sell dried roots as an alexiteric, anthelmintic, expectorant, sedative and vulnerary. Fresh seeds are said to help incontinence of urine in males, while immature fruits are believed to be useful in liver and kidney ailments.

Although the medicinal value of pigeonpea in Africa has not been fully exploited, leaf decoction is diuretic and is used to control nervous breakdown, pulmonary troubles, stomach troubles, naso-pharyngeal affections, small-pox, chicken-pox and measles. The roots are used to cure venereal diseases and the seeds as sedatives (Royal Botanic Garden-Kew 1985). Pigeonpea leaves have been used to treat malaria (Aiyeloja and Bello 2006) in Nigeria, while in Southern Africa pigeonpea is currently one of the indigenous crops being promoted for potential medicinal use (Mander et al. 1996).

The pigeonpea is easily digested and therefore suitable for invalids. While it may have many medicinal properties, excessive use of pigeonpea causes hyper acidity and wind in the intestines. Therefore, it is forbidden in gastric ulcer and heart disease. The following are the natural benefits and curative properties derived from this plant ([best-home-remedies.com/herbal_medicine/grains&pulses/pigeon_pea](http://best-home-remedies.com/herbal-medicine/grains&pulses/pigeon_pea)):

- Baldness - A fine paste made of this pulse is highly useful in bald patches. It should be applied regularly.
- Jaundice - The expressed juice of the leaves given, with a little salt, is highly beneficial in the treatment of jaundice. 60ml of this juice should be taken daily in this condition.
- Checking breast milk secretion - The pulse and leaves ground into a paste, warmed and applied over the mamma, has the effect of checking the secretion of breast milk.
- Inflammation - The leaves of the plant are effective in all inflammatory conditions. A poultice made with the seeds will also reduce swelling.
- Piles (Hemorrhoids) - Paste of the leaves, mixed with a teaspoonful of paste of neem leaves, is highly beneficial in the treatment of piles and itching in the anus. It should be taken once daily for a week.

In several clinical studies scientists have reported that seed extracts of 'guandu' inhibit red blood sickling and may be beneficial for people with sickle cell anemia. Laboratory studies with animals reported that the seeds have some anti-nutritional qualities and are reported to contain trypsin inhibitors and chymotrypsin inhibitors, which reduce or inhibit pancreatic amylase and lipase (Taylor 2005). Other important herbal properties and actions are revealed with the use of the leaves, flowers and seeds together. The dosage is 1 cup twice daily to reduce fever, heal wounds, balance menstruation, reduce inflammation, reduce sickling, stop bleeding, reduce mucus, relieve coughs and increase urination.

Dihua et al. (1985) identified some useful chemical compounds in pigeonpea leaves such as salicylic acid, hentricacontane, 2-carboxyl-3-hydroxy-4-isoprenyl- 5-methoxy-stilbene, lacerol, longistyline A, pinostrobin, sitosterol, longistyline C, naringenin-4', 7-dimethyl ether, and β -amyrin. The pharmacology and toxicology tests conducted on rats demonstrated that the curative effects of *cajan* on inflammation are more prominent than that of salicylic acid and its toxicity is less than that of salicylic acid (Shaomei et al. 1995).

In another important development in China, pigeonpea leaves, due to the presence of flavonoids, are considered an excellent traditional Chinese medicine (TCM) for the therapy of ischemic necrosis of femoral head. Flavonoids or bioflavonoids (also collectively known as Vitamin P and citrin) are a class of secondary metabolites. This medicine can make the dead bone cells and vessels regenerate. The Chinese government has given authorization to produce a new Chinese medicine (*Sheng mai Cheng Gu Pian*) for this illness. In order to understand the mechanism involved in these beneficial effects, a great deal of scientific efforts have been contributed to isolate and identify the active components in pigeonpea leaves. Polyphenols, especially flavonoids, have been considered as the main player in these beneficial effects on human health (Zu et al. 2006). Pigeonpea leaves also contain other components such as hordenine, juliflorine, betulinic acid, stigmasterol, beta-sitosterol and others. The four flavonoids in the extracts of pigeonpea leaves, quercetin (QU), luteolin (LU), apigenin (AP) and isorhamnetin (IS) (Chen et al. 1985), exhibit notable pharmacological activities.

Other potential uses

Pigeonpea stems are used in fencing crop fields and livestocks (Figure 36) and weaving cribs and baskets. The wood is used in light construction such as roofing, thatch (Figure 37), wattling on carts, tubular wickerwork lining for wells, shelter for barns, huts (Figure 38) and other crafts from branches and stems (Morton 1976, van der Maesen 1989). Tall perennial pigeonpea are often used as live fences in homesteads of farmers of Africa and the Caribbean (Phatak et al. 1993). In Southeast Asia, pigeonpea is grown as a support for vanilla while in China, pigeonpea is also grown along highways (Figure 40), on river banks (Figure 41), mountain slopes (Figure 42, 43), as substrate for mushroom production (Figure 44).

In some experimentation, pigeonpea has been found to produce a pulp for paper similar to that of hardwoods, which might be suitable for making good quality writing and printing material. In addition, the plant has been observed to be a good source for apiculture (Figure 45). The nectar collected by honeybees produce honey that has a distinctive greenish hue in the comb (World Agroforestry Centre).

In China, Jianyun and Yun (1998) conducted studies on the processing technology of plywood bond using pigeonpea glue. The results showed that the bond strength of the plywood was 1.28-1.92 Mpa, which parameters meet the National Standards and it was higher than that of soybean glue (*Glycine max*). The pigeonpea glue processing technology is relatively simpler and economical.



Figure 36. Pigeonea used as fence for livestock. (Photo: RV Kumar)



Figure 37. Pigeonpea used as thatch. (Photo: RV Kumar)

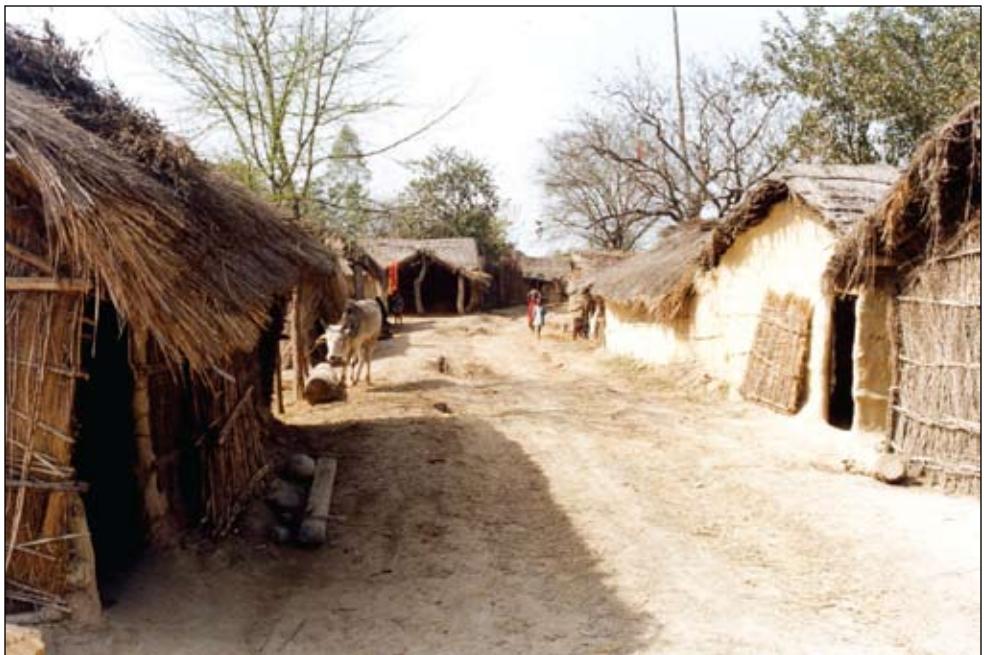


Figure 38. Pigeonpea used as barns and huts in Nepal. (Photo: RV Kumar)



Figure 39. Pigeonpea as live fences in Nepal. (Photo: RV Kumar)



Figure 40. Pigeonpea grown along highways in China. (Photo: KB Saxena)



Figure 41. Pigeonpea grown on riverbanks in China. (Photo: KB Saxena)



Figure 42. Pigeonpea planted on mountain slopes in China. (Photo: KB Saxena)



Figure 43. Pigeonpea planted on mountain slopes in India. (Photo: RV Kumar)



Fig 44. Mushroom harvested from pigeonpea substrates in China. (Photo: KB Saxena)



Figure 45. Pigeonpea for apiculture. (Photo: RV Kumar)

Importance in Cropping Systems

A cropping system refers to a combination of crops in space and time and their interactions with farm resources, other farm enterprises, and available technology that determine their appearance. The term cropping system is also used interchangeably with multiple cropping in which two or more crops are grown consecutively on the same field in the same year. It represents a philosophy of maximum crop production per unit area of land within a calendar year with minimum impact on the soil health and environment (Sekhon and Singh 2005).

Traditional cropping systems are based on resource-poor farmers' subsistence requirements, which are not the most efficient ones. The ideal cropping system should make the most efficient use of the natural resources, and provide stable and high returns. The efficient use of the basic resources in cropping systems depends on the inherent efficiency of the individual crops that make up the system, and partly on complementary effects between the crops (Willey et al. 1981). The choice of crop is determined by rainfall pattern, moisture capacity of the soil, and the availability of water during the cropping season. Stability is achieved by using crops and varieties that have a wide range of adaptability and by improved management practices (Rao and Willey 1980).

Improved production packages are developed to help farmers improve their cropping systems and harvested yields. High input system in rice producing areas, which has begun showing signs of instability, could become more sustainable with the inclusion of pigeonpea into the rotation by providing farmers with an alternative to rice during periods of water scarcity, price incentives, and problems of soil fertility. It gives additional yield after the first harvest if sufficient moisture is available (ratooning), and it has great flexibility in a wide range of cropping systems. Pigeonpea is a superb intercrop and a non-competitive crop to plant with food crops (cereals, etc), cash crops and other plantation crops. Willey et al. (1981) have stated that intercropping systems of pigeonpea have not significantly affected the yields of other crops compared to when the crop is planted as a sole crop. In addition, up to 70% of the yield of pigeonpea alone can also be obtained.

Pigeonpea is cultivated in an array of systems. The plant is a good alternative crop with low fertilizer requirements and with minimum pesticide use. Due to

its hardiness, ability to grow on residual soil moisture, and slow early growth, pigeonpea is an ideal, non-competitive crop to plant with cereals. In traditional cropping systems, throughout the world, pigeonpea is mostly cultivated as secondary or mixed with other crops (Aiyer 1949, Acland 1971, Osiru and Kibira 1981). The crops are alternately grown in rows with rows of wheat (*Triticum aestivum* L.), chickpea (*Cicer arietinum* L.), sorghum (*Sorghum bicolor*) (Figure 46), groundnut (*Arachis hypogaea* L.), sesame (*Sesamum indicum*), cotton (*Gossypium spp.*) (Figure 47), pineapple (*Ananas comosus*), pearl millets (*Pennisetum glaucum*), maize (*Zea mays*) (Figure 48), and in between plantation crops like coconut (*Cocos nucifera* L.) (Figure 49), banana (*Musa* species) (Figure 50), mango (*Mangifera indica* L.) (Figure 51), and citrus (*Citrus* spp) (Figure 52) (Ali and Kumar 2000, Sekhon et al. 1992). The perennial nature of pigeonpea allows farmers to take multiple harvests with surpluses traded in both local and international markets. This is partly because of the possible wide range of phenological development, which is influenced by photoperiod and temperature, and response to these factors governs the ecophysiological adaptation of pigeonpea, from photoperiod-sensitive genotypes grown as perennial crop (more than 11 months), long-season (9-11 months), mid-season (6 to 8 months) crops, to short-season (3 to 5 months) crops (Wallis et al. 1988).



Figure 46. Sorghum intercrop with pigeonpea in India. (Photo: MG Mula)



Figure 47. Cotton intercrop with pigeonpea in India. (Photo: MG Mula)



Figure 48. Maize intercrop with pigeonpea in India. (Photo: MG Mula)



Figure 49. Pigeonpea grown under coconut plantation in Sri Lanka.
(Photo: KB Saxena)



Figure 50. Pigeonpea in between banana plantation in Sri Lanka.
(Photo: KB Saxena)



Figure 51. Pigeonpea grown in mango orchard in India. (Photo: ICRISAT)



Figure 52. Citrus intercrop with pigeonpea in China. (Photo: KB Saxena)

Many different intercropping systems are used (Figures 53, 54, 55, 56), including some systems (Figures 57, 58, 59, 60, 61, 62) in which the pigeonpea component is very low. Such cropping systems are being thoroughly researched and it appears that in particular environments, the potential for good yields is high.

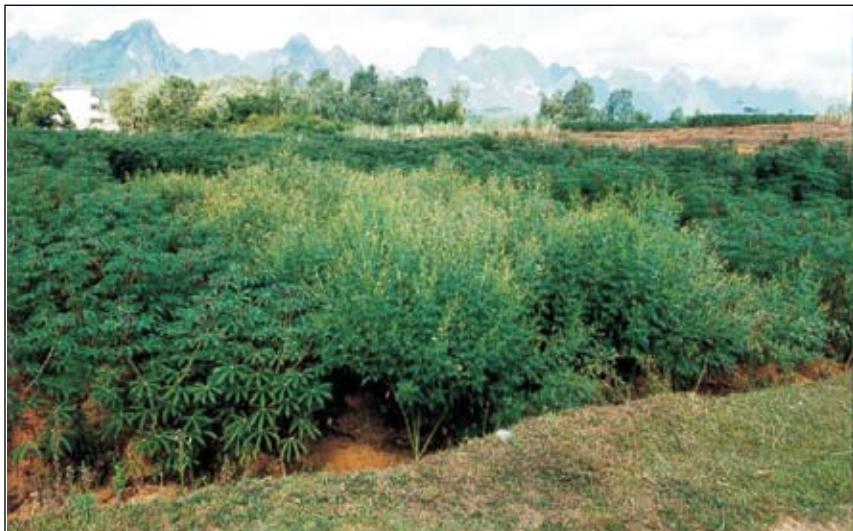


Figure 53. Cassava intercrop with pigeonpea in Sri Lanka. (Photo: KB Saxena)

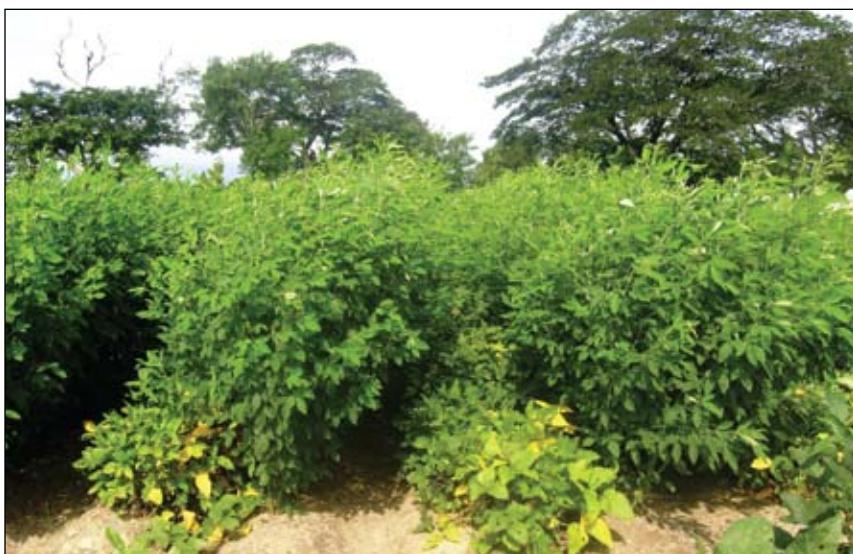


Figure 54. Soya beans intercrop with pigeonpea in Myanmar. (Photo: Khin Lay Kyu)



Figure 55. Cowpea intercrop with pigeonpea in Myanmar. (Photo: Khin Lay Kyu)



Figure 56. Black gram intercrop with pigeonpea in India. (Photo: ICRISAT)



Figure 57. Pigeonpea in hillside farming in China. (Photo: KB Saxena)



Figure 58. Pigeonpea grown in rolling hills in India. (Photo: RV Kumar)



Figure 59. Pigeonpea as hedgerows in India. (Photo: RV Kumar)



Figure 60. Pigeonpea as hedgerows in the Philippines. (Photo: F Sugui)



Figure 61. Pigeonpea along irrigation canals in Myanmar. (Photo: RV Kumar)



Figure 62. Pigeonpea sown after rice (zero tillage) in the Philippines.
(Photo: RV Kumar)

Nutritional Quality

The pigeonpea is well balanced nutritionally and an excellent source of protein whether eaten as a green pea or as dried grain (Faris and Singh 1990). In addition to protein, pigeonpea provides carbohydrates and 5-fold higher levels of Vitamin A and C (Faris et al. 1987).

Pigeonpea seeds are known to be rich in proteins (generally varying from 18 to 25% and as high as 32%), carbohydrates and minerals. Likewise, the seeds are rich in sulfur-containing amino acids, methionine and cystine (Birk 1993). Its abundance in protein makes it an ideal supplement to traditional cereal, banana or tuber-based diets of poor farmers that are generally protein-deficient. Table 3 presents the nutritional composition of pigeonpea *dal* (Figure 63), sun-dried seeds (Figure 64) and immature seeds (Figure 65).



Figure 63. Pigeonpea *dal*. (Photo: ICRISAT)

Table 3. Nutritional composition of pigeonpea for dal, sun-dried seeds and immature seeds.

Chemical composition	Dal	Sun-dried seeds	Immature seeds
Moisture (%)	15.2	9.9	69.5
Starch content (%)	57.6	53	48.4
Carbohydrates (%)	66.7	64.2	21.3
Protein (%)	24.6	20.5	21
Fat (%)	1.6	1.9	2.3
Fiber (%)	1.2	6.6	8.2
Ash (%)	4.2	4.2	1.4
Soluble sugar (%)	5.2	3.1	5.1
Phosphorous (%)	0.26	2.85	1.35
Lysine ¹	7.1	6.8	7.0
Theonine ¹	4.3	3.8	4.7
Methionine ¹	1.2	1.0	1.4
Cystine ¹	1.3	1.2	1.7
Calcium ²	16.3	120.8	94.6
Magnesium ²	78.9	122.0	113.7
Iron ²	2.9	3.9	4.6
Copper ²	1.3	1.3	1.4
Zinc ²	3.0	2.3	2.5
Thiamine ²	0.40	0.63	0.40
Riboflavin ²	0.25	0.16	0.25
Niacin ²	2.2	3.1	2.4
Potassium ²			563
Sodium ²			5
Ascorbic acid ²			26
β-carotene equivalent		55mg	145mg
Vitamin A	220 IU/100g	28 IU/100g	67 IU/100g
Calories		345	117

Source: Duke 1981, Price 1990, Faris and Singh (1990), Faris et al. (1987), USDA (2004).

1 g 100g⁻¹ protein

2 mg 100g⁻¹ dry matter



Figure 64. Sun-dried pigeonpea seeds. (Photo: ICRISAT)



Figure 65. Immature seeds for canning and for frozen peas. (Photo: KB Saxena)

Of the total amino acids, 6.7% is arginine, 1.2% cystine, 3.4% histidine, 3.8% isoleucine, 7.6% leucine, 7% lysine, 1.5% methionine, 8.7% phenylalanine, 3.4% threonine, 2.2% tyrosine, 5% valine, 9.8% aspartic acid, 19.2% glutamic acid, 6.4% alanine, 3.6% glycine, 4.4% proline, 5% serine with 0 values of canavanine, citrulline and homoserine. Methionine, cystine and tryptophane are the main limiting amino acids (Duke 1981).

Pigeonpea is more commonly used as a pulse crop throughout the world. Pulse crops are legumes in which the dried seeds are used as human food. When used as a “vegetable”, the pea is picked when the seeds have reached physiological maturity, that is, when they are fully grown but just before they lose their green color. At this stage the green seed is more nutritious than the dry seed because it has more protein, sugar and fat. In addition, its protein is more digestible. There are considerably lower quantities of the sugars that produce gas (flatulence) in the green seeds. The mature seeds contain a bit more minerals (Table 4).

In comparison with green peas, vegetable pigeonpea takes longer to cook and is not as sweet, but it is much more nutritious. On a fresh weight basis, it has greater edible portion (72% vs 53%), more protein, carbohydrates, fiber and fat than green pea. It also has more minerals and much more of some vitamins (469 vs 83 vitamin A/100g; 0.3 vs 0.01 vitamin B2; 25 vs 9 vitamin C) (Price 1990).

Pigeonpeas eaten in combination with cereals contribute to a nutritionally balanced human food. The oil of the seeds contains 5.7% linolenic acid, 51.4% linolec, 6.3% oleic and 36.6% saturated fatty acids. Likewise, seeds are reported to contain trypsin inhibitors and chymotrypsin inhibitors.

Table 4. Comparison of some nutritional constituents of green and mature pigeonpeas on a dry-weight basis.

Nutritional Constituent	Green seed	Mature seed
Protein (%)	21.0	18.8
Protein digestibility (%)	66.8	58.5
Trypsin inhibitor (units/mg)	2.8	9.9
Starch (%)	44.8	53.0
Starch digestibility	53.0	36.2
Amylase inhibitor (units/mg)	17.3	26.9
Soluble sugars	5.1	3.1
Flatulence factors (g/100g sol. sugar)	10.3	53.5
Crude fiber (%)	8.2	6.6
Fat (%)	2.3	1.9
Minerals and trace elements (mg/100g)	-	-
Calcium	94.6	120.8
Magnesium	113.7	122.0
Copper	1.4	1.3
Iron	4.6	3.9
Zinc	2.5	2.3

Nutritional Quality for Animal Production

Fodder scarcity is widespread in many areas of the SAT and feedstuffs are often too deficient in nitrogen to allow efficient feed digestion in the rumen, which requires a minimum of 1 to 1.2% of feed nitrogen (van Soest 1994); pigeonpea could well contribute to improved feed resources when used for such natural resource management purposes. Given that information available on pigeonpea as forage crop was poor, ICRISAT and the International Livestock Research Institute (ILRI) started collaborative work to systematically investigate its forage potential. From the livestock productivity trials, it was concluded that widely used conventional laboratory forage quality traits such as protein content and in vitro digestibility did not adequately describe pigeonpea forage quality (Alexander et al. 2006, 2006a; Ki et al. 2006). A secondary plant component analysis was needed and reported that condensed tannin content in the pigeonpea forage was highly positively correlated with livestock productivity measurements in sheep

exclusively fed on pigeonpea forage. Mean nitrogen content in the pigeonpea forage was 3.4% and 3.6%, suggesting that pigeonpea forage can serve as an effective supplement to nitrogen deficient feedstuffs. The positive effects of condensed tannins on forage quality have been observed at 2% to 4% concentration with an optimal content being variable and depending on the basal diet and structure of the condensed tannins. However, condensed tannins can also affect the forage quality negatively if present at higher concentration (Alexander et al. 2007).

Previous findings reveal that pigeonpea has a high feeding value for beef and dairy cattle, swine, sheep and goats. The healthy leaves and fully podded branches, cut at 0.8 meters, have 40% to 50% dry matter, and protein up to 16% of the dry matter (Takahashi and Ripperton 1949). Table 5 presents the different variation of nutritional constituents between fresh green forage, dried/ground whole plant forage, seeds, leaves, silage from foliage, and silage of pigeonpea as revealed by Otero (1952) and Duke (1981). The plant is also a good source of vitamin A and vitamin B complex. Cattle do not relish the forage in the immature stage. Grazing should be deferred to the early green-pod stage (Hosaka and Ripperton 1944) and in some cases mature plants may cause irritation of the rumen of cattle (Stanton 1966).

Table 5. Comparison of nutritional constituent of fresh green forage, dried and ground whole plant forage, seeds, silage from foliage, and silage of pigeonpea.

Nutritional constituent	Fresh green forage*	Dried/ Ground Forage*	Seeds**	Seed coat***	Leaves**	Silage from foliage**	Silage**
Moisture (%)	70.4	11.2	10.3				66.7
Crude Protein (%)	7.1	14.8	18.36	4.9	11.46	15.09	
Crude Fiber (%)	10.7	28.9	5.43	31.9	22.6	26.05	66.7
N-free extract (%)	7.9	39.9				32.8	32.8
Fat (%)	1.6	1.7		0.3			
Ash (%)	2.3	3.5		3.5			

Source: *Duke (1981); **Otero (1952); ***Faris and Singh (1990).

Dry-Matter and Green-Matter Yields of Pigeonpea

According to Parberry (1967), the unfertilized pigeonpea grown for 372 days has yielded 25.45 t/ha of dry matter while 37.96 t/ha was harvested when fertilized with 100 kg N/ha on Cunnunurra clay. However, only 1,071 kg/ha was produced on unfertilized pigeonpea on Cockatoo sand in the Kimberley district of northern Australia. Parberry further revealed that 100 kg N/ha depressed the crop yield on Cockatoo sand. The yield of 37.96 t when fertilized with 100 kg N/ha represent 7,704 kg/ha of protein.

CHAPTER III

Global Pigeonpea Statistics and Economies - Global Condition, Market Trends (Domestic, Export and Import), and International Market Trade: A Regional Scenario

Global Condition

Pigeonpea, an important crop in the arid and semi-arid tropics, is grown between latitudes 30°S and 30°N and at elevation as high as 3,000 meters above sea level (Sinha 1977). The major and minor producing regions are Asia, Africa, the Americas and Caribbean, and Oceania (Map). This crop accounts for less than 5% of the total world pulse production. Traditional varieties are mostly grown in the drought-prone areas of developing countries by farmers with small holdings (Joshi et al. 2001).

Pigeonpea is cultivated commercially for canning in the Dominican Republic, Trinidad and Puerto Rico while it is mostly grown for home consumption and export in Africa, Kenya, Malawi, Tanzania and Uganda. Elsewhere in the tropics, it is more a crop of kitchen gardens and hedges. In India, the yields are dry seeds while in the Dominican Republic the yields are fresh seeds or pods (Duke 1981).

Global yield performance for green pods vary from 1,000 – 4,000 kg/ha with up to 9,000 kg/ha (Duke 1983) while dry seed averages 714 kg/ha (Duke 1983, Saxena et al. 2006). However, dried seed yields may reach 2,000-2,500 kg/ha in pure stands (Peace Corps 1981).

The performance of pigeonpea globally is in an upward trend in terms of area and production from 2.86 million hectares (M ha) and 1.96 million tons (MT) in 1980 to 4.63 M ha and 3.46 MT in 2006, respectively (Figure 66). Its productivity level has stagnated over time. The yield per unit area is reported based on the harvested dry seeds and fresh pods by the major producing countries (FAOStat 2008).

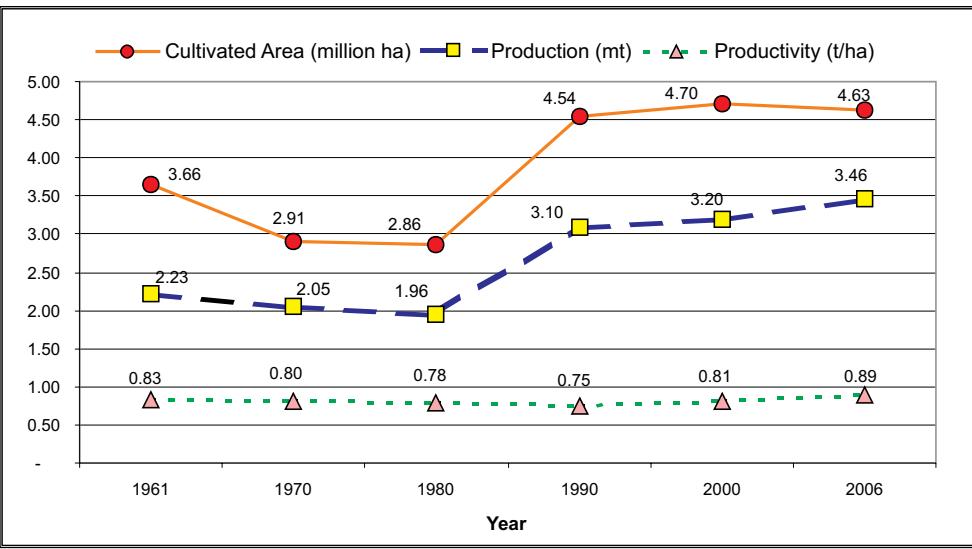


Figure 66. Global pigeonpea area, production and productivity (FAOStat 2008).

Pigeonpea is considered as the third most important pulse crop in India. This country has the largest area devoted for this crop and is the biggest producer thereof. Other countries though consider this crop as their most important crop, like Puerto Rico, which accounts for about 90% of the total pulse production, Trinidad and Tobago 86% and Malawi 36% while others consider it their second such as Panama, Dominican Republic, Jamaica and Uganda (Saxena et al. 2001). But with high demand and a competitive price, greater attention is now being given to managing and improving this crop.

Pigeonpea does not enjoy global popularity, hence there is limited information available on this plant in other regions of the world. Oftentimes, it is grown only as a backyard crop or as an intercrop and sometimes for boundary-marking, hence it is not generally included in agricultural statistics.

Another situation is the international trading system where large unofficial cross-border trade does not enter formal trade statistics across the regions like pigeonpea imports of India from Nepal, of Malawi from Mozambique, and of countries bordering Dominican Republic where export is the driving force for canned pigeonpeas (Müller et al. 1990). Demand and prices for African pigeonpea are high when there are difficult growing conditions and poor crops in India and Myanmar (Monaco 2003). In view of the inaccurate

market reports on the trading of pigeonpea, the work of various authors who study the market trend of this crop is worth considering.

Area

Agriculture is a major component of global environmental change. Humans have transformed around 15 million km² of natural vegetation of the planet into cropland that provides the bulk of the food and fiber essential to their well-being (Monfreda et al. 2008). Worldwide legumes (including pigeonpea) occupy 2.4 million km² or 18% of the global harvested area.

The area under pigeonpea cultivation with over 4.6 M ha (Figure 67) has increased over the last 56 years across the regions (FAOStat 2008). This increase was driven by the rising commercial importance of the crop over time. This pulse bears a high popularity level as shown by its cultivation in countries with minor consideration as intercrop, mix crop, or backyard crop in more than 90 countries of Africa, Asia, the Americas and the Caribbean, and Oceania (Table 6). In some countries like China, pigeonpea is becoming a potential cash crop because of its diverse use in livestock and lac production aside from its contribution as a soil erosion control mechanism. Unlike in major producing countries such as India and Myanmar, pigeonpea is cultivated in these areas as a field crop.

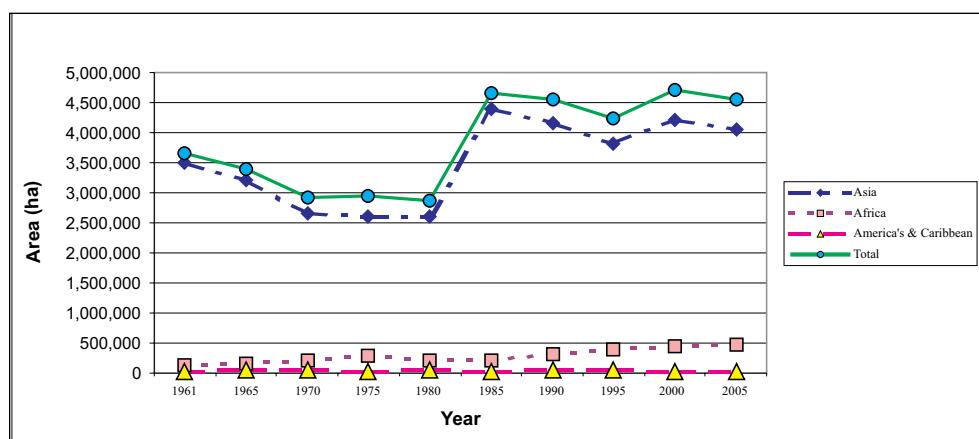


Figure 67. Global trend of area cultivated with pigeonpea by region (1961-2005).

Table 6. Minor growing countries of pigeonpea by region.

Region	Country
Africa	Angola, Benin, Botswana, Burkina Faso, Cameroon, Cape Verde, Côte d'Ivoire, Egypt, Ethiopia, Eritrea, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Madagascar, Madeira, Mali, Mauritius, Mozambique, Niger, Nigeria, Rwanda, Saint Helena; São Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, Sudan, Swaziland, Togo, Zaire, Zambia, Zimbabwe
Americas and Caribbean	Anguilla, Antigua and Barbuda, Argentina, Barbados, Belize, Bermuda Islands, Bolivia, Brazil, Colombia, Costa Rica, Cuba, Dominica, Ecuador, El Salvador, French Guyana, Guadeloupe, Guatemala, Guyana, Honduras, Martinique, Mexico, Montserrat, Netherlands Antilles, Nicaragua, Paraguay, Peru, St. Croix, Saint Kitts and Nevis, Saint Lucia, Saint Thomas, Saint Vincent, Suriname, Turks and Caicos Islands, USA (Florida, Oregon and Virginia)
Asia	Afghanistan, Bhutan, Cambodia, China, Hong Kong, Indonesia, Japan, Laos, Malaysia, the Philippines, Sri Lanka, Taiwan, Thailand, USSR, Vietnam, United Arab Emirates
Oceania	Australia, Caroline Island, Cook Islands, Federated States of Micronesia, Fiji, French Polynesia, Guam, Hawaii, Mariana Islands, Nauru, New Caledonia, Niue, Papua New Guinea, Pitcairn Island, Solomon Islands, Tonga

(Nene et al. 1989; Nyabyenda 1987; van der Maesen 1983, 1986; Boehringer and Caldwell 1989; Wester 1992; Versteeg and Koudokpon 1993; Port 1995; Wagner et al. 1999; Swart et al. 2000; Kamanga and Shamudzairira 2001; Amarteifio et al. 2002; Gibb 2003; ILDIS Coordinating Centre 2005; Aiyelaja and Bello 2006; Kayouli et al. 2006; McCormack 2007).

Countries identified as a minor growing area of pigeonpea by Nene et al. (1989), Nyabyenda (1987) and van der Maesen (1983, 1986) have to be re-classified. Burundi has now been elevated as one of the major producing countries of pigeonpea since 1961 (FAOStat 2008). In the Americas and the Caribbean, the countries Antigua and Barbuda, Barbados, Guadeloupe, Nicaragua, St. Kitts/Nevis/Anguilla, St. Lucia and St. Vincent are now considered minor producing countries of this crop. However, French Antilles (as presented by Nene et al. 1989; Nyabyenda 1987; and van der Maesen 1983, 1986) has to be deleted because it is not considered as a country but instead comprises two countries, the Martinique (which is already included) and Guadeloupe (en.wikipedia.org/wiki/Antilles). Australia, Guam, New Zealand and Palau in Oceania and Cambodia and Thailand in Asia are also incorporated as minor producing countries in their respective region. The latest additional countries are likewise cited in Chapter 4.

The FAOStat (2008) reported that in 2006, pigeonpea is cultivated in over 4.63 M ha in 20 major producing countries across the tropics and sub-tropics, but according to Saxena (2009), the area cultivated has jumped to over 4.92 M ha with the inclusion of China (150,000 ha) as a major producer of this crop. The area under pigeonpea cultivation, however, is often underestimated because a large proportion of the cultivation, especially in the minor growing countries, is done in small patches of land by smallholder farmers.

Asia has the largest cultivated area among the regions where India accounts for about three-quarters of the increase in pigeonpea during the last four decades. Most of the increase occurred during the mid-80s. As gleaned in Table 7 from 3,661,569 ha in 1961, pigeonpea area has decreased to 2,857,209 ha in 1980. However, in 1985 pigeonpea area almost doubled to 4,665,298 ha and this level of cultivation of over 4 M ha was maintained until 2005. India, which dominated the cultivation of pigeonpea, has decreased its area from 4,308,667 ha in 1985 to 3,503,649 ha in 2005 due to drought. Surprisingly, the second major producer of pigeonpea is Myanmar where in 1985 the area cultivated was recorded at 71,990 ha, which leaped to 513,000 ha in 2005 and then to 540,000 ha in 2006 (Appendix 1). In Africa, Kenya likewise increased its area from 95,272 ha in 1985 to 200,000 ha in 2005. The other country with notable increase in area is Uganda while the rest of the countries showed an equal or decreasing trend since 1961. In the Americas and Caribbean, the area devoted to pigeonpea cultivation is at a decreasing trend.

As shown in Appendix 2, the area cultivated during the 2000 cropping season was slightly higher than in 2006 at 1.4%. Since 1984, the global trend for area cultivated to pigeonpea was at the level of over 4 M ha and at one point in the 1994 cropping season, the area increased to 5,099,820 ha with Asia registering 4,717,201 ha and India dominated this by cultivating 4,486,667 ha.

Table 7. Global trend of pigeonpea area (ha) by region and by country (1961-2005).

Region/ Country	Area (ha)						2005			
	1961	1965	1970	1975	1980	1985				
Asia	3,505,975	3,204,814	2,648,325	2,599,064	2,598,883	4,405,892	4,158,696	3,812,099	4,218,540	4,048,908
Bangladesh	7,668	4,940	3,808	5,099	9,665	10,384	5,857	4,054	4,477	3,241
India	3,443,333	3,150,000	2,598,307	2,540,000	2,532,430	4,308,667	4,073,261	3,573,333	3,842,857	3,503,649
Myanmar	46,489	39,203	33,385	40,066	38,155	71,990	59,845	208,759	341,909	513,000
Nepal	8,108	8,784	11,380	12,748	15,833	14,189	19,733	25,953	29,297	29,018
Pakistan	377	1,887	1,445	1,151	2,800	662	-	-	-	-
Africa	119,679	145,885	223,280	299,508	209,710	220,952	320,344	383,844	453,361	485,520
Burundi	2,371	2,371	3,878	5,665	2,524	2,577	2,300	2,577	1,729	2,000
Comoros	-	-	-	-	-	-	352	389	411	440
Congo	4,960	4,960	5,565	9,360	3,423	6,400	6,400	7,361	8,340	8,000
Kenya	-	-	-	-	-	-	95,272	121,730	187,440	200,000
Malawi	82,540	111,111	118,044	182,266	113,823	114,286	102,369	139,555	122,861	123,053
Tanzania	14,493	9,425	28,340	39,409	35,570	72,464	51,990	60,000	66,197	68,027
Uganda	15,315	18,018	67,453	62,808	54,370	25,225	61,661	52,252	66,383	84,000
Americas & Caribbean	35,915	40,653	43,001	36,729	48,616	38,454	63,679	44,505	25,667	29,408
Bahamas	457	614	771	893	743	928	857	200	164	180
Dominican Republic	18,649	18,919	22,522	13,425	19,424	12,094	33,497	26,749	11,903	13,000
Grenada	637	654	552	595	765	535	433	476	510	520
Haiti	5,833	6,250	6,771	7,708	8,292	8,958	8,667	4,054	6,522	6,004
Jamaica	838	731	1,677	2,550	2,450	1,797	1,623	1,478	1,277	1,100
Panama	2,917	2,708	2,917	3,119	2,290	4,887	3,591	4,052	2,358	4,801
Puerto Rico	3,348	2,825	2,131	2,892	6,085	2,222	3,225	396	143	165
Trinidad & Tobago	750	1,202	907	1,270	1,870	1,108	1,294	1,654	302	1,138
Venezuela	2,486	6,750	4,753	4,277	6,697	5,925	10,492	5,446	2,488	2,500
Total	3,661,569	3,391,352	2,914,606	2,935,301	2,857,209	4,665,298	4,542,719	4,240,448	4,697,568	4,563,836

FAOSTAT 2008

FAUStat 2006.

Production

Pigeonpea is the fourth most important pulse crop in the world with almost all production confined to the developing countries of the arid and semi-arid tropics. The marginal increase of this crop, which is about 24%, was attributed to the increase in production from 2.2 MT in 1980-82 to 2.9 MT in 1996-1998. The global production of this crop has increased by 43% since 1970 (www.crnindia.org). The increase was due to the expansion of cultivated land. Although India was the main contributory to the increase in production, Myanmar has the highest annual growth rate of 11.5%. As to the other countries, the increase in production was mainly due to increase in the areas cultivated with pigeonpea.

Asia dominated the world production of pigeonpea between 1961-2006 with as much as 90.64% in 2000 and 89.88% in 2006 compared to the other regions. Figure 68 shows the data gathered since 1961 showing Asia cornering the production of pigeonpea by an average of 91%. Globally, the production was not sufficient to meet the needs of the consumers due to a mismatch in population and production growth in spite of the increase in area. Aside from this, most countries still do not report statistically their pigeonpea production.

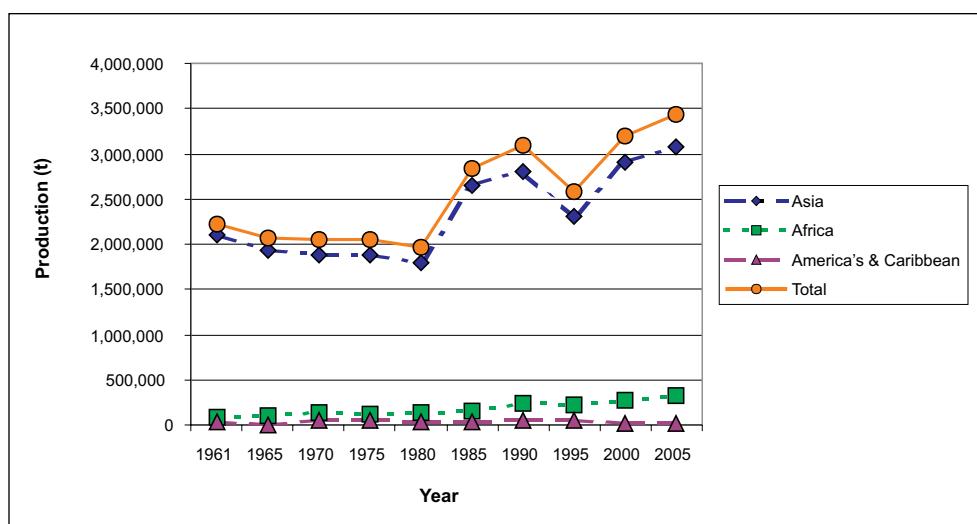


Figure 68. Global production trend of pigeonpea by region (1961-2005).

Global production trend has had its highs and lows from 1961 to 2005. From 1961 to 1980, pigeonpea production decreased from 2,227,955 t to 1,965,319 t. From 1980 to 1990, production increased to 3,100,287 t then dropped to 2,585,243 t in 1995. Since 1995, the production trend was upward with recorded increase of 3,204,187 tons in 2000, 3,428,166 t in 2005 (Figure 68) and 3,458,166 t in 2006 (FAOStat 2008).

Amongst Asia, Africa, the Americas and Caribbean, India dominated the production of pigeonpea over time (Table 8). Production trend is erratic even among the major producing countries. During the production years 1990 and 2000 cropping seasons, India registered 2,746,600 t and 2,690,000 t, respectively, the highest in 4 decades. In Asia, next to India is Myanmar, which is also the second largest producer of pigeonpea with 649,971 t in 2005 while the least major producing country is Bangladesh (2,000 t). In Africa, Kenya (105,000 t), Uganda (84,000 t), Malawi (79,000 t) and Tanzania (50,000 t) were the highest producers of pigeonpea, while Comoros produce only 320 tons in 2005. It is interesting to note that Myanmar and Kenya have improved their production from 1990 to 2005. In the Americas and Caribbean, the production trend is varied. All the identified major countries have their high and low situations. In the 2005 cropping season, Dominican Republic displayed the highest at 13,500 t while the lowest is Puerto Rico (125 t) and Bahamas (250 t).

Table 8. Global production (t) trend of pigeonpea by region and by country. (1961-2005).

Region/ Country	1961	1965	1970	1975	1980	1985	1990	1995	2000	2005
Asia	2,108,109	1,927,402	1,877,363	1,875,900	1,796,320	2,650,042	2,800,205	2,309,205	2,904,205	3,077,971
Bangladesh	4,064	3,048	2,677	3,600	7,300	5,400	3,195	3,000	3,000	2,000
India	2,066,000	1,890,000	1,842,200	1,834,200	1,757,000	2,585,200	2,746,600	2,144,000	2,690,000	2,400,000
Myanmar	31,845	26,865	23,470	28,287	20,520	48,591	37,110	143,000	188,734	649,971
Nepal	6,000	6,500	8,000	9,000	10,000	10,500	13,300	19,205	22,471	26,000
Pakistan	200	1,000	1,016	813	1,500	351	-	-	-	-
Africa	84,400	101,903	132,406	121,600	130,430	156,500	243,650	230,677	276,990	325,120
Burundi	2,300	2,300	2,300	2,300	2,630	2,500	2,400	2,500	1,800	1,800
Comoros	-	-	-	-	-	-	250	276	290	320
Congo	3,100	3,100	3,300	3,800	3,800	4,000	4,000	4,601	5,296	5,000
Kenya	-	-	-	-	-	-	81,000	63,300	65,604	105,000
Malawi	52,000	70,000	70,000	74,000	76,000	72,000	70,000	60,000	79,000	79,000
Tanzania	10,000	6,503	16,806	16,000	22,000	50,000	35,000	42,000	47,000	50,000
Uganda	17,000	20,000	40,000	25,500	26,000	28,000	51,000	58,000	78,000	84,000
Americas & Caribbean	35,446	39,383	45,444	48,390	38,569	33,756	56,432	45,361	22,992	25,075
Bahamas	320	430	540	625	520	650	600	140	115	125
Dominican Republic	20,700	21,000	25,000	29,454	16,598	13,424	38,596	29,692	13,213	13,000
Grenada	-	-	-	-	-	-	-	-	-	-
Haiti	750	770	650	700	901	630	510	570	500	500
Jamaica	2,800	3,000	3,250	3,700	4,000	4,300	3,900	3,000	3,000	2,600
Panama	998	870	1,996	2,143	2,351	2,139	1,533	1,759	1,226	1,300
Puerto Rico	4,989	4,209	3,175	4,309	5,216	3,311	1,814	1,945	2,063	2,300
Trinidad & Tobago	1,500	2,404	1,814	2,540	3,532	2,216	2,000	3,308	100	250
Venezuela	1,989	5,400	7,619	3,422	3,447	4,740	5,863	4,357	1,990	2,000
Total	2,227,955	2,058,688	2,055,213	2,045,890	1,965,319	2,840,298	3,100,287	2,585,243	3,204,187	3,428,166

FAO Stat 2008.

Appendix 3 shows the global trend of pigeonpea production from 1961 to 2006. From 1961 to 1988, there were 19 registered major producing countries in the arid and semi-arid tropics when the FAO started officially recording the production of this crop. Beginning 1989 to 2006, the total major producing countries increased to 20. In 2001, global production of pigeonpea was reduced to below 3 MT due to the drought that hit India in 2001.

Productivity

The global productivity level of pigeonpea is unpredictable. Studies revealed that the average yield per unit area is around 700 kg/ha for dry seeds. The Americas and Caribbean registered the highest productivity level among the regions in four decades even yielding as low as 838.78 kg/ha in 1990. The average yield in Americas and the Caribbean is much higher at more than 1,000 kg/ha because people in this region eat pigeonpea mainly in its fresh or green seed form unlike in other regions. Yield per unit area for Asia and Africa are almost at the same level representing mostly dried seeds of pigeonpea. In Africa, the lowest yield experiences were in 1970 and 1975 where the crop registered 593 kg/ha and 406 kg/ha, respectively. In Asia, the productivity level of pigeonpea is observed to be playing around 613 kg/ha to 866 kg/ha. As shown in Figure 69, the global average yield in 2005 is 893.40 kg/ha, which slightly decreased in 2006 to 891.64 kg/ha (Appendix 4).

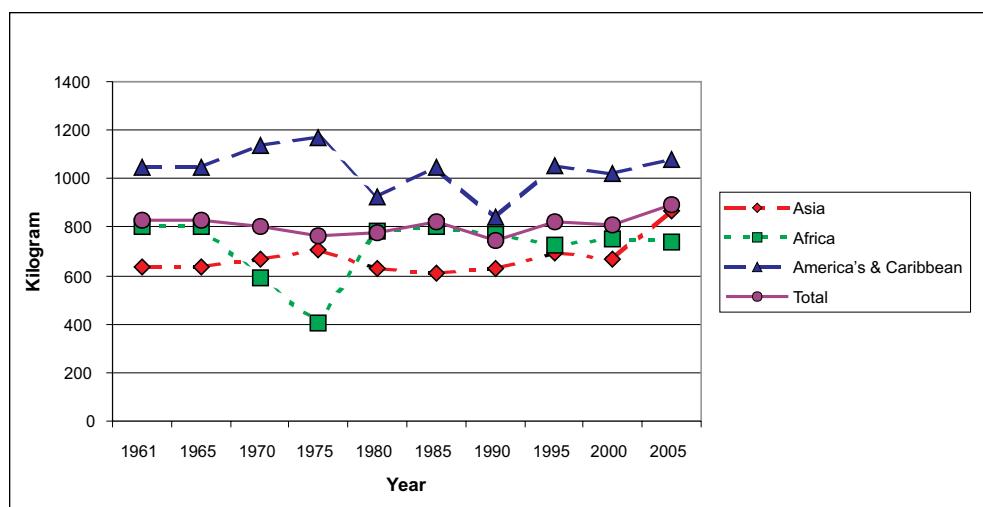


Figure 69. Global productivity trend of pigeonpea by region (1961-2005).

In general, since the 90s, the average yield for dried seeds across the region had stagnated at around 600 kg/ha. Pigeonpea has not achieved its production potential largely due to limited use of appropriate inputs and crop management practices (Smith et al. 2001). The low productivity is a major barrier in improving trade forecast. Under small-scale management, yields of local pigeonpea varieties have been found to be significantly lower at 350 kg/ha of usable seed weight and inconsistent across areas and seasons (Ritchie et al. 2000).

Global yield mainly reflects the situation in Asia especially India, the major producing country, where yields are low at 700 kg/ha (Saxena 2009). The low productivity was attributed to the following factors, particularly, the crop's low status in the cropping system, its being often relegated to marginal soils, its intercrop with cereals and cotton, its receipt of little or no inputs, and the fact that it attracts much of farmers' crop management attention (Troedson et al. 1990, Müller et al. 1990). However, the lack of high yielding cultivars appears to be the major factor for its low productivity (Saxena 2009).

Table 9 shows the yield performance of pigeonpea by country. In Asia, Myanmar has increased its productivity level per unit area from as low as 525 kg/ha in 2000 to as high as 1,267 kg/ha in 2005 followed by Nepal (from 632 kg/ha in 1980 to 896 kg/ha in 2005). In India, the highest yield obtained per unit area is in 1975 with 722 kg/ha. In Africa, productivity level among the major growing areas is erratic. In 2000 and 2005, Uganda, Burundi and Tanzania are the highest among their counterparts. In Kenya, the yield per unit area has reduced from 850 kg/ha in 1990 to 525 kg/ha in 2005 and it experienced the lowest yield in 2000 at 350 kg/ha. In the Americas and Caribbean, Trinidad and Tobago has maintained the same level of productivity at above 2,000 kg/ha from 1961 to 2005.

Table 9. Global productivity (kg) trend of pigeonpea per hectare by region and by country (1961-2005).

Region/ Country	1961	1965	1970	1975	1980	1985	1990	1995	2000	2005
Asia	634.40	634.40	669.60	709.20	631	613	628.25	691.25	665	866.25
Bangladesh	617	617	703	755	520	545	740	670	617	
India	600	600	709	722	694	600	674	600	700	685
Myanmar	685	685	703	706	538	675	620	685	525	1267
Nepal	740	740	703	706	632	740	674	740	767	896
Pakistan	530	530	706	536	530	-	-	-	-	-
Africa	805	805	593	406	783.20	805	773.14	723.57	751.43	736.28
Burundi	970	970	593	406	1042	970	1043	970	1041	900
Comoros	-	-	-	-	-	-	710	710	705	727
Congo	625	625	593	406	1110	625	625	625	635	625
Kenya	-	-	-	-	-	-	850	850	350	525
Malawi	630	630	593	406	668	630	684	430	643	642
Tanzania	690	690	593	406	618	690	673	700	710	735
Uganda	1110	1110	593	406	478	1110	827	1110	1176	1000
Americas & Caribbean	1047.44	1047.44	1136.67	1167.89	923.22	1047.44	838.78	1050.78	1020.55	1077.67
Bahamas	700	700	700	700	700	700	710	710	700	694
Dominican Republic	1110	1110	1110	2194	854	1110	1152	1110	1110	1000
Grenada	1177	1177	1177	1177	1177	1177	1177	1197	980	961
Haiti	480	480	480	480	482	480	450	480	460	433
Jamaica	1190	1190	1190	960	1190	944	1190	960	960	1181
Panama	480	480	480	480	875	480	450	480	875	479
Puerto Rico	1490	1490	1490	1490	857	1490	562	1490	700	1515
Trinidad & Tobago	2000	2000	2000	1889	2000	1545	2000	1545	2600	2636
Venezuela	800	800	1603	800	515	800	559	800	800	800
Total	828.95	828.95	799.77	761.03	779.14	821.81	746.72	821.87	812.33	893.40

FAOStat 2008.

The Dominican Republic sustained its productivity level of over 1,000 kg/ha and only experienced a poor yield performance in 1980 (854 kg/ha). The same situation is also observed in Jamaica. The most noticeable fluctuation of yield beginning 1980 to 2005 was Panama and Puerto Rico, while Bahamas, Grenada and Haiti have lowering trend yield (Table 9).

Global Contribution (%)

As gleaned in Table 10, Asia dominated the area cultivated and production of pigeonpea from 1961 to 2005 with ranges from 88 to 94%. Africa's performance was an increasing trend from 3% in 1961 to 10% in 2005 for cultivated area and from 4% in 1961 to 9% for production of pigeonpea. Although the Americas and Caribbean are among the regions considered as major producers of this crop (mainly for its green-pods as vegetable), this region has not been aggressive in terms of expanding its area as compared with Asia and Africa since its documentation in 1961.

Table 10. Percent contribution of area cultivated and production by region (1961-2005).

Region	Area cultivated and Production (%)																			
	1961		1965		1970		1975		1980		1985		1990		1995		2000		2005	
	A	P	A	P	A	P	A	P	A	P	A	P	A	P	A	P	A	P	A	P
Asia	96	95	94	93	91	91	88	92	91	91	94	93	91	90	90	89	90	90	89	90
Africa	3	4	4	5	8	6	10	6	7	6	5	5	7	8	9	9	9	9	10	9
Americas & Caribbean	1	1	2	2	1	3	2	2	2	3	1	2	2	1	2	1	1	1	1	1

Legend: A - Area; P - Production; FAOStat 2008.

Market Trends

Domestic Market and Consumption

The importance of pigeonpea in the smallholder economy goes beyond the food dimension since the plant also provides forage, fodder, fuel and medicine (Mergeai et al. 2001). In either form (dry grain and as a green vegetable), it makes an important contribution to the diet of resource poor farmers (Audi et al. 1999). Likewise, the consumption varies according to local inclination, income level, ethnic grouping and between urban and rural populations (Lyimo and Myaka 2001).

Domestically, an active demand of pigeonpea exists in both traditional and new outlets but this is hard to quantify. Green and dried pigeonpea are sold in both rural and urban retail markets and in the active markets of high-income areas of major cities. In Kenya, pigeonpea is consumed as dry seeds by low-income urban consumers while the high-income areas prefer the green pods or seeds (Lyimo and Myaka 2001). Freeman et al. (1998), Technoserve (1998b) and Freeman and Jones (2001) provided comprehensive issues related to pigeonpea commercialization in domestic markets.

In Asia, particularly in India, *dal* is the dominant form in which pigeonpea is sold to consumers. In India, considered as the world's largest producer of pigeonpea, the annual demand of this crop is always in the shortfall because of the growing population, rise in income and shift of consumer preferences towards high-value products such as processed pulses, combined with the long-term stagnation in domestic production. Pigeonpea is sold directly by farmers in rural assembly markets to middlemen or to local *dal* millers (von Oppen 1981). Market shortfalls are met by imports from Africa, Nepal and Myanmar. In Myanmar, the consumption of pigeonpea is preferred by people of Indian and Nepalese descent (Nene et al. 1990).

In Africa, pigeonpea marketing is widespread throughout the region with varying degrees of integration into commercial channels. An estimated 65% of regional pigeonpea production is consumed by the farmers themselves. These estimates are consistent with micro-level observation of on-farm consumption, retention of seed for planting and pigeonpea exchanges at community level (Muwalo et al. 1999). Around 10% of production in Kenya, Malawi and Tanzania are traded in domestic markets. Domestic markets in Tanzania are smaller than in Kenya, particularly for the green and processed forms. Thirty-five percent (35%) of the total production are consumed on-farm (Monaco 2003).

In the Americas and Caribbean, about 8% of the households consume dried pigeonpeas, especially in areas where there is a concentration of ethnic Indian population while in Trinidad and Guyana, 26% consume green pigeonpea as vegetable. About 60% of the produce is processed into canned pigeonpea, 15% sold as mature, green, fresh peas and the remaining quantities in frozen form (Nene et al. 1990).

Export

Pigeonpea marketing is widespread throughout the region in the arid and semi-arid tropics with varying degrees of integration into commercial channels. Extensive analysis of the crop sub-sector has different marketing channels and actors involved (Freeman and Jones 2001). The international market potential for *dal* and whole seed of pigeonpea is unknown since only small amounts of these products enter world trade. However, it is clear that considerable potential exists for export of pigeonpea to people of Indian descent. Price will be determined by characteristics such as seed size, color and the more complex attributes associated with appearance, cooking time and taste. In the 1970s, a market in excess of US\$5 million per annum existed for canned or frozen green pigeonpea seed from the Caribbean region exported to expatriates living in USA, Canada and the United Kingdom.

The statistics of the quantity of pigeonpea traded internationally is insignificant and incomplete because of the complexities in knowing or gathering the data. Most countries, even the major producing countries, do not keep separate documents since pigeonpea is considered as one commodity under the category of pulses.

The FAOStat (2008) reported that Dominican Republic and Malawi were continuously involved in exporting pigeonpeas from 1961 to 2009. The accumulated export in the 20s has substantially increased owing to the aggressiveness of Myanmar in exporting its pigeonpeas around the world (Table 22). A total of 888,927 t with a value of \$390.611 M were exported with the bulk of the export of 887,793 t coming from Myanmar (Table 11).

Table 12 presents the three-year aggregate of exported pigeonpea from 1961 to 2009. The period 2006–2008 showed an upsurge in export of pigeonpea with a total quantity of 589,345 t and with a street value of \$291,236,278.80.

However, according to Joshi et al. (2001), besides Myanmar, African countries like Kenya and Tanzania are also important exporters for the last 10-15 years. However, the exports made by these two countries were not recorded in the statistics data of FAO.

Table 11. Status of pigeonpea exported by region and by country (1961-2004).

Region/ Country	Cumulative Export Data							
	60s ('61 - '69)		70s ('70 - '79)		80s ('80 - '89)		90s ('90 - '99)	
	Qty (t)	Value (000\$)	Qty (t)	Value (000\$)	Qty (t)	Value (000\$)	Qty (t)	Value (000\$)
Asia								
Myanmar	90905	12573	52658	13462	4327	2741	21442	9565
India	80863	10825	48631	12344	-	-	20160	8482
Nepal	10042-	1748	4027	1118	1552	1534	1282	1083
Africa								
Malawi	147507	13427	83873	18660	143855	48951	98788	29828
Americas & Caribbean								
Barbados	2411	408	54	22	13675	12795	6606	5534
Dominican Republic	-	-	-	-	10	9	-	-
Jamaica	2411	408	29	11	13659	12781	6006	5534
Total	240823	26408	136585	32144	161857	64487	126236	44927

FAOStat Data (April, 2008); *USDA GAIN Report (2002 to 2009).

Table 12. Three (3) year world aggregate of export data (1961-2009).

Year	Quantity (t)	Value (M \$)
Mid 2009	33,775	22,460,375
2006-2008	589,345	291,236,278
2003-2005	203,103	61,128,766
2000-2002	62,704	14,805,733
1997-1999	49,576	15,943,000
1994-1996	38,651	13,001,000
1991-1993	33,144	13,527,000
1988-1990	26,398	10,568,000
1985-1987	88,083	28,174,000
1982-1984	39,189	22,918,000
1979-1981	21,908	4,583,000
1976-1978	31,826	11,729,000
1973-1975	25,523	7,519,000
1970-1972	70,089	10,499,000
1967-1969	77,606	8,550,000
1964-1966	101,531	11,653,000
1961-1963	61,686	6,208,000

FAOStat 2008; USDA GAIN Report (2002 to 2009).

Import

Globally, every country experienced a gross deficit of pulses of dried or green peas and therefore required meeting its shortfall through imports from major producing countries.

According to Joshi et al. (2001), in the 80s, the volume of total annual imports was only 10,720 t and increased to 140,800 t in the 90s. But this is in contrast to the data supplied by the FAOStat (2008) where during the period 1980–1989 and 1991–1999, the aggregate data of importation recorded was at 58,986 t and 22,703 t, respectively (Table 13). In the 20s, the total import of pigeonpea was recorded at 900,379 t with total value of \$414,060,037. India imported from Myanmar a total of 830,119 t. In the data acquired from USDA Foreign Agricultural Service GAIN Report (2005), it was stated that whole pigeonpea (vegetable) accounted for 26% of the total pulse import.

Table 13. Data of imported pigeonpea by region and by country.

Region/ Country	Cumulative Import Data															
	60s ('67 - '69)				70s ('70 - '79)				80s ('80 - '89)				90s ('90 - '99)			
	Qty (t)	Value (000\$)	Qty (t)	Value (000\$)	Qty (t)	Value (000\$)	Qty (t)	Value (000\$)	Qty (t)	Value (000\$)	Qty (t)	Value (000\$)	Qty (t)	Value (000\$)	Qty (t)	Value (000\$)
Asia	570	78	5,169	939	39,591	13,829	220	738	884,308	388,641.363						
Bangladesh	-	-	-	-	-	-	-	-	-	-	315	148,573				
Bahrain	-	-	-	-	-	-	-	-	-	-	8	4.2				
China	-	-	-	-	-	-	-	-	-	-	26,542	12,424.409				
Indonesia	-	-	-	-	-	-	-	-	-	-	-	-	48	25.2		
Japan	-	-	-	-	-	-	-	-	-	-	-	-	3,976	1,712.7		
Korea	-	-	-	-	-	-	-	-	-	-	-	-	248	130.2		
Kuwait	-	-	-	-	-	-	-	-	-	-	-	-	148	77.7		
Malaysia	-	-	-	-	-	-	-	-	-	-	-	-	79	41.47		
Pakistan	-	-	-	-	-	-	-	-	-	-	-	-	1,902	836,469		
Qatar	-	-	-	-	-	-	-	-	-	-	-	-	24	12.6		
Saudi Arabia	-	-	-	-	-	-	-	-	-	-	-	-	295	130,533		
Singapore	-	-	-	-	-	-	-	-	-	-	-	-	4,510	2,239,335		
Thailand	-	-	-	-	-	-	-	-	-	-	-	-	1,683	737.55		
United Arab Emirates	-	-	-	-	-	-	-	-	-	-	-	-	14,386	7,863.317		
India	570	78	5,169	939	33,280	12,335	-	-	-	-	-	-	830,119	362,149.107		
Nepal	-	-	-	-	6,311	1,494	220	738	-	-	25	108.0				

Continued

Table 13. Data of imported pigeonpea by region and by country *continued*.

Region/ Country	Cumulative Import Data												20s (00 - '09)			
	60s (67 - '69)				70s (70 - '79)				80s (80 - '89)				90s (90 - '99)			
	Qty (t)	Value (000\$)	Qty (t)	Value (000\$)	Qty (t)	Value (000\$)	Qty (t)	Value (000\$)	Qty (t)	Value (000\$)	Qty (t)	Value (000\$)	Qty (t)	Value (000\$)	Qty (t)	Value (000\$)
Americas & Caribbean	-	12,589	4,948	19,397	11,173	8,727	6,236	1,628	18,764,066							
Barbados	-	-	-	-	731	513	1,352	970	-	-	-	-	-	-	-	-
Dominican Republic	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	72,066
Grenada	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Jamaica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Portugal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Trinidad & Tobago	-	-	-	-	3,517	2,628	5,799	4,041	-	-	-	-	-	-	-	17,652.0
Venezuela	-	-	11,997	4,760	15,147	8,029	426	269	-	-	-	-	-	-	-	-
Africa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mauritius	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tanzania	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Oceania	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Australia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Europe	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Belgium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	372,252
France	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	99,435
Italy	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8.54
Netherlands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	202,756
United Kingdom	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30,827
Poland	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	48.0
Total	570	78	17,758	5,887	58,988	25,002	22,703	15,452	900,379	414,060,037						

Table 14 shows that the highest total three-year aggregate of imported pigeonpea was in 2006-2008 at 589,345 t with a value of \$291,236,279, which is an abrupt increase since 1961. Meanwhile in the first half of 2009, only about 33,775 t were imported despite the increase in area and improved high yielding cultivars. Again, like in export and in the domestic trade, the situation of marketed pigeonpea is insignificant because there are no studies conducted in pigeonpea markets (Müller et al. 1990).

Table 14. Three (3) year world aggregate of import data (1967-2004).

Year	Quantity (t)	Value (M USD)
Mid 2009	33,775	22,460,375
2006 - 2008	589,345	291,236,279
2003 - 2005	207,687	64,006,766
2000 - 2002	69,572	18,719,275
1997 - 1999	7,494	4,550,000
1994 - 1996	6,505	5,258,000
1991 - 1993	5,914	3,895,000
1988 - 1990	8,667	4,182,000
1985 - 1987	13,760	5,377,000
1982 - 1984	22,895	9,832,000
1979 - 1981	19,337	8,885,000
1976 - 1978	7,050	2,356,000
1973 - 1975	6,790	1,862,000
1970 - 1972	1,037	143,000
1967 - 1969	570	78,000

FAOStat 2008; USDA GAIN Report (2002 to 2009).

International Market Trade: A Regional Scenario

There are three regions where pigeonpea is grown with major productivity in the arid and semi-arid tropics. In Asia and Africa, a majority of pigeonpeas produced are milled into split *dal* while in the Americas and the Caribbean, 80% are processed into canned peas or fresh peas and eaten as vegetable and 20% as matured seeds.

In the international market trade, during the period 2000-2009, Asia dominated the market by exporting 99.87%, as compared to just 17% in the 90s, mostly of the dry seeds. The Americas and the Caribbean region merely exported 0.07%, a reduction from the data recorded in the 90s at 5% because of the presence of a canning industry in the Dominican Republic. Africa has only 0.06% share in the export market from 2000-2009, a reduction from previous years where it dominated the export market from the 60s until the 90s (Table 15).

Table 15. Percent share of exported pigeonpea by region and by decade.

Region	60s	70s	80s	90s	20s ('00 -'09)
Asia	38	38.5	03	17	99.87
Africa	61	61.4	89	78	0.06
Americas and Caribbean	01	00.1	08	05	0.07

FAOStat 2008; USDA GAIN Report (2002 to 2009).

The percent of import by region revealed that Asia increased its import demand from 0.97% in the 90s to a remarkable 98.22% from 2000-2009. Likewise, Africa and the Americas and Caribbean have rapidly reduced their import requirement (Table 16). Europe and Oceania have started importing only in the 20s. However, there are large quantities of pigeonpea imported across countries where pigeonpea is considered as one of their staple foods but the data were not recorded.

Table 16. Percent share of imported pigeonpea by region and by decade.

Region	60s ('67 – 69)	70s	80s	90s	20s('00 -'09)
Asia	100	29	67	0.97	98.22
Africa	-	-	-	60.59	1.32
Americas and Caribbean	-	71	33	38.44	0.18
Europe	-	-	-	-	0.26
Oceania	-	-	-	-	0.02

FAOStat 2008; USDA GAIN Report (2002 to 2009).

In both trading systems (export and import), the quantities are not in equal proportion for the past three and a half decades when FAO started documenting pigeonpea for the international market. As previously stated,

large unofficial cross-border trading does not enter formal trade statistics across the regions like pigeonpea *dal* from India to Nepal or vice versa, from Mozambique to Malawi and in countries bordering Dominican Republic where export is the driving force for canned pigeonpeas (Müller et al. 1990).

CHAPTER IV

Pigeonpea: A Regional Situation (*Major and Minor Producing Countries*)

This Chapter illustrates how each country evolved as a major and minor producer of pigeonpea. There are four regions presented, namely: Asia, Africa, The Americas and Caribbean, and Oceania. The type of geography and agricultural systems of each region and country are described to show how pigeonpea is cultivated and to show the potential of this crop in terms of adaptation, importance to livelihood and economy.

Asia

Asia has made amazing advances in food production in the last 40-50 years to meet the needs of its growing population. Asia's staple food is rice and wheat. Cereal production almost doubled and the availability of food has increased by 24%. With continued investments in research, Asia hopes to continue to experiment and hopefully succeed in wiping out hunger across its continent. Smart investing allowed for research on 'smarter food' (Rabah 1981). Pigeonpea is considered a 'smart food' due to its very diverse use and characteristics.

In Asia, Bangladesh, India, Myanmar and Nepal are the only major producers of pigeonpea (Figure 70). Pigeonpea yields more energy, protein and beta-carotene per hectare than any other major pulses (Nene and Sheila 1990, and Jambunathan et al. 1991). India dominates the scene with 92% of the total area and 94% of total production of pigeonpea in 1999. Since 1970, the area planted to pigeonpea has increased steadily in India, but productivity has remained static at 400-800 kg/ha (Nene and Sheila 1990). The area planted in Myanmar has more than quadrupled from 1989 to 1999. The yield of pigeonpea increased from 776 kg/ha in 1989 to 787 kg/ha in 1999, and pigeonpea area increased from 3.6 M ha in 1989 to 3.8 M ha in 1999 while increase in production has come primarily from increase in area in Myanmar, Nepal and Bangladesh (Table 17).



Figure 70. Map of Asia.

Table 17. Area, Production and Productivity of Pigeonpea in Asia, 1989 and 1999.

Countries	Area ('000 ha)			Production (mt)			Productivity (kg/ha)		
	1989	1999	GR*	1989	1999	GR*	1989	1999	GR*
Bangladesh	5.8	6.1	0.5	3.3	3.0	-0.5	569	491	-1.0
India	3,890.0	3,500.0	-0.5	2,717.7	2,800.0	-1.1	779	800	-0.6
Myanmar	62.0	255.0	18.0	41.5	159.5	19.0	669	625	0.8
Nepal	17.9	26.0	4.1	12.3	18.3	5.8	687	704	1.6
Pakistan	0.8	-	-	-	0.5	-	-	-	-
Asia	3,575.5	3,787.1	-0.3	2,774.8	2,981.3	1.2	779	787	1.5

Source: FAO Production Yearbook and FAOStat 2000.

Note: *GR = % average annual growth rate.

India, the largest consumer and producer of pigeonpea remains the only market to absorb any significant increase in African exports. However, trading opportunities have changed significantly in the last three years. Myanmar has rapidly become the largest supplier of cheap, low quality pigeonpea in India. Imports from Myanmar take place all-year round reducing the competitive edge of seasonal exports in Africa (Monaco 2003).

Area

In Asia, between 1972 and 2003, pigeonpea recorded 57% increase in area (2.44 to 3.81 M ha) and 61% increase in production (1.72 to 2.77 MT) (www.ICRISAT@CGIAR.org). Bangladesh, India, Myanmar and Nepal were among the top 20 major producers of pigeonpea in the 90s until 2006 (Table 14). However, in the 60s, 70s and 80s, Pakistan was identified as one of the major producing countries (FAOstat 2008). Asia contributes 89% and 90% of pigeonpea for total global area cultivated and produced, respectively, as compared to Africa, the Americas and Caribbean in 2006. India is the largest provider at 86% of the total area cultivated in Asia. Next to India is Myanmar followed by Nepal and Bangladesh (Table 18). According to Saxena (2007), China has already cultivated around 100,000 ha of land from 5,000 ha in 1989 where the crop is planted along highways, on steep and sloping mountains, for soil erosion control and /ac production.

Based on records provided by FAOStat (2008), Myanmar has significantly increased its area and production from 1961 until 2005 (Figure 1 and Table 18) as compared with the other major producers of pigeonpea. Although not widely eaten by local people, the increase was due to farmers' income derived from export.

Production

Total production of pigeonpea from 1961 to 2005 cropping season in Asia increased from 2,108,109 t to 3,077,971 t. India dominated the production at 2,400,000 t in 2005 as compared to other major producing countries in Asia (Table 19). The increase in production was due to the increase in area cultivated to pigeonpea. Myanmar was recorded by FAOstat (2008) as the second largest producer of this crop because of the importance of this crop to the country's economy. The dried pigeonpeas are exported mostly to India while the green pigeonpeas are exported mostly to the Americas and the Caribbean.

In 2006, India's annual production contribution in Asia of around 78% has decreased significantly as compared to year 2000, when it was 92.6% (Table 20). This was attributed to the reduction of land area cultivated during this period. However, during the same period there was a substantial increase in area cultivated in Myanmar where most of their production was intended for export.

Productivity

Myanmar's production per unit area was higher than its counterpart in Asia. The average yield obtained by Myanmar in 2001 to 2006 was increasing (Table 21). India, the leading pigeonpea producer globally has not increased its yield per unit area as compared to Nepal and Myanmar. The recorded yield is considered very low considering the effort poured towards research and development by leading institutions such as ICRISAT, ICAR and the private sector.

Table 18. Pigeonpea area (ha) cultivated by country in Asia (1961-2005).

Country	Area (ha)					
	1961	1965	1970	1975	1980	1985
Bangladesh	7,668	4,940	3,808	5,099	9,665	10,384
India	3,443,333	3,150,000	2,598,307	2,540,000	2,532,430	4,308,667
Myanmar	46,489	39,203	33,385	40,066	38,155	71,990
Nepal	8,108	8,784	11,380	12,748	15,833	14,189
Pakistan	377	1,887	1,445	1,151	2,800	662
Total	3,505,975	3,204,814	2,648,325	2,599,064	2,598,883	4,405,892
FAOStat 2008.						

Table 19. Pigeonpea production (t) by country in Asia (1961-2005).

Country	Production (t)					
	1961	1965	1970	1975	1980	1985
Bangladesh	4,064	3,048	2,677	3,600	7,300	5,400
India	2,066,000	1,890,000	1,842,200	1,834,200	1,757,000	2,585,200
Myanmar	31,845	26,865	23,470	28,287	20,520	48,591
Nepal	6,000	6,500	8,000	9,000	10,000	10,500
Pakistan	200	1,000	1,016	813	1,500	351
Total	2,108,109	1,927,402	1,877,363	1,875,900	1,796,320	2,650,042
FAOStat 2008.						

Table 20. Percent of pigeonpea area cultivated and production (2000-2006).

Asia	Area cultivated and Production (%)											
	2000		2001		2002		2003		2004		2005	
	Area	Prod.	Area	Prod.	Area	Prod.	Area	Prod.	Area	Prod.	Area	Prod.
Bangladesh	00.11	00.10	00.08	00.07	00.08	00.07	00.10	00.07	00.08	00.07	00.08	00.10
India	91.09	92.60	89.70	85.05	86.00	82.09	85.36	81.19	87.21	82.15	86.53	77.97
Myanmar	08.10	06.50	09.40	12.10	13.06	16.93	13.80	17.82	11.98	16.90	12.67	21.12
Nepal	00.70	00.80	00.82	02.78	00.86	00.91	00.74	00.92	00.73	00.88	00.72	00.85

FAOStat 2008.

Table 21. Average productivity (kg) per hectare by country in Asia (1961-2005).

Country	Productivity (kg/ha)					
	1961	1965	1970	1975	1980	1985
Bangladesh	617	617	703	706	755	520
India	600	600	709	722	694	600
Myanmar	685	685	703	706	538	675
Nepal	740	740	703	706	632	740
Pakistan	530	530	530	706	536	530
Total	634.40	634.40	669.60	709.20	631	613
					628.25	691.25
						665
						866.25

FAOStat 2008.

Major Pigeonpea Producing Countries in Asia

Bangladesh

Geography

Bangladesh is a land of rivers that crisscrossed throughout the mostly flat territories of the country. It is located in South Asia and has an area of 144,000 km². Bangladesh with geographic coordinates of 21°27'N to 26°16'N latitude and 87°53'E to 92°38'E longitude is bordered on the west, north and east by a 2,400-km land frontier with India and in the southeast, by a short land and water frontier (193 km) with Myanmar (Figure 70). Roughly 80% of the landmass is made up of fertile alluvial lowland called the Bangladesh Plain. The plain is part of the larger Plain of Bengal, which is sometimes called the Lower Gangetic Plain. Although altitudes up to 105 masl occur in the northern part of the plain, most elevations are less than 10 masl. With such low elevations and numerous rivers, water is a predominant physical feature. About 10,000 km² of the total area of Bangladesh is covered with water, and larger areas are routinely flooded during the monsoon season. Bangladesh's alluvial soil is highly fertile, but vulnerable to flood and drought. Hills rise above the plain only in the Chittagong Hill Tracts in the far southeast and the Sylhet division in the northeast. Bangladesh has a tropical monsoon climate characterized by heavy seasonal rainfall, high temperatures and high humidity. Natural disasters, such as floods, tornadoes and tidal bores affect the country yearly (en.wikipedia.org/wiki/Geography_of_Bangladesh).

Agriculture

In Bangladesh, agriculture is the single most important sector of the economy and a major source of livelihood in the rural areas where about 80% of the population live. About 67% of Bangladesh's non-urban land is arable. Permanent crops cover only 2%, meadows and pastures cover 4% and forests and woodland cover about 16%. Approximately two-thirds of the labor force is employed in agriculture. Although its share in the GDP is predictably declining, agriculture (crops, livestock, fisheries and forestry) contributes approximately one-third of the GDP and agricultural production accounts for 32% of the value of exports. With irrigation covering only around 42% of the potentially irrigated area, crop production in Bangladesh

is predominantly monsoon dependent and has grown slower particularly because of the predominantly small farm holdings (Hoque 2000).

The principal determinant of the cropping pattern in Bangladesh is land elevation. It affects the annual extent and duration of flooding, which in turn influence cropping calendars. About 71% of the total cultivated area is in the highlands and medium highlands where shallow flooding occurs. On these lands, two to three crops are grown. The remaining arable area is in the lowlands where one or two crops are cultivated. In the lowlands, the high-yielding rice variety *boro* is the main crop when irrigation is available during winter. Land use and cropping intensity are lower in the lowlands than in the highlands. The calendar window available for growing diversified crops is primarily during the *rabi* season when low-lying lands are not flooded by the monsoons and temperatures are moderate. Thus, one strategy for farmers to engage in more commercial-scale diversified agriculture is to make their *rabi* season cropping pattern more flexible. Most regions of the country have a variety of land elevations and soil characteristics that allow each to grow a diverse range of crops. In this environment, however, areas of crop specialization have emerged on the basis of differences of access to markets and services wherein, areas with easy access to urban markets have specialized in highly perishable crops such as vegetables. Areas in the drier and less accessible regions such as the northwest/have specialized in minor cereals, oilseeds, pulses and other crops, which require less irrigation and can survive the trip to the southern urban centers (Ateng 1995).

The upland in the hilly areas of the greater Chittagong district, Chittagong Hill Tracts and Sylhet district constitute a special agricultural zone. High potentials exist for the production of fruits, spices, vegetables and pulses. Of the total rainfed areas, about 3 M ha is estimated to be prone to severe drought. The entire Barind and Modhupur Tracts, constituting about 12% of the total arable area are characterized by soils of shallow depth having low moisture holding capacity and heavy sub-surface clay. Crop production in these areas and in the Gangetic flood plains is mainly dependent on rainfall and on the inundation from the Ganges River and its tributaries. However, for the whole of the Ganges belt, including the Barind and Modhupur Tracts, no rainfed farming practice specially suited to the prevailing soil and agro-climatic condition has yet been developed. There is, therefore, an urgent need to develop drought tolerant crop varieties and drought mitigating technologies that will make maximum use of the land resources

of the rainfed farming systems. Rainfed farming practices will also include supplementary irrigation, which will help increase crop production during the *kharif* season. Agricultural development potentials in these areas are quite substantial (www.fao.org). In 1996/97, Bangladesh achieved an estimated cropping intensity of about 185%. Out of the net cropped area of 7.6 M ha, 55% is double cropped, 15% triple cropped, and 30% is single cropped (www.fao.org).

Pigeonpea Area, Production and Yield

The pulses of Bangladesh comprise six major crops, namely, lentil, khesari, blackgram, mungbean, chickpea and pigeonpea. These pulses are traditionally grown during the dry winter months. The land used for cultivating pulses are classified on the basis of a water regime that falls into three categories: a) level, marginal, unirrigated land where pulses are cultivated as a sole crop or as a mixed crop with various cereals and oilseeds such as wheat, barley, millet, mustard and linseed; b) low-lying areas where lentil and lathyrus may follow deep-water paddy; and c) relatively terraced land, subject to periodic drought, unsuitable for any cereal or oilseed crop in the *rabi* (winter) season (Amiruzzaman and Shahjahan 2000).

The cropped area and production of these pulses have been on the decline over the past few years mainly because of the increased emphasis on high yielding variety (HYV) rice and wheat. But pulses like pigeonpea are very important because of their protein supply to the human diet and nitrogen fixation for soil nutrition. According to Upadhyaya (2007), there are 73 pigeonpea accessions identified in Bangladesh that have been used by breeders to come up with high yielding varieties. According to Pasha (1998), the land for pulse cultivation has been squeezed considerably competing with rice cultivation. A couple of decades back, the land for cultivation of pulses was about 0.3 M ha, but now, the area has been considerably reduced, and the present production is also less than half the requirement for the country.

In Bangladesh, pigeonpea is mostly cultivated in Kushtia, Rangpur, Dinajpur and Jessore districts. Locally known as *arhar*, pigeonpea is traditionally grown as a minor crop because it grows on less than 1% of the gross cropped area of around 0.12% or 14,000 ha with annual production of 3,000 t (FAOStat 2006). But in 2008, FAO considered Bangladesh as one of the

major producers of pigeonpea in Asia. This crop takes over 300 days to mature.

According to FAOStat (2008), Bangladesh production trend for pigeonpea was not constant and at one point production reached 11,000 t in 1978 (Appendix 3). From 1961 up to 1975, production was playing between 2,000 and 4,000 kg/ha. From 1976 to 1987, production was recorded between 4,000–11,000 t/ha. However, production ranged between 2,915 and 3,857 t/ha in 1988–1999. Pigeonpea has slumped in the 2000–2006 production seasons registering 2,000 to 3,000 t/ha. The area cultivated was 4,477 ha in 2000 and reduced to 3,237 ha in 2006 (Appendix 2). The average yield recorded in 2006 was 618 kg/ha (Appendix 4).

To increase the potential of pigeonpea in Rajshahi and Nawabganj regions, about 30,000 ha of black gram is cultivated after the harvest of upland rice. In this system, pigeonpea can be grown as an intercrop with black gram with the use of improved varieties of short- and medium-duration cultivars. Likewise, in the western part of Barind, which is semi-arid in nature, farmers grow only a single crop of Aman rice and the rest of the season is fallow. This cropping system will help the farmers increase their cropping intensity and also increase their income if ever the cultivation of pigeonpea is considered after rice.

Uses

In Bangladesh, pigeonpea is a multipurpose plant. All the plant parts are used in some form or another. The green pods are used as vegetable and the mature seeds are cooked or boiled and eaten as a pulse. The tops of the plant and its fruits provide excellent fodder and are also made into hay and silage. A majority of the people use the pigeonpea after de-husking and splitting of cotyledons to make *dal*. The husk and pod walls are used as cattle feed. Rural families use the stems as fuel. The dried stalks are used as firewood and for thatching and making baskets. Pigeonpea is also used to rear silkworm and *lac* insects (Amiruzzaman and Shahjahan 2000).

Aside from its importance as a source of protein in the diet in Bangladesh, *arhar* or pigeonpea shows wide adaptability to different climates and soils. It is drought resistant with a deep root system that permits good growth under semi-arid conditions with fewer than 65 cm of rain per year. It is less

suitable in very wet areas. Pigeonpea is also planted as green manure, as a cover crop and is also used as a windbreaker. It can be grown on almost all types of soil provided it is well-drained and not markedly deficient in lime. Almost all villages in Bangladesh maintain pigeonpea in the kitchen gardens exclusively for its leaf juice used to cure jaundice (Reddy LJ, personal observation, 1999).

India

Geography

India, the 7th largest country in the world with a total land area of 3,287,263 km², is often said to be a continent and not a country. It has a diverse geographical entity. Separated in Asia by the Himalayas in the north and bordered by the seas in the south, east and west, India lies to the north of the equator between 8°4' and 37°6' north latitude and 68°7' and 97°25' east longitude. It has a land frontier of 15,200 km and a coastline of 7,517 km. The country is bounded to the southwest by the Arabian Sea, to the southeast by the Bay of Bengal and to the south by the Indian Ocean. India is bordered by Pakistan to the north-west, China, Bhutan and Nepal to the north, Myanmar to the east and Bangladesh to the east of West Bengal. Sri Lanka, the Maldives and Indonesia are island nations to the south of India (Figure 70). Politically, India is divided into 28 states and 7 federally administered union territories. The political divisions generally follow linguistic and ethnic boundaries rather than geographic transitions. The land mass falls into three natural regions, namely, the Himalayas in the north, the Deccan Plateau in the south, and the Indo-Gangetic plain in the middle (en.wikipedia.org/wiki/Geography_of_India).

Agricultural Topography

About 43% of India's geographical area is used for agricultural activity wherein 70% of India's population is directly dependent on agriculture. Agriculture is the main component for most of the state economies in India. The Punjab region is suited for wheat growing. The south Indian states of Andhra Pradesh, Tamil Nadu and Karnataka are major producers of rice. These states are mostly irrigated by the rivers Krishna, Godavari and Cauvery. Haryana is self-sufficient in food production and the second largest contributor to India's central pool of food grains. The high-altitude states of Himachal Pradesh

and Jammu and Kashmir are ideal for production of apples. Arunachal Pradesh also has a large number of fruit orchards. Tea is the other produce of the high altitude regions of Assam, West Bengal (Darjeeling), Tripura, Tamil Nadu (Ooty), Himachal Pradesh and Kerala. Assam produces some of the finest and most expensive teas in the world (Assam tea). In the north-eastern states like Arunachal Pradesh and Nagaland, shifting cultivation known locally as *jhum*, was practiced by the tribal groups, but that has come to be less practiced. In mountainous states like Sikkim, farming is done on terraced slopes. The state has the highest production and largest cultivated area of cardamom. Karnataka is the largest producer of coffee and accounts for 59% of the country's coffee production. It is grown mostly in the lower slopes of the Western Ghats in Kodagu district. Karnataka is also the largest producer of sandalwood based products like perfumes. The state is also the largest producer of raw silk and Mysore silk saris are famous. The other state manufacturing silk is Tamil Nadu. Rajasthan is among the largest producers of edible oils and the second largest producer of oilseeds. Likewise, it is also the biggest wool-producing state in India (en.wikipedia.org/wiki/Geography_of_India).

Agriculture

The Government of India places high priority on reducing poverty by raising agricultural productivity. Sustained agricultural growth in the 1990s reduced rural poverty to 26.3% by 1999/2000. Although agriculture is one of the most prominent sectors in its economy, and accounts for 18.6% of the GDP and employed 60% of the country's population in 2005, its importance in the country's economic, social, and political fabric goes well beyond this indicator. It contributes 8.56% of India's exports. Despite a steady decline of its share in the GDP, agriculture is still the largest economic sector and plays a significant role in the overall socio-economic development of India (en.wikipedia.org/wiki/Geography_of_India).

The 1970s saw a huge increase in India's wheat production that heralded the Green Revolution in the country. Bringing additional area under cultivation, extension of irrigation facilities, use of better seeds, better techniques, water management and plant protection has brought about the increase in post-independence agricultural production. Dependence on India's agricultural imports in the early 1960s convinced planners that India's growing population, as well as concerns about national independence, security and

political stability required self-sufficiency in food production. This perception led to a program of agricultural improvement called the Green Revolution, which focused on public distribution system and price support on farmers. The growth in food-grain production is the result of concentrated efforts to increase all the Green Revolution inputs needed for higher yields such as better seeds, more fertilizers, improved irrigation facilities and education of farmers (Indian Agriculture Industry 2000). The sharp rise in food grain production during India's Green Revolution in the 1970s enabled the country to achieve self-sufficiency in food grains, which staved off the threat of famine. This agricultural intensification led to increased demand for rural labor that raised rural wages and decreased food prices, which in turn reduced rural poverty. The rural areas are still home to some 72% of India's 1.1 billion people, a large number of whom are poor. Most of the rural poor depended on rainfed agriculture and fragile forests for their livelihood (en.wikipedia.org/wiki/Geography_of_India).

Ranked second in the world in terms of agricultural output, India is the world's largest producer of milk, cashew nuts, coconuts, tea, ginger, turmeric and black pepper. It has the world's largest cattle population (193 M) and it is the second largest producer of wheat, rice, sugar, groundnut and inland fish. It is also the third largest producer of tobacco. While this country accounts for only 10% of the world's fruit production, it ranks first in the production of banana and sapota. Moreover, in 2006, India has the world's largest total area cultivated (76.5%) and production (70.25%) of pigeonpea (en.wikipedia.org/wiki/Geography_of_India).

Pulses in India

India is the largest producer and consumer of pulses in the world. It accounts for about 25% of the total global production, 27% of consumption and 34% of food use (FAO). Pulses are grown over an area of 21 M ha accounting for about 17% of its total area and less than 7% of total food grain production. The yield ranged between 600-650 kg/ha. Stagnant production has contributed to declining per capita consumption over the past 20 years. During this period, domestic pulse prices have increased relative to other foods. Despite a liberal import regime, imports have generally remained a small share of supplies. Pulses are grown in India mainly under unirrigated conditions; the irrigated area accounts for less than 10% of the total area under pulses crop. Major pulses grown in India are chickpeas (desi type) and pigeonpeas (*arhar* or

tur). Their share in the total pulse production is about 40% chickpea and 18% pigeonpea (Canny Overseas Pvt. Ltd. 2008).

Pulses not only form a major source of protein for the majority of the Indian population but they also are the most affordable for the large section of the populace below the poverty line. While the population ‘growth trap’ is partly responsible for this decline, much of the responsibility lies in the stagnation in the production of pulses after the advent of the Green Revolution with the availability of pulses declining from 61.6 g/kg in 1965 to only 33 g/kg in 1997. India produces over a dozen varieties of pulses of which, chickpea (gram) and pigeonpea (*arhar*) account for 45%. The area for gram has shrunk over time but has been compensated by an increase in the area for pigeonpea, *moong* bean and black gram (*urad*). Yet, with the exception of the increase in the area during the early years, the area for pulses has remained rather stagnant ranging from 22 M ha to 24 M ha in the last three decades. Similarly, the yield per hectare has also stagnated between 476 kg and 549 kg. It is no wonder then why production stagnated around 12 MT between 1960-61 and 1989-90. Despite the evolution of high yielding variety seeds, there has been no substantial increase in productivity. While the failure to adopt improved technology remained a major cause of stagnation in yield rates, the other significant constraints are poor physical environment, adoption constraints for improved technology and marketing problems. Most of the pulse growers are unaware of the existence of improved technology while those who have the information are hampered by the fact that a complementary package of practices is not available. To carry improved technologies to farmers, a National Pulse Development Program covering 13 states was launched in 1986. The Special Food Production Program augmented efforts to boost pulse production, which is why in 1995-96, pulse production was recorded at 13.2 MT (Embassy of India, May 2008).

Pigeonpea Area, Productivity and Yield

Tur or the pigeonpea in the Indian context is a tropical crop and its second most important crop after peas. It is the dominant pulse in southern India but of secondary importance in northern India. Pigeonpea is mainly grown as a ‘kharif’ crop during monsoon rains, which matures in the subsequent dry season. It is considered as one of India’s staple foods as shown by the huge number of accessions identified in this country. According to Upadhyaya (2007), there are a total of 10,740 accessions (India, 9,126 accessions;

ICRISAT, 1,614 accessions) and these accessions have been the root of the numerous high yielding varieties of early, medium and late maturing cultivars of pigeonpea in which the crop is grown depending upon the agro-ecological situations and domestic needs of farmers (Ali 1996).

Pigeonpea is considered a subsidiary crop in the cropping systems of Indian farmers. It is planted in marginal soils and intercropped with cash crops where it receives little or no purchased inputs. As such, it does not attract much of the farmers' crop management attention (Sharma and Jodha 1982). Production stands at around 2.5 MT, which is 78% of global production and 18% share in the total pulses produced in the country. Among the major pigeonpea producing countries in Asia, India accounts for 86% of the total area cultivated globally (FAOStat 2008).

Production of pigeonpea in India has slowly but steadily increased over time. However, the production level still cannot satisfy internal demand. The main areas in which *tur* are cultivated in India are: Maharashtra (700,000 t), Uttar Pradesh (500,000 t), Karnataka (300,000 t), Madhya Pradesh (300,000 t), Gujarat (100,000 t), Rajasthan, Haryana, Punjab, Tamil Nadu, Orissa and Bihar. The state of Uttar Pradesh, Maharashtra, Madhya Pradesh, Karnataka and Gujarat accounted for about two-thirds of India's pigeonpea production. In most cases, the sowing of pigeonpeas in India is from June to July. In North India, the annual medium- and long-duration cultivars flower in January and first harvested from March to April. In Central and South India, the early- and medium-duration cultivars flower from October to November and yield in December to January.

In 2008, around 2,000 ha of degraded soils, rocky unused lands and slopes were planted with ICPL 88039, also known as VL *Arhar* 1 in 2007, by Vivekananda Parvathiya Krishi Auusandhan Sansthan (VPKAS). The said variety which was planted between mid-May to mid-June yielded 1,400 kg/ha during the 2008 cropping season even at 1,580 masl elevation (ICRISAT Happenings 2009).

Research breakthrough and commercialization of hybrid pigeonpea

In 1994, 'PPH4', a hybrid pigeonpea was released in Punjab. This variety matured in 140-145 days (Sekhon et al. 1996) and yielded 15-30% more than

the next best short duration varieties. 'PPH4' was released after the 'ICPH8', the world's first pigeonpea hybrid released by ICRISAT in 1991. This hybrid yielded 30% more than 'UPAS 120' and 15% more than 'Pusa 33' and 'ICPL 87' and was recommended for Central India. Apparently neither of these hybrids was based upon the ms2 source of genetic male sterility identified by the UQ team in 1981. Singh (1996) indicated that in 1995-96, four more hybrids were in advanced testing with six determinate and 52 indeterminate early hybrids evaluated in coordinated trials.

The world's first-ever cytoplasmic male sterility-based (CMS) pigeonpea hybrid was launched commercially in July 2008. The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) developed the medium-duration hybrid pigeonpea, ICPH 2671, under strong public-private partnership. ICRISAT and other partners in the project produced about 40,000 kg hybrid seeds. This will be used in about 10,000 ha on-farm validation in different environments and cropping systems for CY 2008 (Business Standard 2008, The Hindu Newspaper 2008).

According to Saxena (2008), for the past 50 years, pigeonpea productivity has not increased in spite of the release of several new varieties. To achieve a breakthrough in yield, ICRISAT developed an innovative breeding technology to develop commercial hybrids in this crop, the first such attempt in any food legume. After 25 years of intense research, the world's first cytoplasmic male sterility (CMS) based pigeonpea hybrid ICPH 2671 was developed in 2005. This hybrid is suitable for cultivation in Andhra Pradesh, Karnataka and Maharashtra.

Saxena further stated that at ICRISAT, the experimental hybrids have recorded 20% to 150% yield advantage over the best checks, the ideal for bringing the next quantum jump in yield. On the basis of the results from these three year test in 21 test locations, this high yielding, drought-tolerant and disease (wilt and sterility mosaic) resistant hybrid gives about 30–40% yield advantage over the popular variety Maruti.

Trading: Domestic and Import

Pigeonpeas are commercially important in India, which imports 8,000 to 10,000 metric tons (MT) of peas per year. India's population, which is 80% vegetarian, comprises the world's largest legume-consuming market and

is projected to overtake China as the world's most populated country. India cannot produce enough pigeonpea to satisfy its internal demand. Pigeonpea is also gaining a niche market in the US because of the growing Indian population thereat (Payne 1998).

Domestic

Split *dal* is the primary form in which pigeonpea is sold to Indian consumers. The domestic consumption demand in the country is quite high and is estimated at around 3.4 MT. Pulse production has fluctuated widely with no long-term trend leading to a steady decline in per capita availability over the past 20 years (Price et al. 2003).

Domestic pulse prices often vary on a daily basis with most fluctuations attributable to market supply conditions rather than quality differences. Domestic prices can also fluctuate widely on an annual or seasonal basis due to changes in production. Despite the fragmented market structure, regional markets in India appear to be well integrated with respect to price. Pulse traders have close ties to those in other areas, keeping abreast of relative prices and opportunities (Price et al. 2003). Most Indian consumers are highly sensitive to prices when making food purchase decisions. While quality is an important factor, price plays a major role in decision making by buyers. Higher relative prices cause consumers to switch to lower priced pulse varieties and grades and to other food items, such as cereals and vegetables.

There are wholesale-specialized pulse markets throughout India, which route domestic and imported pulses to retailers. Delhi's Naya Bazaar is the largest wholesale pulse market. Other major wholesale markets are located in Mumbai (Vashi), Kolkata (Postha) and Chennai (GN Street). About 150-200 wholesalers operate in the Delhi and Mumbai markets. As each seller operates independently, the wholesale trade is generally fragmented. There is no official price reporting or regulating mechanism in place in any of these markets.

Pulses are generally not branded. Lately, however, some millers have started branding their products while the wholesalers generally pass on to the retailers the labelling as regards the country of origin. There are several layers in the marketing chain between the farmer or importer and the consumer,

namely: importer/trader, splitting plants or dal millers, wholesaler, retailer and consumer. In most cases, wholesalers and *dal* millers are importers themselves. The frequency of transactions is highest at the wholesale level where commodities change hands several times with the assistance of brokers or commission agents (Canny Overseas Private Ltd. 2000).

There are no quality standards in India. Most of the pulses are classified as "fair to average quality", which is the only recognized grade in the Indian marketing system. This grade is also not standardized and people assess the grade by visual inspection of color, size and texture. However, moisture content is also considered while importing pulses.

Import

India imports about 1.5 to 2 MT of pigeonpea annually. It is the top importer with an 11% share of world imports from 1995-2001. Importation of pulses is unrestricted and with relatively low tariffs. It is virtually the only food item afforded such open access to the Indian market (FAO). Its import accounts for about 71% of the global production during the 2006 cropping season. With domestic production stagnant at 2.4 MT and build-up of speculative pressures, prices have hardened considerably in 2006. Recently, India's plan to import 1.3 MT of pigeonpea to meet the rising demand was hit by political instability and catastrophe in Myanmar. In view of the delay in shipment, the prices of pulses have started firming up in the local market. In 2008, India faced an estimated shortfall of 3.2 MT of pigeonpea. The government is concerned that despite the import of about 1.8 MT of pigeonpea in 2007, the prices have not come down to the desired level (economictimes.indiatimes.com, October 2007).

Though India is the largest producer of pigeonpea, it is not engaged in exports of the crop due to high domestic demand. In fact, history shows India imports its *tur* needs from Myanmar, Tanzania, Kenya, Malawi, Uganda, Mozambique (crnindia.com, 2008) and even Australia (1984/85 - 420 t; 1985/86 - 1,173 t) and Thailand (1984/85 - 85 t) (Directorate General of Commercial Intelligence and Statistics 1987). Through the years, the volume of pigeonpea traded in India is very difficult to estimate in the international market.

Consumption

Pulse consumption in 2008/09 is forecast to remain unchanged or marginally decline due to high prices of imported pulses. Consumption in 2007/08 is estimated at around 17 MT, including around 2.8 MT of imported pulses. Despite the fact that India imports significant quantities of pulses, prices continue to remain high due to increasing total demand. Though the per-capita pulse consumption is shrinking, households substitute between pulses and other food groups based on relative prices and budget constraints (USDA GAIN Report 2008).

Uses

In India, pigeonpea is used in a variety of meat and vegetable preparations (www.gracefoods.com/site/gungopeas). Virtually all Indians, rich and poor as well as vegetarian and non-vegetarian, consume pulses. As mentioned in the previous chapters, pigeonpea is used in a wide variety of ways but its main use in the Indian subcontinent is for human food. However, regional preferences exist with respect to pulse consumption. Pigeonpea is used to make *dal*, a thick, gravy-like dish served at home and in all types of establishments ranging from roadside eateries to fancy restaurants. The *dal* is also used in curries and snack foods.

Arhar or *tur* is very important in the Indian diet, as some can ill afford the price of meat, and others, whose religion discourages eating animal protein, find a supplementary source of protein in pigeonpea. Due to stagnant production of pulses, rising population and limited imports, the per capita availability of pulses has come down to 29.1 g/day in 2001 as compared with over 70 grams in mid-fifties (Canny Overseas Private Ltd, January 2008). This is similar to the findings of Bidinger and Nag (1981) in a survey of diets in villages in the semi-arid tropics of India where rural people eat between 35-40 grams pigeonpea per day.

About 10% of the production of pigeonpeas is used for animal feed. The seed husk and pod walls are commonly fed to cattle and green leaves are used as cattle fodder. After the pods are harvested, plants are left in the field for cattle and goats to graze on the new green leaves the plants produce.

These crops are also grown to mark the boundaries of farmers' fields. The stems are used as household fuel wood. About 2 MT of woody stalks are

obtained per hectare in a growing season (NAS 1980). Most farmers likewise used the stems as field fences, huts and baskets. In the eastern part of India, the state of Assam grows pigeonpea to serve as important host for scale insect (*Kerria lacca* Kerr) that produces lac (Nene et al. 1990).

Indian folks use pigeonpea to treat ailments, such as colic, convulsion, leprosy, skin, liver, lung and kidney diseases and abdominal tumors using the dry roots, leaves, flowers and seeds (Nene et al. 1990, Taylor 2005). Some herbal practitioners or researchers believe that it can diminish the swelling of internal organs like stomach, liver, intestines, etc, and help reduce cancer. Its recommended usage is as follows: finely grind 10 grams green leaves of pigeonpeas and 7 black peppers and mix with water, then drink the mixture; grind green leaves of pigeonpeas and add to half boiled water, then apply externally on the affected body part or cook pigeonpeas in water (as *dal*, an Indian recipe) and give the water to the patient (www.domaintools.com/en.wikipedia/bioline.org).

Myanmar (Burma)

Geography

Myanmar is the 3rd largest Asian mainland country situated in the western end of Southeast Asia and is a member of ASEAN (Association of South East Asian Nations). Its land area is 676,577 km². The country, which consists of 7 divisions and 7 states, is geographically located between 92°09' to 101°10'E and 9°58' to 28°31'N and is bordered with Bangladesh, India, China, Laos and Thailand in the west to east through north and looks unto the Andaman Sea in the south (Figure 70). The western, northern and eastern parts of the country are hilly regions with altitudes varying from 915 to 2,134 masl (MAI 2000).

The whole country of Myanmar belongs to the tropical to subtropical monsoon climate. The whole year is separated into the following three seasons: hot, rainy and dry-cold. In general, the hot season lasts from mid February to mid May, the rainy season from mid May to mid October and the dry-cold season from mid October to mid February. The temperature in the southern part of the country differs a little from season to season. In the central plain, however, seasonal variation of temperature lies in the magnitude of about 40-43°C in the hot season and 10-15°C in the cold season.

There are three (3) agroclimatic regions that govern the production systems of pigeonpea, namely, the Central Dry Zone comprising Magwe, Mandalay and Sagaing divisions, which receive an annual rainfall of 500-700 mm and where most of the pigeonpea production is concentrated; the Transition Zone covering the Yezin state, which has an annual rainfall of 1000 mm and where the concentration of pigeonpea research through breeding and technology generation is done; and the Delta Zone, which constitutes the Ayeyarwady, Tanintharyi, Mon and Rakhine division, which receives an annual rainfall of 2000 mm. This zone is the major rice producing area with pulses, including pigeonpea, commonly grown after rice.

Agriculture

The Union of Myanmar, Southeast Asia's second largest country, continues to evolve towards a market economy. Crop yields are below regional averages. Nevertheless, Myanmar's agricultural sector offers enormous potential for improvement. At present, about 10 M ha (15% of the total area of 68 M ha) are cultivated with arable crops and only 3 M ha is cultivated more than once per year (IPNI 2001). Agriculture dominates the economy constituting 36% of the GDP in 1998 and 35% of export earnings. In 1998, only 12 M of the available 18 M ha were cultivated and about 3.2 M ha are rainfed drylands (Myanmar Information Gateway 1999).

Rice is the major crop both in terms of acreage and export potential. Likewise, food legumes form an important component of Myanmar agriculture. The next most important group of crops is oilseeds for the production of edible oil. Major crops are peanut, sesame and sunflower. These crops receive high priority since edible oil is a major component of Myanmar's diet. Food legumes (non-oil crops) are also an important part of the agricultural sector. Different kinds of pulses are cropped and at present, the country is the leading producer of pulses among ASEAN member countries (MAI 2004). The major crop is chickpea although significant areas of lablab, lima bean, black gram and pigeonpea are produced (Wallis et al. 1988).

Pigeonpea Cropping System, Area, Production and yield

There are 81 pigeonpea accessions in Myanmar (Upadhyaya 2007). These accessions were the foundation in improving the production of this crop for export purposes. 'Pesimal' or 'Toor whole', the local name for pigeonpea, is

the third most important food legume. Although it is not consumed widely by the local populace, it is grown primarily for export and as source of fuel.

The crop accounts for about 14% of the area sown with major pulses and slightly less than 10% of Myanmar's pulse production (Nene et al. 1990). Traditionally, the crop is grown as an intercrop with sesame, blackgram, greengram, sorghum and cotton at the Central Dry zone (Egashira and Than 2006). Long-duration (>200 days maturity) local pigeonpea varieties (Shewdinga and Five-Seeded) are cultivated under normal sowing (May/June) in a wide range of cropping systems. But recently, the medium duration pigeonpea is being cultivated at the Central Dry zone where delayed sowing is practiced (July/August) and at the Transition and Delta zones where the crop is planted after the harvest of rice. Pigeonpea or *toor* whole is a one-season crop and is planted in Sagaing, Mandalay, Magway Division and in Kayah, Kayin and Northern/Southern Shan States where the Government of Myanmar (GOM) has selected these special zones to grow this crop. Pigeonpea is seeded during the rainy season from July–August and harvested in January–February. It constitutes 11% of the total beans and pulses area (USDA GAIN Report 2002).

Seventy-five percent of the pigeonpea area is sown by intercrop system while the remainder is sown as sole crop. The cultivars used are of approximately the 285-day duration and planted on the most marginal areas where even *aboreal* cotton is not able to survive. In intercropping, pigeonpea is first sown as a hedgerow and the green gram, groundnut and sesame are grown between the hedgerows of pigeonpea. Pigeonpea is sown in May and is intercropped in July. The distance between the pigeonpea hedgerows is 1.5 m and the height of the hedgerow is one meter at the time of intercropping. Pigeonpea is harvested after 8 months from sowing. Green gram is harvested after 2 months from seeding while groundnut and sesame are harvested after 3 months from seeding. The roots of the previous pigeonpea are dug out for fuel in May when the next pigeonpea is sown (Egashira and Than 2006).

In 2004, the growth in production is due entirely to an anticipated increase in the harvest area and a return to more normal weather patterns. According to ICRISAT (2004), pigeonpea is cultivated as a one-season crop on 513,000 ha in Sagaing, Mandalay and Magway divisions of the central dry zone and it accounts for about 16% of the total area under legumes.

Over 650,000 t of pulse is produced annually with an average yield of over one t/ha, the highest among all the pigeonpea growing countries. The increasing rate of production of pigeonpea from 1990 to 2005 was attributed to the increase in the area (Tables 18, 19 and Appendix 2, 3).

Since 1988, the cultivated area of pigeonpea has gradually grown year-by-year, reaching 540,000 ha in 2006 with a production of up to 649,971 t (FAOStat 2006). According to Wallis et al. (1988), the production of pigeonpea in 1985–1986 was tallied at 52,000 t harvested from 77,000 ha. This finding was comparable with FAO data where the production was recorded at 51,526 t in 1986 from an area of 76,335 ha (FAOStat 2008). However, according to the Agriculture Service of the Ministry of Agriculture and Irrigation of Myanmar (2009) , in the last 19 years, pigeonpea recorded significant increase in area from 57,064 ha (1990) to 616,000 ha (2009) with a production of 37,110 to 774,000 tons, respectively. Of the total land area planted into pigeonpea, Sagaing District has the highest at 34% followed by Mandalay District (31%), Magway District (28%), Shan District (4%), Bago District (1%), and Others (2%).

Myanmar and ICRISAT Collaboration

ICRISAT and Myanmar signed a Memorandum of Understanding in 1986 when the participation of Myanmar scientists in the Cereals and Legumes Asia Network (CLAN) led by ICRISAT started. This collaboration has been in the areas of crop improvement, natural resource management, and in building the national research capacity of Myanmar through training of agricultural scientists and technicians. ICRISAT supplied 3,000 pigeonpea lines to the Food Legumes Division for testing, and from this material, four pigeonpea varieties: Yezin-1 (HPA-1), Yezin-2 (BR-172), Yezin-3 (ICPL 87), Yezin-4 (ICPL 93003), Yezin 5 (ICPL 87119), Yezin 6 (ICPL 96061), and ‘Monywashwedenga’ have been released for commercial cultivation (ICRISAT Brochure. 2004; MAI. 2009). In 2008-2010, multi-location trials of ICRISAT’s promising hybrids (ICPH 2671, ICPH 2740 and ICPH 3461) were found to produce 1,596 to 2,931 kg/ha (Khin Lay Kyu, personal communication).

Market Information

Myanmar’s Commodity Exchange Center (CEXC), locally called ‘Kon-Si-Daing,’ was established in Yangon and Mandalay cities and some other

large towns. Traders deliver the crop samples to the CEXC to be displayed for marketing. Buyers and sellers negotiate based on the crop sample displayed and upon reaching an agreement, spot prices and turnover are recorded by the CEXC. As for market information dissemination, daily market information is gathered from 7 CEXCs, particularly from Yangon, Myingyan, Magway, Mandalay, Monywa, Pakokku and Taunggyi. In addition, daily market information is collected from traders in 3 markets, namely, the Pyay market in the Western part of Bago Division, Aunglan market in Magway Division and the Hinthada market in Ayeyarwady Division (Kyaw Myint and ETRADE-MIS 2008).

Export

Pigeonpea is the major export grain legume crop of Myanmar. The government is keen on expanding the pigeonpea area in the coming years to achieve significant increase in the export of this commodity. Myanmar is designated as a leading country among other ASEAN countries in the cultivation of beans and pulses for trading. Beans and pulses have become the major foreign exchange earner for the country after the Government of Myanmar (GOM) imposed a rice export ban in January 2004. The GOM also plans to increase beans and pulses area through land reclamation projects carried out by private entrepreneurs in Upper and Lower Myanmar (Egashira and Than 2006). According to the GOM, Myanmar has become the second largest exporter of beans and pulses in the world after Canada. The country now aims to penetrate high-end markets such as Japan and various Middle Eastern Countries for Mung beans, Matpe and *Toor Whole* (pigeonpea).

Previously, Myanmar exported 1 MT of beans and pulses annually mainly by sea route. This mode of transport/has been replaced by land route through border points to neighboring countries. Exportation was erratic and figures were not precise with other literatures, including that of FAO Statistics Division, during the 20s. According to figures from the Union of Myanmar Federation of Chambers of Commerce and Industry, Myanmar's exportation was decreased to 900,000 t of various items of beans and pulses in the fiscal year of April 2006 to March 2007, compared with 1.2 MT in 2003-04 and 800,000 t in 2001-02 (Shanghai Daily, July 2007).

In 2003, Myanmar's pigeonpea export constituted 25% of its total export. For that reason, the agricultural sector, which accounts for 41.2% of Myanmar's

national economy and 11% of its export, grew 11.8% in the fiscal year of 2005–06 (Shanghai Daily, July 2007). The major buyer of its pulses is India. India's demand, however, dropped in 2004 due to the decline in Myanmar's bean and pulse export (152,660 t). Of this, 22% or 33,572 t comprised pigeonpea, which volume is way below the figures exported in 2003 (Shanghai Daily, July 2007). Aside from its trading partners in the region, which includes China, Indonesia, Malaysia, Philippines, Thailand, and Vietnam, Myanmar also exports its beans and pulses to Sweden, Netherlands, Spain, Poland, Belgium, South Korea, Switzerland, Hong Kong and Ireland (Myanmar e-Newsletters 2004).

The country's beans and pulses also entered the Japanese market. The quality of its beans and pulses however cannot compete in the European market, which is why the GOM intends to establish special beans and pulses cultivation zones that are aimed at yielding quality agricultural crops for its European and Middle East markets (Shanghai Daily, July 2007).

Table 22 shows how Myanmar exports its pigeonpea as *toor whole* to different parts of the world (USDA GAIN Report, 2002 to 2009). The most dominant country where pigeonpea is exported is India, which has acquired 93.5% of pigeonpea imports in 8 years. In 2007, a total of 78,860 metric tons (MT) have been exported. With an average buying price of \$475.83/MT, the total value was estimated at \$37,523,953.80. In 2008, there was a substantial increase in export as compared to the previous year.

Myanmar exported a total of 445,520 MT pigeonpea with a street value of \$233,898,000.00 and the majority was shipped to India. Interestingly, Myanmar expanded its coverage in exporting pigeonpea as shown in Table 22 (MediumGrain Rice.com 2008; USDA Gain Report, April 2009). In May 2009, a total of 33,775 MT *toor whole* with a value of \$22,460,375 have been recorded. Yearly, prices of pigeonpea have been increasing from \$237.5/MT in 2002 to \$665/MT in 2009.

In a span of eight years, Myanmar has exported 830,119 MT of *toor whole* to India followed by China (26,542 MT), United Arab Emirates (14,386 MT), Singapore (4,510 MT), Japan (3,976 MT), Pakistan (1,902 MT, Thailand (1,683 MT), Belgium (1,145 MT), Tanzania (860 MT) and the Netherlands (688 MT). Countries with less acquisition of pigeonpeas are Bangladesh, Dominican Republic, France, Italy, Portugal, Saudi Arabia and the United

Table 22. Myanmar's export (MT) of pigeonpea in 2002 to 2009.

Country	Volume (metric tons)						
	2002	2003	2004	2005	2006	2007	2008
Australia							
Bangladesh							
Belgium	201	115	22	608	69	247	46
Bahrain						106	46
China						8	1,145
Dominican Republic						17,490	26,542
France							230
India	60,427	27,256	122,566	43,037	64,820	73,800	407,567
Indonesia						48	830,119
Italy	42	46	24	24		48	48
Japan	496	844				2,636	3,976
Korea						248	248
Kuwait						148	148
Malaysia						79	79
Mauritius						48	48
Netherlands	156	376	23	480	24	5	
Pakistan				240		144	1,142
Portugal	43			24			
Qatar						24	24
Saudi Arabia						180	295
Singapore	113	462	115	141			
Tanzania	860						860
Thailand						1,152	1,683
United Arab Emirates						11,390	2,421
United Kingdom			23	22		32	14,386
Total	62,338	33,419	123,140	45,776	64,965	78,860	445,520
Average Price (\$)	237.5	250	313.33	310	305	475.83	525
Total Value (\$)	14,805,275	8,354,750	38,583,456.2	14,190,560	19,814,325	37,523,953.8	233,898,000
						22,460,375	389,630,695

USDA GAIN Report 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009.

Kingdom. Countries like Australia, Bahrain, Indonesia, Korea, Kuwait, Malaysia, Mauritius and Qatar imported pigeonpea from Myanmar in 2008. For the period 2002 to 2009, a total of 887,793 MT/had been exported with a total value of \$389,630,695.00.

Uses

Pigeonpea is not widely consumed by local people hence it is mainly exported. In most cases, the crop is used as a substitute for chickpea by poorer consumers and on a wider scale when chickpea is in short supply. The dry split seed (*dal*) is the preferred use of pigeonpea by some sections of the Myanmar population particularly those of Nepalese and Indian descent. The *dal* is made into the traditional Indian curry and consumed with rice.

Other important uses of the pigeonpea plant in Myanmar are as a source of fuel for domestic purposes (stems after harvest) and as a source of animal feed after harvest. Both the leaves and the pod walls are fed to animals. In general, animals, both cattle and buffaloes, are fed a diet of chopped rice straw plus a protein source in the dry season. The major protein sources available are derived from the meals produced as a by-product from the oilseed mills: peanut, sesame and sunflower meals. No information is available on the income derived from these sources nor the extent and importance that pigeonpea plays in this system (Wallis et al. 1988).

Nepal

Geography

Nepal is a small and land-locked country with 75 districts. Hills and mountains account for more than three-fourths of the total land area, lying within and adjacent to the Himalayan range. It is bounded on the north by China and in the south, east and west by India (Figure 70). It is located within 26°22'N to 30°27'N latitude and 80°4'E to 88°12'E longitude with a total geographical area of 14.72 M ha. Nepal has unique topographic characteristics with its altitude rapidly increasing from about 60 masl in the plains in the south (Tarai) to the world's highest peak at 8,848 masl (Mount Everest) in the north. The climate shows sharp variation from humid and subtropical in the Tarai to alpine-arctic above 4,000 masl. The rainfall decreases from southeast westward. The mountain peaks and the higher mountain summits above 5,500 masl remain under permanent snow cover, giving rise to some of the major rivers of India and China. Based on this difference in altitude, the country is broadly divided into three ecological regions, which are lowland, hilly and mountainous regions (ADB 2000).

Agriculture

The agriculture in Nepal is not only diverse but also rendered complex by the variable environmental condition encountered within short distances, due to changes in the altitude, slope, aspect or orientation of the mountain ranges. The cultivated land of about 2.9 M ha constitutes about 20% of this country's total land area. About 80% of Nepal's population is farmers. The share of agriculture in the GDP is 40%, which has continued to decline in recent years. This country with surplus food two decades ago has now become an importer. The increase in population has steadily outpaced agricultural growth resulting in higher demand for food. Land distribution is much skewed. Over 50% of households own only 6.6% of the total cultivated land with more than two-thirds owning less than a hectare, around 24% owning more than a hectare and about 10% landless (Pandey et al. 2001).

Nepal's economy depends largely on agriculture, which engages over 90% of the total labor force and accounts for 53% of the country's GDP. Agriculture in Nepal is basically subsistence, with crops, livestock and trees forming integral parts of the existing farming system. The farming system is

based predominantly on cereal crop production to sustain the farm family. This is supplemented by smaller amounts of legumes, some perennial fruits and livestock for cash income and home consumption. Nationally, rice is the preferred annual crop, which is cultivated even at high elevations where water-holding terraces are possible. In the hills, however, maize is even more important as a food crop and is grown on slopes and terraces. Wheat is rapidly increasing both in acreage and production and it is the country's most important winter cereal. While farming in the hills is mostly subsistence with characteristic diversity in an effort to meet the needs of the family, tarai farming is more uniform. About 90% of cultivated land is under food crops.

Rice, which is the dominant crop in the country, is being cultivated on 1.5 M ha or 38% of the total cropped area of about 4.0 M ha. The yields of major crops in Nepal have been low and stagnant since the 1960s while yields in other South Asian countries improved significantly. Nepal did not sufficiently benefit from improved agricultural technology. Various secondary crops, also called subsidiary crops, cover about 40% or 1.6 M ha of the total cropped area. These crops provide vital nutritional supplements such as vegetable protein, vitamins and minerals for people's diet in a country where more than 50% of children below three years of age suffer from malnutrition.

Although pulses are very important in nutrition, as source of protein in particular, and are grown extensively in Nepal, information on cultivation, acreage, production, trade, and consumption have not been readily available until very recently. Virtually all farmers in Nepal grow one or more species of pulses or grain legumes. In the mountains and hills, legumes are grown primarily for home consumption while in the tarai and in some warmer valleys, they are grown both for home consumption and for the market. The bulk of production in the Tarai and inner Tarai is from the winter pulses of grass pea, lentil, chickpea, and in the summer, from pigeonpea. Cumulatively, pulses rank fourth in terms of acreage and fifth in production after rice, maize, wheat and millet.

Pigeonpea area, production and yield

In Nepal, 120 accessions of pigeonpea have been recorded (Upadhyaya 2007). Pigeonpea is an important summer legume and likewise an important component of indigenous cropping systems in the tarai and inner tarai area. According to FAOStat Data (2008), this crop is cultivated in about 29,000

ha or 1.8% of the total cropped area for legumes (Appendix 2). However, the said area has been reduced to about 20,988 ha in 2007 (Nepal Ministry of Agriculture and Cooperatives 2007). Most of pigeonpea produced is cultivated in Banke and Bardia districts in western Tarai, Rupandehi and Kapilbastu districts in central Tarai, and Sarlahi, Mahottari, Dhanusha and Siraha districts in eastern Tarai.

In the hills and higher hills, the crop does not usually compete with other crops, as they are generally planted in areas where other food crops are not planted. Farmers plant the long duration type of pigeonpea, which are generally grown as a sole crop, but are often intercropped with maize in the summer and harvested the following spring. In central and eastern Tarai, planting on rice bunds is very common. According to Bharati (1982), pigeonpea is frequently grown as a subsidiary crop on rice bunds in low-lying areas. In 1976, pigeonpea area in Nepal was estimated at 16,000 ha or 4% of total area under grain legumes. The cultivated area had declined to 12,200 ha in 1983/84 producing some 4,800 t and only yielding around 377 kg/ha (Rachie and Bharati 1985). However, as reported by Manandhar and Shakya (1996), pigeonpea output/had increased in areas where the cultivation had doubled to 26,000 ha. Based on FAO findings, production of pigeonpea in Nepal increased substantially in 2001 and was at 73,463 t but decreased to just 26,000 t in 2006 (Appendix 3) and 19,245 t in 2007 (Nepal Ministry of Agriculture and Cooperatives 2007). Nepal's production level per unit area is the second highest after Myanmar at 896 kg/ha in 2006 (Appendix 4).

Nearly all the pigeonpea is produced in the Terai region (Khatiwada et al. 1988). The average pigeonpea area of farms surveyed by Khatiwada et al. (1988) was only 400 m² per household. Although the average farm household production is only 31 kg, it exceeds the average annual household consumption of 29 kg per capita consumption. Its availability is influenced not only by production but also by the amount exported - mostly through unregulated trade (Virmani et al. 2001).

There are two (2) distinct cropping seasons for pigeonpea in Nepal. The traditional medium to long duration varieties (*Bageshwari* and *Rampur Rahar 1*) are mostly planted during the rainy season in the month of June and harvested in March or April. The other cropping season is the post-rainy season where the crop is planted after the harvest of maize or rice in early

September and harvested in March or April. This type of cropping calendar is experienced in the districts of Siraha, Dhanusha, Saptari and Sarlahi. The common variety used is the medium duration called *Maghi*.

Trading

Marketing is organized by the private sector without government regulation, and most of the production is processed into *dal*. Trade in assembly markets is in very small lots as can be expected from the small quantities produced by individual farmers. At the primary market level, traders assemble produce from farmers who do not meet the minimum lot size of 10 kg required by wholesale traders. Farmers receive about 50% of the consumer expenditure for *dal*. *Dal* mills in Nepal have a low capacity of only 60 bags of pigeonpea per day (Khatiwada et al. 1988).

Most of Nepal's trade on pigeonpea are all in India, which trade is only partially reported. Based on Khatiwada et al. (1988), 386 t was exported in 1983/84 and in 1984/85 Nepal experienced importation of around 287 t. According to Bharati, Nepal exported pigeonpea to China in 1982 although there were no records to substantiate this. From 1981 to 1986, Nepal exported to India a total of 1,845 t of pigeonpea (Directorate General of Commercial Intelligence and Statistics 1987).

Agricultural Limitation

Limited marketing opportunities and lack of proper infrastructure posed serious limitations in harnessing the country's agricultural potential. New technology, management practices and improved methods and materials have not yet reached the farming community. The hills have features that limit both agricultural potential and development. The rugged topography limits accessibility. Diverse microclimates, predominantly small farm sizes and farming systems with limited scope for change are some of the problems faced. Limited availability of resources and weak institutional support services are some of the major constraints to agricultural development in the hills. Not much research work on the improvement of pigeonpea is being done in the country, although identification of certain lines for cold tolerance is reported. Collaborative research with ICRISAT and other agencies has been planned (Pandey et al. 2001).

The problem of land is already a serious one. Large areas of infertile, erosion prone, marginal land are now planted to field crops in the hills and foothills. It is generally believed that additional land for cultivation of crops is no longer available. The thrust, therefore, should be to increase productivity per unit of land (Khadka 1986).

Uses

Pigeonpea are used in many forms for human consumption in Nepal. Tender pods and green seeds are used as vegetables. The most common form of preparation for consumption is by cooking the mature dried seeds whole, split, broken or ground. Dried seeds are also steeped in water and then cooked as a vegetable or used as poultry feed. The leaves are used as fodder for livestock (Khadka 1986).

Minor Pigeonpea Growing Countries in Asia

The criterion in identifying Asian countries as minor growing area of pigeonpea is based on the findings of Nene et al. (1989), Nyabyenda (1987) and van der Maesen (1983, 1986). Few efforts have been made to document the status of pigeonpea grown in this region, which has the potential and capacity to increase its economic growth. Nevertheless, this section will provide the reader insights on the extent to which the crop has been grown and used therein.

Afghanistan

Geography

Afghanistan is located in the center or middle of Asia with coordinates of 29°32'N to 38°32'N latitude and 33°25'E to 71°43'E longitude. The country is landlocked and mountainous with a total land area of 647,500 km² (Figure 71). The variety of climate is immense but the remarkable feature of Afghan climate is its extreme range of temperature within limited periods. The least daily range in the north is during the cold weather, the greatest in the hot. For seven months of the year (from May to November) this range exceeds 30°F (17°C) daily. Waves of intense cold occur, lasting for several days, and one may have to endure a cold of 12°F below zero (-24°C), rising to a maximum of 17°F (-8°C). On the other hand the summer temperature is

exceedingly high, especially in the Oxus regions, where a shade maximum of 110°F to 120°F (45°C to 50°C) is not uncommon (en.wikipedia.org/wiki/Geography_of_Afghanistan).

Agriculture

Afghanistan is still facing a serious environmental crisis. With arable land of 12.13% and permanent crops of only 0.22% of total land area, a huge percent of Afghanistan's land is subject to soil erosion and desertification. The area of irrigated land per household varies from 0.3 to 3.0 ha, while the area of rainfed land varied from less than 0.01 to 1.9 ha per household. Moreover, arable land between 0.7 and 1.7 ha was used to grow irrigated crops and between 0.5 and 1.0 ha was used to grow rainfed crops each year. Economically speaking, Afghanistan is one of the world's poorest countries and 70% of Afghans depend on the agricultural sector for survival. The main source of income in the country is agriculture, and during its good years, Afghanistan produced enough food and food products for domestic use and to create a surplus for export. Agriculture forms the largest sector of the economy and the source of livelihood for over 85% of the population. To date, a large segment of the Afghan population still depends on food imported from abroad or that distributed by the aid community (www.southtravels.com/asia/afghanistan/geography).

The major food crops produced are: corn, rice, barley, wheat, vegetables, fruits and nuts. The major industrial crops are: cotton, tobacco, castor beans and sugar beets. Sheep farming is also extremely valuable. Livestock forms a main source of the household economy in rural areas. Many families in rural areas sell their livestock to buy wheat during the spring months when they run out of stocks. The major sheep product exports are wool and highly prized Karakul skins. The drought in Afghanistan from 1998 to 2001 was the worst in living memory, the most severe drought since 1891. In mid-2002, livestock numbers were too low to provide even the small amounts of milk, meat and eggs needed to supply protein and certain other essential micro-nutrients that help to balance the population's largely wheat-based diet. Small amounts of wheat and rice bran and cottonseed and linseed cake are derived from crops grown on arable land. However, the animals' diets still need to be supplemented with protein and minerals, to balance the nutrient supply and thereby improve their performance (www.southtravels.com/asia/afghanistan/geography).

About pigeonpea

According to Nene et al. (1989), Nyabyenda (1987) and van der Maesen (1983, 1986), pigeonpea in Afghanistan is grown in minor quantity. The cultivation of this crop is purely as subsistence crop for small-scale farmers. Attention is now given in growing pigeonpea and other legumes in this country because of the rich protein content of this plant and the use of its residue as animal feed. An important element in any multi-component, long-term strategy to restore the productivity of the livestock industry in Afghanistan is the production of more high quality feed by growing forage crops on fallow land and improving the yields of the existing feed crops. A better supply of feed would result in more productive livestock and increase the supply of animal-derived foods. This would have a positive impact on the health and livelihoods of the rural and urban poor.

Bhutan

Geography

Bhutan is situated in the fragile eastern Himalayas, landlocked between two of the world's most populous nations — India to the south and China to the north (Figure 70). With coordinates of 22°54' N to 28°18' N latitude and 88°46' E to 92°17' E longitude, it is about 47,000 km² and is located between Tibet in the north, Indian states of West Bengal and Assam in the south, and Arunachal Pradesh in the east (en.wikipedia.org/wiki/Geography_of_Bhutan).

Bhutan's climate is as varied as its altitudes. The climate is humid and subtropical in the southern plains and foothills, temperate in the inner Himalayan valleys of the southern and central regions, and cold in the north, with year-round snow on the main Himalayan summits. Temperatures vary according to elevation. In west-central Bhutan, temperature ranges from approximately 15°C to 26°C during the monsoon season of June through September then drop to between about -4°C and 16°C in January. Most of the central portion of the country experiences a cool, temperate climate year-round. In the south, the temperature ranges between 15°C and 30°C year-round, although temperatures sometimes reach 40°C in the valleys during the summer. Annual rainfall varies between 850 mm and 2,500 mm. Bhutan's generally dry spring starts in early March and lasts until mid-April. Summer

weather commences in mid-April with occasional showers and continues through the pre-monsoon rains of late June. The summer monsoon lasts from late June through late September with heavy rains from the southwest. The monsoon weather, blocked from its northward progress by the Himalayas, brings heavy rains, high humidity, flash floods and landslides, and numerous misty, overcast days. Autumn, from late September or early October to late November, follows the rainy season (en.wikipedia.org/wiki/Geography_of_Bhutan).

Agriculture

Agriculture is a major source of income and livelihood to the small farmer households, and most important, it is part of the daily existence of the majority of the Bhutanese. Despite the growth in the urban population in recent years, the country is predominantly an agrarian economy with more than 79% of the people deriving their livelihood from subsistence agriculture. Only 7.8% of the total area of the country is arable, out of which only 21% is dedicated to paddy cultivation. However, traditional farm practices are still prevalent in Bhutan despite government support and initiatives towards modern technologies and improved farming methods. Though landlocked by geography with no access to seas, Bhutan is blessed with a rich bio-diversity and wide range of agro-ecological zones. Nevertheless, a majority of the Bhutanese population are still small and marginal farmers constrained with inadequate land holdings and remoteness. In addition to the subsistence nature of farming, scattered villages that are sparsely populated with limited accessibility characterize rural livelihood. Amidst this reality, Bhutan is going through rapid socio-economic transformation. Over the past decade, the country has maintained a steady growth rate of 6-7%. The agricultural sector as a whole performed well, exceeding the projected target of 1.3% over the plan period. The main impetus of the growth in the sector came from forestry and cash crop production (Tobgay 2005).

In 2000, agriculture accounted for 35.9% of GDP of the nation (Babu and Gulati 2005a). Despite this, agriculture remains the primary source of livelihood for the majority of the population. Approximately 80% of the population of Bhutan are involved in agriculture (Babu and Gulati 2005b). Farm size holdings in Bhutan are limited to 1.4 ha and working within the limited operated area of 106,028 ha across the nation. Of this, an estimated 21% are wetland (irrigated), approximately 43% are dryland (rainfed), nearly

27% are used for shifting cultivation, approximately 8% are used for orchards and 1% is kitchen gardens (Babu and Gulati 2005b). Major crops cultivated in Bhutan are maize and rice. Maize accounts for 49% of total domestic cereal cultivation, and rice accounts for 43%. Rice is the major staple crop. Apart from paddy rice, other crops like wheat, barley, oil seeds, potato, citrus and different vegetables are also cultivated in these lands. Maize is mainly cultivated in dryland regions at lower elevation (Ramakant 1996).

About pigeonpea

Pigeonpea is purposely grown as a subsistence crop by small-scale farm households mainly as a mixed crop in kitchen gardens and in traditional shifting cultivation at borders of farm lands and along rice bunds at the dry sub tropical, humid sub-tropical and wet sub-tropical agro-ecological zones in Bhutan. The crop can thrive in an altitude of 150 to 1,800 masl and with an annual rainfall of 850– 2,500 mm (Tobgay 2005, MoA 2003).

Cambodia

Geography

Cambodia, also known as Kampuchea, is a country located in Southeast Asia that is bordered by Laos, Vietnam and Thailand (Figure 70). Its approximate geographical coordinates of 10°24' N to 14°36' N latitude and 102°23' E to 107°29' E longitude covering an area of about 181,035 km² (AsianInfo.org). Forest covers about two-thirds of the country, but it has been somewhat degraded in the more readily accessible areas by burning (a method called slash-and-burn agriculture), and by shifting agriculture (en.wikipedia.org/wiki/Agriculture_in_Cambodia).

As a tropical country, Cambodia is covered in almost all year sunshine and has a high average temperature. There are two distinct seasons, the dry and the monsoon. The monsoon lasts from May to October. The dry season runs from November to April averaging temperatures from 27 to 40°C. December and January are considered to be the coolest months and fall in the dry monsoon season. Annually, Cambodia gets about 1,400 mm of rainfall and the temperature averages around 27°C (80°F) (sales@cambodia-travel.com; AsianInfo.org).

Agriculture

Family agriculture plays an important role in Cambodia providing employment opportunities for around two thirds of the population and contributing to national food security and the economy. In addition, it has important cultural and environmental values and functions for Cambodian society. However, there is an increasing inflow of products from other countries. Generally, imported commodities are more competitive than local ones, which discourage small farmers, mainly subsistence farmers, to invest in agriculture. Furthermore, Cambodian farmers are not competitive because they have very limited access to technology, seeds, irrigation and other facilities. Sad to say, Cambodian farmers are not organized (www.cedac.org.kh).

In Cambodia, 70% of the population derives its livelihood from agriculture. Rice is the predominant agricultural crop and vegetables are the second largest crops produced followed by maize, rubber, soybean, groundnuts, sesame, jute, cotton and tobacco. In 1994, the calculated arable land was 17% while pasture was 3% of the total land area of the country. The total land area used for vegetable production was 33,755 ha. Most of the Cambodian farmers are poor and live under extreme agro-ecological, socio-economical constraints. The lack of basic infrastructure has been hindering the development of rural areas. The poor farmers with small and scattered holdings have been surviving on rainfed, monocropped and rice based farming (FAO 1995a, Keller 2003).

About pigeonpea

Considered as a minor crop by Nene et al. (1989), Nyabyenda (1987) and van der Maesen (1983, 1986), there are no other literatures cited indicating that pigeonpea is grown in Cambodia.

China

Geography

China, a mountainous country, is situated (21°17' N to 53°44' N latitude and 74°10' E to 134°17' E longitude) in the eastern part of Asia, on the west coast of the Pacific Ocean (Figure 70). China has a total land area of 9.6

M km² that comprises about 6.5% of the world's total land area with two-thirds of its total land area covered by mountains, hills and plateaus. The climate in China is extremely diverse: subtropical in the south and subarctic in the north. The northern portions of Heilongjiang Province experience an average January mean temperature of below 0°C (32°F), while the average July mean may exceed 20°C (68°F). In contrast, the central and southern parts of Guangdong Province experience an average January temperature of above 10°C (50°F), while the July mean is about 28°C (82°F) (en.wikipedia.org/wiki/Geography_of_China).

Agriculture

Agriculture has played an important role in poverty reduction in China. China has experienced one of the fastest rates of agricultural and overall economic growth. Its agricultural growth of 6% and industrial growth of over 8% per capita, for two full decades (from 1978 to 1997), has also been remarkable for its speed and duration (www.index-china.com). China ranks first in worldwide farm output, primarily producing rice, wheat, potatoes, sorghum, peanuts, tea, millet, barley, cotton, oilseed, pork, and fish. Due to China's status as a developing country and its severe shortage of arable land, farming in China has always been very labor-intensive. However, throughout its history various methods have been developed or imported that enabled greater farming production and efficiency (en.wikipedia.org/wiki/Agriculture_in_China).

Although China's agricultural output is the largest in the world, only about 15% of its total land area can be cultivated. China's arable land, which represents 10% of the total arable land in the world, supports over 20% of the world's population. Of this approximately 1.4 M km² of arable land, only about 1.2% (116,580 km²) permanently supports crops and 525,800 km² are irrigated. The land is divided into approximately 200 M households, with an average land allocation of just 0.65 ha (en.wikipedia.org/wiki/Agriculture_in_China).

About 75% of China's cultivated area is used for food crops. Rice is China's most important crop, raised on about 25% of the cultivated area. Wheat is the second most-prevalent grain crop, grown in most parts of the country. Corn and millet are grown in north and northeast China, and oat is important in Inner Mongolia and Tibet. Other crops include sweet potatoes in the south, white potatoes in the north, and various other fruits and vegetables.

Tropical fruits are grown on Hainan Island, apples and pears are grown in northern Liaoning and Shandong, and citrus fruits are grown in South China. Oil seeds are important in Chinese agriculture, supplying edible and industrial oils and forming a large share of agricultural exports. In North and Northeast China, Chinese soybeans are grown to be used in tofu and cooking oil. China is also a leading producer of peanuts, which are grown in Shandong and Hebei provinces. Other oilseed crops are sesame seeds, sunflower seeds, rapeseeds, and the seeds of the tung tree. Other important food crops include green and jasmine teas (popular among the Chinese population), black tea (for export), sugarcane (Guangdong and Sichuan province), and sugar beets (Heilongjiang province and on irrigated land in Inner Mongolia). Tea plantations are located on the hillsides of the middle Yangtze Valley and in the southeast provinces of Fujian and Zhejiang (en.wikipedia.org/wiki/Agriculture_in_China).

About pigeonpea

Pigeonpea in China was introduced from the eastern parts of India about 6th century, wherein 2 accessions have been identified (Nene et al. 1989, Nyabyenda 1987 and van der Maesen 1983, 1986). Since then this crop was sporadically cultivated in the southern provinces (Zhoujie 1997). Of the 28 provinces, 5 provinces — Fuchin, Hunan, Guangdong, Guangxi, and Yunan — cultivate pigeonpea in the southern part of China. The total area cultivated is not accurately documented. Among the legumes, groundnut is considered a major crop while pigeonpea is grown as a minor crop.

In the 50s, pigeonpea was identified as a favorable host for *lac* insect (*Kerria lacca* Kerr) and as fuel wood because of the plant's fast growth, easy cultivation, high yield of high quality *lac* (an ingredient in shellac, electrical insulation, and fruit and vegetable preservative), which allows *lac* harvest at least one year ahead of other perennial hosts (Yude et al. 1993). For 40 years, pigeonpea was a major income-generating source for small-scale farmers in the southern provinces of China because the *lac*, produced organically, fetches better price than synthetic lac in the international market. The high profitability of the crop helped spread pigeonpea cultivation in the neighboring provinces. But in 1989, farmers abandoned the cultivation of pigeonpea in their farmlands because there was a severe downfall in the demand for *lac* due to the production of artificial resins that killed the market for the natural product.

Guangxi is the most important province in China for its livestock. Its rural economy relies heavily on the animal industry. In sustaining this industry, the availability of quality fodder and feed throughout the year is very critical and a perennial problem particularly during the post-rainy season. In previous years, the provincial government spent large amounts of money on importing corn and rice domestically and internationally, to feed their livestock (Chengbin et al. 1999). Because of this circumstance, the provincial government embarked on the idea of utilizing and cultivating large areas of mountain slopes (which are lying fallow and are unfit for the cultivation of food crops) to grow pigeonpea as source of fodder for its livestock. After extensive testing, pigeonpea was identified as the most suitable crop because it can grow well under rainfed conditions and provide high protein (20-22%) fodder for domestic animals (ICRISAT 2005). To this writing, the estimated area under pigeonpea is 150,000 ha (Zong, personal communication).

Pigeonpea as Soil Conservation

About 90% of the land in southern China is covered with mountains and the ecology of the region has been damaged extensively due to lack of vegetation cover leading to soil erosion and frequent landslides. Each year, tons of topsoil and valuable nutrients are lost and such large areas have become unfit for agriculture. It is estimated that in Guangxi Province alone, about 6.5 M ha is currently a wasted mountain slope (steep-sided, bare hills eroded almost to the bare rock, and in the dry season, not even enough grass to feed the livestock) on which pigeonpea could be grown. These barren slopes are a familiar sight in many parts of the world; Yunnan and Guangxi Provinces found a way to reclaim the slopes for productive agriculture (ICRISAT 2006).

To combat this harsh environment, screening of suitable forest tree species, likewise, did not meet the desired expectation, which has bothered the Forestry Department of China. Numerous shrub species were evaluated for forestation and it was found out that these species grow slowly and have low or no economical value. In a recent development, pigeonpea was identified as an important species for forestation because the crop showed better adaptability to degraded soils, drought tolerance, grows faster to cover the vacant land and can be easily adapted by local people due to its potential uses. In 2000, more than 700 ha of forest area in Yunan province were planted with pigeonpea for soil conservation. Pigeonpea has been selected

as the forestation species in major government reconstruction projects such as the ‘Protection of forest in the upper-middle reaches of Yangzi River’, ‘Protection of forest in Lancangjiang River’, and the ‘Protection of natural forest’ (Saxena 2000).

Status of Pigeonpea Germplasm in China

In China, although pigeonpea was introduced about 1,500 years ago (Zhuojie 1997), the landraces of the crop have been preserved and are still grown in various provinces of southern China. These include Yunnan, Guizhou, Hainan and Guangxi where large extents of pigeonpea were cultivated until 1989 for lac production and wood fuel (Zhenghong et al. 1997). The crop also spread to some areas in Guangdong, Jiangxi, Sichuan, Fujian and Hunan provinces. In all the nine provinces, pigeonpea is maintained in hilly forests and in the backyard of some farmers. These landraces contain significant variation for different traits but so far there has been no systematic effort to collect, evaluate, and preserve this wealth of germplasm. Considering the importance and danger of losing these genetic materials due to introduction of new crops and clearing of forests, some attempts have been made by local scientists to collect pigeonpea landraces within their own province (Xuxiao et al. 2001).

The first pigeonpea collection mission was undertaken as early as 1960 in some areas of Yunnan Province by the Institute of Insect Resources, Chinese Academy of Forestry, Kunming. About 20 landraces were collected, but there is no record of availability of this material at the institute and it was lost over a period of time. The second collection mission was undertaken sometime in 1980s. In this mission 28 landraces were collected and the documentation record of some of their agronomic characters is available. During 1996-98, the third pigeonpea collection mission was undertaken and 76 landraces representing 10 countries were collected from Lincang, Cuxiong, Simao, and other regions. These germplasm lines contain a significant genetic variability for seed color, seed shape, flower color and pod color (Table 23). The landraces of Yunnan Province with a life span of 5-10 years have been cultivated for a long time and are similar in maturity. The seed yield is around 35 g/plant. The variation among the landraces for color of flower, pod and seed was significant. The flower color was red, yellow or mixed. The variation in seed color was also large, which included white, cream, grey, dark brown and variegated (Xuxiao et al. 2001).

Pigeonpea germplasm was collected in 1987 from the adjoining areas of Guizhou and Guangxi provinces and this represented 10 counties located in the Nanpan river valley. Although the record of the genetic variation in the collection is available, the number of collections was not recorded. The material had large variation for important characters such as flower and pod color, plant height, maturity, seed size, seed color and seed shape (Table 23). The plant height in the germplasm varied between 3 m and 6 m, when perennial (1-4 years old) plants were measured. Plants with both red and yellow flower colors were found. The mature pod colors observed were brown, yellowish brown and dark brown. The seed color of the material was cream, brown or dark brown. Analysis of the nutritional contents of whole seed samples showed that the protein content was 16-19% while lipid content was 1.5% and the starch content 38.8-45.6%. The local landraces were commonly distributed in the river valleys from the elevation of 380 m to 700 m. Most of the landraces were found growing in the hills and forests (Feijie et al. 1991, Julin and Xunsheng 1991).

In Hainan Province, 25 pigeonpea landraces representing 13 counties were collected. The collection was classified into two groups: yellow-flowered pigeonpea and double color-flowered pigeonpea. Most of the yellow-flowered pigeonpeas were short in height and early in maturity. The dorsal and ventral surfaces of the flowers were yellow. The matured pods were small, yellow-brown in color and have 2-3 seeds. The seed color was cream with dark speckles. Most perennial pigeonpea landraces had mixed flower color. This group was characterized by high vigor, large plant size, late maturity and yellow flower color with red stripes. The pods were brown or dark brown when mature and contain 4-5 seeds per pod. The seeds were round or oval and black or light grey. The plant height was 1.5-3.5 m. Pigeonpea landraces in Hainan Province were found in marginal lands or in backyard gardens. Seed damaged by insects was usually high (Xuxiao et al. 2001).

Table 23. Summary of pigeonpea germplasm collections in China.

Year	Area	Number of collections	Main characters
1960s	Partial areas in Yunnan	20	Material lost and no documents available
1980s	Partial areas in Yunnan	28	Seed color: grey, brown and speckled Seed shape: round and oval
1987	10 counties in Guizhou	Unknown	Flower color: red and yellow Dry pod color: brown, drab and blackish brown Seed color: cream, blackish brown, and dark brown Seed shape: round and oval 100-seed mass: 8–10 g Plant height: 3–6 m Maturity: long duration
1985–89	13 counties in Hainan	25	Seed color: grey, brown, black and spotted Seed shape: round, oval and rectangular 100-seed mass: 4.5–11.7 g. Maturity: long duration
1991–95	5 counties in Guangxi	12	Flower color: yellow Seed color: brown and cream Seed shape: round and oval Plant height: 3–4 m. Maturity: long duration
1996–98	10 counties in Yunnan	76	Flower color: yellow, red and reddish yellow Fresh pod color: green, purple and streak Seed color: white, cream, grey, brown, black and speckled Seed shape: round and oval

ICRISAT's collaboration

ICRISAT started introducing pigeonpea materials in 1985 at the Pigeonpea Observation Nursery (PON) in Guangzhou. In spite of demonstrating high yield potential, research and development activities were stalled due to the decline in the demand of *lac* in the international market. But after 10 years of abandonment, the hardy legume is making an astonishing comeback with the help of ICRISAT. ICRISAT re-introduced pigeonpea by providing suitable seed materials, production technology packages and training. Pigeonpea

was revived to reintroduce its other uses other than lac, such as food, fodder and for soil erosion control. The provinces of Guangxi and Yunan are the first beneficiaries. The Guangxi Academy of Agricultural Sciences concentrated on research with emphasis on fodder production, grazing and soil erosion conservation while the Insect Institute in Yunan focused on the potential of pigeonpea for soil conservation (Saxena 2000).

These concerted efforts spearheaded by ICRISAT resulted in the remarkable expansion of area planted to pigeonpea from just 50 hectares in two (2) provinces during 1999 to 100,000 hectares in 12 provinces in 2007. The crop is now commonly seen growing on roadsides, mountains and hilly slopes, and riverbanks. The strong root system of this plant, particularly the perennial varieties, helps hold the soil in place. Dr Zong Xuxiao of the Chinese Academy of Agricultural Sciences at Beijing in 2007 manifested that "Pigeonpea has been found to be very successful in covering the soil and reducing soil erosion", and further stated, "If perennial pigeonpea is planted after the first rains, it grows within four months and covers the ground and remains there for 3-5 years. It is much better compared with other crops whose ability of holding the soil takes years to establish." Since then, the Chinese government has established strong research and extension programs for introducing pigeonpea in diverse cropping systems (ICRISAT 2007).

ICRISAT's hybrid conquers China

In the latest development, the first hybrid seed production program was piloted at Yunnan province by the farmers' organization in Yuanmou County. The technology was developed by Dr KB Saxena (Principal Scientist) of ICRISAT by using cytoplasmic male sterility (CMS). Chinese farmers, in collaboration with the Research Institute of Resource Insects (RIRI) based in Kunming, shared the responsibility of producing seeds of hybrid ICPH 2671 and ICPH 3381. The hybrids performed better due to their fast canopy development, greater biomass production and strong root system. Pigeonpea hybrids are known not only for their 30-40% yield advantage but also their resistance to major yield-reducing stresses such as drought, soil borne diseases, water logging and soil salinity. In 2008, around 150,000 ha of land had been planted with pigeonpea varieties for soil conservation in the hilly slopes of Southern China (BioSpectrum 2009).

Uses

Innovative farmers in Yunnan, Guangxi and other provinces have found diverse uses for the crop. Aside from soil erosion, pigeonpea serves as a substrate for mushroom production and rearing of *lac* insects. They also use this crop in expanding the livestock industry by using the tender leaves and branches of pigeonpea as fodder or by simply allowing their cattle, goat, sheep and rabbits graze on standing crop (Fuji and Zhenghong 1995). This does not only reduce their importation feedstuffs, but serves also as a vegetable in the human diet.

Chinese in general consume a lot of fresh legume vegetables everyday. The new pigeonpea cultivars have become so popular because of their large seed size, color and pleasant flavor. To further popularize the use of pigeonpea for food, Chinese food technologists have developed a variety of snacks and other items like pigeonpea noodles using dry and green pigeonpea seeds, spicy-crisp grains and they are also added to moon cakes, which are traditionally prepared during their annual mid-Autumn festival (Jianyun et al. 2000, ICRISAT 2007).

Although the market for *lac* collapsed when synthetic resins became widely available, the international market's renewed interest for naturally derived products would likely lead to the return of *lac* production for which pigeonpea is ideally suited. *Lac* is the scarlet resinous secretion of *Kerria lacca* Kerr, a plant-sucking insect of the *Coccoidea* family. Brood *lac* insects are bound to the stem just below the first branch of one-year old pigeonpea plants. The larvae of the insect colonize the branches on where they secrete the gummy, resinous *lac*. The coated branches are then harvested twice a year. After crushing, sieving and washing, the resulting substance known as 'seedlac' can be further processed by heat or solvent extraction to produce shellac. In China, *lac* was used as a dye for leather until supplanted by synthetics. Shellac is used in industrial applications for surface coatings, wood treatment, printing, pharmaceuticals, textile, adhesives and the electrical industry.

The traditional folk medicinal use of pigeonpea is also being practiced by local farmers. Chinese shops sell dried roots as an antidote, alexeritic, anthelmintic, expectorant, sedative, vermifuge, and vulnerary for tumors. Leaves are also used for toothache, mouthwash, sore gums, child-delivery, dysentery, and staunch blood, as an analgesic and to kill parasites. Scorched seeds, added to coffee, are said to alleviate headache and vertigo. Fresh

seeds are said to help in incontinence, while immature fruits are believed to be effective for liver and kidney ailments (Duke 1981, *Journal of Ethnobiology and Ethnomedicine* 2007).

Hong Kong

Geography

Hong Kong is situated approximately 22°12' N to 22°30' N latitude and 113°52' E to 114°20' E longitude, on the southeast coast of China. Hong Kong lies on the boundary of the Palearctic and Indomalayan biogeographical regions (Figure 70). It comprises two main islands (Hong Kong and Lantau), over 200 smaller islands and an area of mainland (Kowloon and the New Territories). Hong Kong is mountainous with deeply incised submerged coastal features. Approximately 80% of the Territory is over 100 masl. Urban development and agriculture are concentrated in the lowlands and extensive coastal reclamations have been carried out to provide land for development. Hong Kong's climate is subtropical with marked seasonality. The summer is typically hot and humid with the heaviest rainfall between April and September. The winters are mild and relatively dry. The average total annual rainfall is 2,224.7 mm. The mean daily minimum temperature is 13.2°C (January) and the maximum 31.6°C (July) (www.iwmi.cgiar.org/wetlands/pdf/Hongkong).

Agriculture

Agriculture and Aquaculture in Hong Kong are considered sunset industries. Most agricultural produce is directly imported from the neighboring mainland China. In 2006, the industry accounted for less than 0.3% of the labor sector (Hong Kong Census 2007). Geographically Hong Kong consists largely of steep, unproductive hillside. The local aquaculture industry is also facing challenges from competition with imported aquatic food products and concern of fish and seafood safety (HKAFC 2007a).

In 2006, there were 2,100 farms in the territory, employing directly about 5,300 farmers and workers. By the end of 2005, the land used for vegetable, flower, field crop and orchard are 330 ha, 190 ha, 30 ha and 290 ha, respectively (HKAFC 2007b). Vegetable crops are grown all year round. Flower cultivation has gained importance in recent years. While a wide range

of fruit is grown on the lower hill slopes (en.wikipedia.org/wiki/Agriculture_in_Hongkong).

About pigeonpea

Since there are no other literatures indicating the existence of this crop in Hong Kong, pigeonpea is considered as a minor crop by Nene et al. (1989), Nyabyenda (1987), and van der Maesen (1983, 1986). However, even if there are no accessions found in Hong Kong, the country still utilizes pigeonpea as a treatment for hair loss. A fine paste made from pigeonpea is applied regularly on bald patches (Ting Ting 2006).

Indonesia

Geography

Indonesia is an archipelagic nation in Southeast Asia lying between the Indian Ocean and the Pacific Oceans with geographical coordinates 9°47' S to 5°36' N latitude and 95°16' E to 127°37' E longitude (Figure 70). The country encompasses an estimated 17,508 islands, only 6,000 of which are inhabited. It comprises five main islands; Sumatra, Java, Borneo (known as "*Kalimantan*" in Indonesia), Sulawesi, and New Guinea; two major archipelagos (Nusa Tenggara and the Maluku Islands); and sixty smaller archipelagos. Three of the islands are shared with other nations; Borneo is shared with Malaysia and Brunei, Timor is shared with East Timor, and the newly divided provinces of Papua and West Papua share the island of New Guinea with Papua New Guinea. Indonesia's total land area is 1.9 M km². Included in Indonesia's total territory is another 93,000 km² (straits, bays and other bodies of water). The complexity of the geography of Indonesia makes generalization of climate and soils almost impossible. The major islands have been classified on the basis of climate and soils. Split by the equator, the archipelago is almost entirely tropical in climate, with the coastal plains averaging 28°C (82.4°F), the inland and mountain areas averaging 26°C (78.8°F), and the higher mountain regions 23°C (73.4°F). The area's relative humidity ranges from between 70 and 90%. Monsoons usually blow in from the south and east in June through October and from the northwest in November through March (en.wikipedia.org/wiki/Geography_of_Indonesia).

Agriculture

In Indonesia, extension and intensification programs to maximize rice production have enabled the country to become self sufficient in rice production. Plantation crops (rubber and palm oil) are being encouraged for both export and job generation. The indigenous species are important in the people's diets and include the aquatic cabbage, taro leaves, parkia beans, sagu, cassava, yam, taro and sweet potato. Indonesia is rich in fruit species such as durians and its relatives, rambutans, duku, mangoes and its relatives, mangosteen, salak or snake fruits. Important introduced industrial plants include coffee, tea, rubber, oil palm, quinine and cocoa. Several plants are used to produce traditional medicines and cosmetics (FAO 1995b).

The major legume crops are peanuts and soybean. Other legumes were considered to be of minor importance. Statistics for pulse crops (leguminous crops excluding soybean and peanut) are available only as a group. Thus it is difficult to determine the actual planted areas and productivity for individual crops. All non-rice crops or secondary crops are traditionally expected to have low productivity. This expectation in turn has led to low inputs to such crops, and to their production during the more difficult times of the year on the poorer soils. These limitations restrict these crops (particularly the legumes) to a secondary role. A major sociological change will be required to increase production and productivity.

About pigeonpea

Since the 6th century, pigeonpea has been cultivated in Indonesia as a vegetable. Although the plant/has spread to almost all islands of the Indonesian Archipelago, the crop was never intensively cultivated. Pigeonpea is usually intercropped with other legumes or food crops and rarely grown as a monocrop. The crop is grown on fry ridges or on the dykes of wetland rice fields (Sumarno and Brotonegoro 1987). Farmers, especially in Java, Bali, Madura and the eastern island of the country, have traditionally grown many local varieties of pigeonpea. The crop has many local names such as *gude* in Central and East Java; *hiris* in West Java; *undis* in Bali; *kacang turis* in Timor and *kace* in South Sulawesi (Damardjati and Widowati 1985, Sumarno and Brotonegoro 1987).

Pigeonpea, currently a minor crop in Indonesia has recorded 57 accessions (Upadhyaya 2007). These are grown in the eastern islands and in some parts of central Java. The crop forms an important component of the farming system. As repeatedly discussed, pigeonpea is produced in a diverse array of systems. Besides being a perennial plant, it has a number of advantages over other leguminous crops including drought tolerance, lodging and shattering resistance and ability to grow on soils of low fertility. The technical suitability of the crop on a wide range of environments in Indonesia has been demonstrated, however, it is still a new crop with no established end-uses or market outlet (Wallis et al. 1988). Likewise, no clear information on suitability of the various soils and land systems for pigeonpea is available from farmers or from experimentation (Wallis and Byth 1984).

In view of the limited land resources available, the ability of this crop to compete with other crops will depend on its profitability as a cash crop, its contribution to subsistence farming objectives and its ability to blend into the existing social structure. Even if pigeonpea will be accepted and found suitable for production in areas with fertile, well-drained soils, the absence of an established market for this crop will discourage farmers from adopting it especially if the level of risk due to technical uncertainties is high. It follows that pigeonpea will probably find initial acceptance in more marginal environments and on less suitable soils where the special advantages of pigeonpea may allow more profitable exploitation than the other cropping options currently available (Wallis et al. 1988).

Most likely, the major areas most suitable for pigeonpea production in Indonesia are on the outer islands, particularly on the well-drained acid soils of Sumatra, Sulawesi and the eastern islands. Research data directly applicable to the areas identified earlier are limited and there are no commercial production data available to base the estimates. From the discussion of demand for pigeonpea, it is apparent that the potential on a large-scale in the main urban markets (as an animal feed or for human consumption) will depend largely on the scope for production at a lower unit cost than any other legume like soybeans.

Pigeonpea of medium and long duration landraces is generally planted in rice bunds and intercropped with maize or cassava. Long duration black, a seeded variety of pigeonpea is planted along the edges of the main crop in the eastern part of Java. In the drier southern Sulawesi region, the crop

is normally grown along the perimeter of the main cereal crop. However, in the Flores Island, pigeonpea is grown as a monocrop with a growth period of 150–195 days. The local duration black seeded cultivars are cultivated for the purpose of using this as vegetable (green pods) and for medicinal purposes. The subsistence food base in Timor-Leste has very limited range. Supplemented by some wild-harvest from forest and coastal resources, the diet is based on a system of staples of cassava (manioc), corn, sweet potato, potato taro, rice and beans with coconut, banana, papaya and citrus. The main types of local subsistence are the variations of the slash and burn, growing corn. Cassava, beans/pigeonpea combinations are interplanted with other main crops (for example, sweet potato, tomato, snake beans) during the wet season (Coy 2007). In Timor and Lombok, where rainfall ranges from 1000–1500 mm, long duration landraces are grown in rice bunds whenever it is convenient and congenial. The most popular variety is the Megha (ICP 14057), a short duration variety, which yields around 1.5–2 t/ha of green pods.

On the marketing aspect, Indonesia has a potential advantage as a trader over Malawi and Tanzania as a result of the lower cost of freight to India. In spite of this, there are no studies completed on the potential of pigeonpea as an export crop.

Uses

The plant and its products are not significant traditional components of human or animal diets. Legumes in general are less important than cereals. The crop is grown mostly as kitchen crop for its green seeds or tender pods. In the eastern part, the green seeds or tender pods (approximately 1 cm long) are cooked whole. The dry seeds have several products such as *tempeh* (a traditional Indonesian food where the legume seeds are fermented with a *Rhizopus* mold, then soaked, dehulled and cooked) (Widowati and Damardjati 1987) and ketchup (pigeonpea sauce, a replacement for soy sauce that is made by fermenting *C. cajan* with *Apergillus oryzae*. In Java, the young leaves are used as medicinal plant by applying it to sores, herpes and itches (Morton 1976, Payne 1998) while in West Java, people mix the raw young pods and fresh seeds of pigeonpea with ground spices — chili, coconut, sugar, garlic, salt, fried groundnut and *kencur* (*kamferia galanga*) — to prepare a popular dish, called *pencok hiris*. Sometimes, pigeonpea is served as a salad or a soup. But ironically, people in this island don't know

how to use or prepare the mature grain as food. The matured seeds are fed to livestock and poultry. Dry grains are not sold in the market except for a small quantity as seed (Damardjati and Widowati 1989).

In Central Java, a traditional food, which is well accepted, is the *brubus* and *bongko*. The *brubus* is made from green pigeonpea seeds mixed with grated coconut and ground spices consisting of coriander, coconut, sugar, salt, chili, garlic and onion, then cooked for about 30 minutes. However, if the said mixture is wrapped in banana leaf and steamed for about 30 minutes, this is already called *bongko*. Mature grain is consumed as side dishes namely *rempeyek* and *serundeng* and a snack called *gandasturi*. *Rempeyek* is a mixture of matured pigeonpea seeds with concentrated solution of rice flour, egg and coconut milk. Ground spices (coriander, candlenut, salt and garlic) are added and then deep-fried. *Serundeng* is a mixture of mature pigeonpea seeds with grated tender coconut, coriander, onion, sugar, salt, garlic, bay leaf, greater galangal (cut pieces of perennial rhizomes that are aromatic, pungent and bitter), tamarind and then fried. *Gandasturi* is made by mixing soaked green pigeonpea seeds with coconut, sugar and salt. The mixture is cooked, made into small balls covered with cassava or wheat flour and then fried (Damardjati and Widowati 1989).

The contribution to human diets of this form of consumption is likely to be low and expansion for this use is unlikely on a large-scale where the crop is harvested for human consumption as a green vegetable. The importance of pigeonpea in this system is difficult to quantify.

ICRISAT research collaboration

Collaborative pigeonpea on-station research by the Government of Indonesia with ICRISAT started as early as 1988. The focus of the research is on identifying high yielding short and medium duration varieties suitable in different agronomic environmental conditions. Non-determinate and determinate traits (NDT and DT) of vegetable type were tested. During the 1994 dry season, results showed that NDT short duration variety (ICPL 91048) from ICRISAT out yielded the local variety Megha by 17-38% and DT short duration variety (ICPL 87) by 26-44%. However, during the 1991-92 and 1992-93 wet cropping season, the Megha out yielded ICRISAT's short and medium duration cultivars. From these findings, extra short duration lines have a good potential in the dry season and during the wet season.

Japan

Geography

Japan is an island nation in East Asia comprising a large stratovolcanic archipelago extending along the Pacific coast of Asia. The country is 30°8' N to 46°4' N of the equator and 129°33' E to 149°35' E of the Prime Meridian. The country is north-northeast of China and Taiwan (separated by the East China Sea) and slightly east of Korea (separated by the Sea of Japan). The country is south of Siberia in Russia (Figure 70). Japan's territory is 377,923.1 km² (374,834 km² is land and 3,091 km² water). Japan belongs to the temperate zone with four distinct seasons, but its climate varies from cool temperate in the north to subtropical in the south. The climate is also affected by the seasonal winds that blow from the continent to the ocean in winters and vice versa in summers. Due to the large North South extension of the country, the climate varies strongly in different regions. The climate in most of the major cities, including Tokyo, is temperate to sub-tropic and consists of four seasons. The winter is mild and the summer is hot and humid. There is a rainy season in early summer, and typhoons hit parts of the country every year during late summer. The climate of the northern island of Hokkaido and the Sea of Japan coast is colder, and snow falls in large amounts. In Okinawa, on the other hand, the mean temperature of January is a warm 16°C (www.japan-guide.com; en.wikipedia.org/wiki/Geography_of_Japan).

Agriculture

Only 15% of Japan's land is suitable for cultivation, but the agricultural economy is highly subsidized and protected. The importance of agriculture in the national economy has continued to decline rapidly, and the share of net agricultural production in GNP finally reduced from 4.1 to 3% between 1975 and 1989. Farmers became mass producers of rice, even turning their own vegetable gardens into rice fields. Their output swelled to over 14 MT in the late 1960s, a direct result of greater cultivated area and increased yield per unit area, owing to improved cultivation techniques. In 1993, only 3.4 M farmers are engaged in farming (down from 8.1 M in 1970) and about 120,000 farmers are into rice production with an average farm size of 1.4 ha. Small size farms practice high intensity of crop production (www.msu.edu/~makinm/geo337/japan; en.wikipedia.org/wiki/Agriculture_forestry_and_fishing_in_Japan).

About pigeonpea

Pigeonpea was an introduced crop in Japan (ILDIS 2005). According to Nene et al. (1989), Nyabyenda (1987) and van der Maesen (1983, 1986), pigeonpea is considered as a minor crop grown by smallholder farmers. The crop is grown on the agricultural areas of the country and includes Ryukyu Island. The green peas are roasted and salted, and eaten as snacks (TripAtlas.com 2008).

Laos

Geography

Laos is a landlocked nation in southeast Asia with geographic coordinates of 14°5' N to 22°25' N latitude and 100°6' E to 107°34' E longitude that covers 236,800 km² in the center of the Southeast Asian peninsula (Figure 70). Laos has a tropical monsoon climate, with a pronounced rainy season from May through October, a cool dry season from November through February, and a hot dry season in March and April. Generally, monsoons occur at the same time across the country, although that time may vary significantly from one year to the next. Rainfall also varies regionally, with the highest amounts at 3,700 mm annually, which was recorded on the Bolovens Plateau in Champasak Province. Savannakhét averages 1,440 mm of rain annually; Vientiane receives about 1,700 mm, and Louangphrabang receives about 1,360 mm. Rainfall is not always adequate for rice cultivation, however, and the relatively high average precipitation conceals years where rainfall may be only half or less of the norm, causing significant declines in rice yields. Such droughts often are regional, leaving production in other parts of the country unaffected. Temperatures range from highs around 40°C along the Mekong in March and April to lows of 5°C or less in the uplands of Xiangkhoang and Phongsali in January (en.wikipedia.org/wiki/Geography_of_Laos).

Agriculture

At least 5 M ha of Laos's total land area of 23.68 ha are suitable for cultivation. However, just 17% of the land area (between 850,000 and 900,000 ha) is actually cultivated. Rice accounted for about 80% of cultivated land during the 1989–90 growing season, including 422,000 ha of lowland wet rice and 223,000 ha of upland rice. This demonstrates that although there

is interplanting of upland crops and fish are found in fields, irrigated rice agriculture remains basically a monoculture system despite government efforts to encourage crop diversification. Principal non-rice crops include cardamom, sometimes considered a forestry product, coffee, corn, cotton, fruit, mung beans, peanuts, soybeans, sugarcane, sweet potatoes, tobacco and vegetables (en.wikipedia.org/wiki/Agriculture_in_Laos).

Most farmers employ one of two cultivation systems: either the wet-field paddy system, practiced primarily in the plains and valleys, or the swidden cultivation system, practiced primarily in the hills. However, erosion from deforestation is a direct and serious result of swidden agriculture. Swidden cultivation was practiced by approximately 1 M farmers in 1990, which grew mostly rice on about 40% of the total land area planted to rice (en.wikipedia.org/wiki/Agriculture_in_Laos).

In 1997, according to Hettel, a substantial drop of some 300,000 farmers now practice the slash-and-burn farming. Swidden cultivation is a way of life based on tree felling and bush burning to clear land for cultivation. After 1 or 2 years, families move their cultivation to another area and start the process again. It takes years for the vegetation to return.

About pigeonpea

According to Barclay (2007), a study was conducted in Laos to identify potentials and constraints of introducing upland rice/pigeonpea intercropping practices to the local conditions, and to evaluate agronomic performance of different upland rice/pigeonpea intercropping systems. These crop combinations with improved fallow rotations reduce soil erosion and weed infestation, enhance soil fertility, and generate income. Besides grain production, pigeonpea has also served as a host for the insects that secrete *sticlac*, which is used as an industrial resin and fetches a good market price. After several years of harvesting *sticlac*, pigeonpea was incorporated into the soil as a green manure in preparation for a return to rice or other crops (Barclay 2007).

In another research conducted by Keoboualapha (1999), he stated that intercropping pigeonpea into rice reduced rice yield as well as biomass production. Rice grain yield was reduced by 84%, and by 100% for strip intercropping, and row intercropping, respectively. Rice above ground

biomass was also reduced by 82%, and by 96% for strip cropping and row intercropping, respectively, when compared to sole rice cropping. However, intercropping pigeonpea into rice increases pigeonpea grain yield by 10% and above ground biomass by 3%. Pigeonpea grain yield in sole cropping was 515 kg/ha. In terms of both yield and above ground biomass, intercropping pigeonpea into rice was more profitable than cropping only one crop (rice or pigeonpea). However, farmers might not accept the increased output per unit of land in which the yield of the main crop was substantially reduced.

Furthermore, in 2001, the commercial value of Job's tears in Luang Prabang was superior to that of rice. The Houay Pano catchment experiments were conducted to quantify tillage erosion on steep slopes. For Alfisols, downward soil transport amounted to 2 t/ha, 5 t/ha and 20 t/ha each year on slopes with gradients of 30%, 60% and 100%, respectively (Dupin et al. 2002). Systems 2 and 3 included the planting of the improved fallow species (cover crops), pigeonpea and crotalaria, three weeks after the sowing of the main crop. The densities used were similar to those recommended by Roder (2001) at 20,000 hill/ha. The steepest slopes were in the catchment with improved fallow and contour planting (system 3), and these inclines were mainly responsible for the moderate level of erosion recorded there. The areas planted with improved fallow, with and without contour planting, probably suffered less from erosion because of the better overall soil cover. Soil losses were least in the system with mulch planting due to the combination of no tillage, good cover and only moderately steep slopes. Mixed cropping of Job's tears and pigeonpea caused yield reduction of 26-53%, with 11-29% less biomass produced compared to pure stands of Job's tears. Pigeonpea might reduce weed growth as well, but being a more aggressive plant, it seems to also reduce the yield of Job's tears (Pakai 2003).

Several crop combinations, including pigeonpea, peanut and soybean proved suitable at the research sites in Laos. These rotations improved soil fertility, reduced weed populations, and also provided additional income to farmers (www.irri.org).

Malaysia

Geography

Malaysia with geographic coordinates of 1°29' N to 6°26' N latitude, 100°38' E to 115°24' E longitude, is strategically nestled in the center of South-East Asia, is close to the Equator, and is located south of Thailand, north of Singapore and east of the Indonesian island of Sumatra (Figure 70). East Malaysia is located on the island of Borneo and shares borders with Brunei and Indonesia (en.wikipedia.org/wiki/Geography_of_Malaysia).

Malaysia, which is shaped somewhat like a sweet potato, covers an area of 329,758 km², and is free from natural calamities such as earthquakes and typhoons. The country has a tropical climate that is hot and humid throughout the year. Annual rainfall exceeds 2000 mm. Its average temperature is 27°C with monthly relative humidity between 75 to 90%. The climate in the east coast of Peninsular Malaysia and the coastal areas of Sabah and Sarawak is very much influenced by the monsoon season from November until March. However, heavy rainfall occur in the northern parts of West Malaysia and east Sabah, between the months of June and October in the former and between the months of August and October in the latter. During this rainy season, the monsoon wind sweeps across these areas bringing frequent heavy rains. Meanwhile, the western side of Malaysia is not affected by the monsoon because it is protected by the soaring mountain ranges. This means that this part of Malaysia enjoys rainfall, which is more or less evenly distributed throughout the year (CircleOfAsia.com).

Agriculture

In Malaysia, the contribution of agriculture to the national Gross Domestic Products has declined from 29% in 1970 to 15% in 1994 due to the rapid growth of the industrial and service sectors. The country is not an important agricultural country, but as far as productions are concerned, the country maintains strong positions. Indeed, Malaysia produces 70% of the palm oil production in the world. In 2001, the arable land in Malaysia is 5.5% of the total land area. Croplands consist of 17.6%, and pasture 0.9%. The cultivated surface area is 7.9 M ha. The following plantation crops dominated the agricultural sector: oil palm, rubber and cocoa. Of the food crops, rice is the most important, followed by fruits (banana, coconut), root crop (manioc), and vegetables (FAO 1995a, FITA 2009, World Bank 2004).

About pigeonpea

Pigeonpea was taken to the New World in early post-Columbian days, but the crops did not reach the Pacific until 1772. Historians have disputed the origins of pigeonpea and have said that pigeonpea is of Indian origin, and is believed to have travelled from India to Malaysia, then to East Africa, up the Nile Valley to West Africa. Pigeonpeas are now widely spread throughout the tropics of the Southeast Asia and its areas of cultivation include Malaysia (Best-home-remedies.com, Nene et al. 1990). According to ILDIS (2005), the crop has been introduced in Malaysia and Nene et al. (1989), Nyabyenda (1987) and van der Maesen (1983, 1986) stated that the crop is grown in minor importance; the peas are roasted and salted, and eaten as a snack (TripAtlas.com 2008). According to Taylor (2005), pigeonpea has been identified for ethnomedical uses for abdominal pain, coughs, dermatosis, diarrhea, earache, enteritis and sores.

Pakistan

Geography

Pakistan is located between 23°53' N to 36°44' N latitude and 61°20' E to 75°14' E longitude and is the world's seventh most populous country with 138 M people (Figure 70). Pakistan's 796,095 km² of territory includes a wide variety of landscapes, from arid deserts to lush, green valleys to stark mountain peaks. The country is divided into four provinces (and two territories): Baluchistan in the southwest, Punjab in the east (both India and Pakistan have a Punjab region), Sindh in the southeast, and the North-West Frontier in the northwest. The provinces of Punjab and Sindh, in the east and south, are well irrigated by the Indus and its tributaries. The southwestern province of Baluchistan covers almost/half of Pakistan's territory. The land consists of a stony plateau, sparsely populated and very dry. The region's topography is constantly changing, as frequent earthquakes help the mountains grow at the remarkable rate of 7 mm a year.

The climate is arid with low rainfall and humidity and high solar radiation over most parts of the country. Most areas receive less than 200 mm annual rainfall, except for the high altitude northern mountains, which receive more than 500-600 mm annually. The rainfall distribution varies widely: 60% of rainfall in Sind and Punjab Provinces occurs during the monsoon season,

ie, from July to early September. Balochistan and the northern mountains receive maximum rainfall during October to March (FAO 1987).

Agriculture

Agriculture constitutes the largest sector and is the backbone of the economy of Pakistan with about 75-80% dependency. In 1947, when Pakistan gained its independence, the agricultural sector accounted for 53% of the GDP. While per-capita agricultural output has grown since then, it has been outpaced by the growth of non-agricultural sectors, and the share of agriculture has dropped to roughly one-fifth of Pakistan's economy. About 25% of Pakistan's total land area is under cultivation and is watered by one of the largest irrigation systems in the world. To date, agriculture accounts for about 23% of GDP and employs about 44% of the labor force.

Pakistan is one of the world's largest producers, suppliers and net food exporter of chickpea, apricot, cotton, sugarcane, onion, date palm, mango, oranges, rice, wheat, and milk, except in occasional years when its harvest is adversely affected by droughts (FAO 2005). Wheat, sugarcane, cotton and rice together account for more than 75% of the value of total crop output. The country's largest food crop is wheat. In 2005, Pakistan produced 21.6 MT of wheat, more than all of Africa (20.3 MT) and nearly as much as all of South America (24.5 MT) (FAO 2006).

About 5 M ha of the cultivated area (24% of total area) is rainfed while 16 M ha is irrigated. Mohammad (1989) and NCA (1988) estimated that around 60% (45.2 M ha) of the total area is rangelands. Most of these rangelands receive less than 200 mm rainfall, and are located on rocky soils, deserts and rough topography. Therefore, productivity is very low and it is not possible to utilize them for sustained farming purposes. However, these rangelands partly support 93.5 M livestock during the summer (Mohammad 1989).

Integrated farming systems are practiced and shortage of feed is a major limiting factor in livestock production. The land is fertile and produces most of Pakistan's food. However, in recent years, due to persistent hikes in the prices of essential commodities, pulses, onions, potatoes, chillies and tomatoes have also gained economic importance. In 1999-2000 season, the area under food crops was 12.5 M ha while its production was 24.8 MT. The area under cash crops was 4.1 M ha with production of 50.3 MT

while the area under pulses was 1.5 M ha and its production was 902,000 t (Agriculture Statistic of Pakistan 1999-2000).

About pigeonpea

Pulses like pigeonpea are the most important sources of vegetable protein in Pakistan. They are cultivated on 5% of the total cropped area. Their use ranges from baby food to delicacies of the rich and the poor. Because of the population growth, demand for pulses is increasing day by day. The total area under major pulse crops in Pakistan is about 1.5 M ha. Among pulses, chickpea is the major winter food legume and mungbean is the major summer legume. Chickpea occupies 73% of the total pulses area with 76% contribution to the total production, whereas mungbean occupies 18% of total area devoted to pulses contributing 16% to the total pulses production. Black gram and lentil, each are cultivated on 5% of the total pulses area and each of them contributes 5% to the total pulses production. Pigeonpea area covers only 4% of the total pulse area (Pakistan Agricultural Research Council 2007).

As per FAOStat (2008), pigeonpea in Pakistan was a major producing area from 1961 to 1989. However, from 1990 to 2006, the country was not identified as a major pigeonpea producer but instead considered a minor growing area because farmers still cultivate pigeonpea in small patches in Pakistan (PARC 2007). The crop is grown either in summer or winter. Based on FAOStat (2008), the production of pigeonpea in Pakistan was recorded from 1961 to 1989 only. No data were established during the 1990s and since 2000. The trend of production was not stable as seen in Appendix 3. During the 1961 cropping period, production was recorded at the lowest at 200 tons to as high as 1,727 t in 1973. In 1980 to 1984 production was around 1,500 to 1,600 t but abruptly reduced to 351 t in 1985 and 500 t in 1989. Following the calculation of Smith et al. (2001) where production per unit area is computed at 600 kg/ha in Asia, the area cultivated with pigeonpea in 1961, 1973 and 1984 would be 333, 2,878 and 2,667 ha, respectively.

The major factor for the reduction in area of pigeonpea cultivation and its production was the increase in the production of food grains like rice and wheat because of improved irrigation facilities. In this regard, due to low yield per unit area obtained from pigeonpea, there is a need to develop varieties with higher yield potential that respond to improved management practices so as to meet the increasing demand of pulses.

During 2001-2002 and 2002-2003 cropping season, Nawab (2003) conducted a study regarding the best cropping pattern for increasing wheat production. In his study, pigeonpea has carved its name as a crop that improves soil fertility as a green manure to wheat. Production of wheat after pigeonpea has the highest biological, straw and grain yield recorded at 8,091 kg/ha, 2,856 kg/ha and 5,235 kg/ha, respectively. In addition, heavier grains were produced by wheat following pigeonpea. Based on a two-year average, it has been concluded from his study that, cropping pattern of pigeonpea-wheat produced the highest yield among the different cropping patterns (rice-wheat, mungbean-wheat and groundnut-wheat) under irrigated and rainfed conditions.

The Philippines

Geography

The Philippines is an archipelago comprising 7,107 islands, which lies in the western rim of the Pacific Ocean and fronts the southernmost extension of the Eurasian Continent and is located between latitudes 5°5' N to 18°48' N and longitudes 117°4' E to 126°33' E. It is bounded by three large bodies of water: on the west and north by the South China Sea; on the east by the Pacific Ocean; and on the south by the Celebes Sea and the coastal waters of Borneo (Figure 70) (en.wikipedia.org/wiki/Geography_of_the_Philippines).

The total land area of the Philippines is 299,404 km² (30 M ha). About 298,170 km² is land area with the remaining 1,830 km² covered with water. There are three composite islands, Luzon (141,000 km²), Visayas (57,000 km²) and Mindanao (102,000 km²), which are characterized by high mountains with alluvial plains and narrow fertile valleys. Unlike the larger islands with their relatively diverse topography, the smaller islands are mountainous with surrounding flat lowlands; resulting from this situation are great variations in climate, geography and vegetation (en.wikipedia.org/wiki/Geography_of_the_Philippines).

Considered to be part of the tropics, the Philippines' mean annual temperature is about 27°C (80°F) with the interior valleys tending to be a little warmer and the mountain peaks a little cooler than the mean. The relative humidity averages about 77%. The rainy season is from May to November, which is the summer monsoon, while the dry season occurs during the winter monsoon from December to April. Typically, the weather is cool from November to

February, while it's very hot and dry from March to May. The rainiest times are from June to October, and the average rainfall in the lowlands is about 2,030 mm/year (en.wikipedia.org/wiki/Geography_of_the_Philippines).

Agriculture

Based on the 1991 Census of Agriculture and Fisheries (CAF), there were about 10 M ha of agricultural land (BAS 2004). About 54% of the farmlands were used for growing temporary crops and permanent crops covered 42%. The 1991 CAF also showed that the country has about 2.4 M ha rice farms, 1.8 M ha maize farms, 2.7 M ha coconut farms and 208,600 ha sugarcane farms. Coconut continued to be the major dollar earner. For the past several years, the country has not been self-sufficient in rice and maize. Average farm size was 2.16 ha. BAS also reported that the recent Census of Agriculture recorded a total of 4.5 M ha farms in 2002, which was 2.36% less than 4.61 M ha farms in 1991. The 4.5 M ha farms were contained in 9.19 M ha of agricultural land. Average farm size was 2.04 ha devoted to crops, fruit trees, livestock, poultry and other agricultural activities. From 1971 to 1991, the area devoted to farming increased but towards 2002 farmlands have decreased. The increase up to 1991 can be attributed to encroachment of crop cultivation in forest, grassland and plantation areas, while the decrease can be attributed to conversion of agricultural lands to settlements, housing and industrial uses in later years.

About pigeonpea

Among the grain legumes cultivated in the Philippines, groundnut, soybean and mungbean are the major crops. These crops are usually planted after rice. Pigeonpea locally known as *kadyos* or *kardis* is considered a very minor crop and a subsistence crop among a few farmers given that 61 accessions have been reported (Upadhyaya 2007). Nene et al. 1989; Nyabyenda 1987; and van der Maesen 1983, 1986 identified the Philippines as a minor producing country. Aside from providing food and as folk medicine, pigeonpea production supports the livelihood economy of small farm families. There were no records indicating that pigeonpea is in existence or part of the cropping system of small-scale farmers. But based on visual experience, the crop is grown on rainfed highland, upland and lowland areas of the Philippines, and is grown from April to February (Myer Mula, pers observation 2007).

According to Rasco and Maghirang (1989), pigeonpea is ideal for home gardening because of its nutritive value to combat malnutrition especially among pre-school children. In addition, they revealed that the crop is perennial or with a long picking period, tolerant to poor soils, high yielding and resistant to drought, shade, pests and diseases.

With the pronounced climatic condition of the Philippines, pigeonpea is an ideal and a potential cash crop especially in areas where rice and corn are grown. It is well accepted and eaten as a vegetable (green pods) due to its high protein content in lieu of animal products or in association with meat (pork, chicken and beef). Growers consume most of the produce of pigeonpea and hence it is seldom found in the market.

Pigeonpea landraces are grown in a limited scale in some dry areas of the country; these are cultivated, semi-cultivated, and in some places, spontaneous as a late maturing crop from April to February (9-11 months). The pigeonpea landrace is an erect, branched, hairy shrub, 1-2 meters high. Leaves are oblong-lanceolate to oblanceolate with three leaflets. Flowers are yellow, in sparse peduncled racemes, about 1.5 cm long. Pod is hairy, 4-7 cm long, 1 cm wide, containing 2-7 seeds (Philippine Alternative Medicines 2008).

The crop is planted on rice bunds in low-lying areas, on roadsides, on rainfed upland areas after rice, and in the highlands where farmers practice the slash and burn farming system. Because of its perennial habit, it is used as fodder by smallholder farmers since there is a shortage of high quality fodder for their livestock. Pigeonpea's diverse utilization can likewise improve the livestock and poultry industry in the Philippines. The green fodder can be utilized as a good protein source in animal diets and the seeds can be substituted as feed for poultry raising. In a research conducted by Sugui et al. (2007), pigeonpea was found to be a cheap source of poultry feed. The researchers revealed that birds fed with 15% pigeonpea seeds and 85% broiler mass produced heavier and higher daily gain in weight, more efficient in feed conversion, and good quality carcass.

In a research conducted in 1995 by the University of the Philippines, the crop was found to be able to cure diabetes and hyperlipidaemics (www.progress.org, 2003). This University of the Philippines team in Quezon City tested specific health effects of five legumes, concluding that pigeonpeas "could therefore be added to the list of foods for diabetics and

hyperlipidaemics" (persons with a high level of fats in the blood, a condition related to atherosclerotic cardiovascular disease) (Panlasigui 1995). Aside from the above-mentioned use, pigeonpea is used by indigenous people as decoction or infusion of leaves for coughs, diarrhea and abdominal pains. Tender leaves are chewed for aphthous stomatitis and spongy gums. Pulpied or poulticed leaves are used for sores (Philippine Alternative Medicines 2008).

Philippine-ICRISAT research collaboration

The collaboration between the Philippines and ICRISAT started way back in 1975 marked by an agreement with the Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCARRD). Research revealed that medium and short duration cultivars were tested during the dry season after rice (October to February planting) and have obtained yields of 1 to 3.9 t/ha after spraying 3–4 times against pod borer. On-station researches were conducted in the provinces of Laguna and Ilocos Norte. To this writing, experimentation vis-à-vis seed production of pigeonpea spread towards Nueva Vizcaya, Cagayan Valley and Benguet.

The research did not stop here. After realizing the potential of this crop, a series of studies were conducted using ICRISAT cultivars. From 1977–1987, numerous varieties were tested and yields per unit area were realized from 1–3.9 t/ha for short and medium duration varieties. However, storability of the local landraces has been found to be better than the introduced materials. Types of research conducted are the varietal trials, insect resistance and zero tillage (planted after rice) in irrigated and rainfed areas.

From 1986 to 1989 dry season, Cudapas et al. (1989) tested 16 improved high yielding cultivars from ICRISAT at the Mariano Marcos State University (MMSU), Batac, Ilocos Norte. They stated that the promising varieties were ICPL 85016, ICPL 151, ICPL 85015, ICPL 85014, ICPL 84032 and UPAS 120, which yielded 2.2 t/ha to 2.8 t/ha. The researchers likewise emphasized that ICPL 85016 was consistent in its yield performance giving the highest mean of 2.8 t/ha and also performed very well in the first year at 3.74 t/ha. Aside from ICRISAT cultivars, five (5) promising Queensland pigeonpea varieties were also evaluated. QPL 67 has the highest seed yield of 2.1 t/ha.

A follow up evaluation of 16 new early pigeonpea cultivars from ICRISAT were established from 1986 to 1988 at the same institute. Of the 16 varieties, ICPL 1, ICPL 840045, ICPL 151, ICPL 146, ICPL 8327, ICPL 87, ICPL 161 and ICPL 81 yielded an average 2.2 t/ha to 2.7 t/ha. However, the researchers have identified ICPL 269 and ICPL 1 varieties because of their consistent performance with the highest mean yield of 2.69 t/ha and at one point, ICPL 1 yielded 3.35 t/ha on its first year adaptation (Cudapas et al. 1989).

From 1991-1993 a few short duration lines were tested in different dates of sowing (November, December and May) but no clear-cut trend of the yield performance at different dates of sowing was registered. However, ICPL 87 yielded the highest at 2,442 kg/ha. Aside from the two provinces mentioned, on-farm research was initiated at Quirino Province. ICPL 85010, a short duration variety, planted in Ilocos Norte has the highest yield of 2,285 kg/ha while Quirino yield levels were very low. In 1996–1997 dry seasons, Sugui et al. (1997) revealed that ICPL 93015 produced the highest mean yield of 8,214 kg/ha when harvested as green pods and 2,085 kg/ha as grain among the 8 vegetable lines tested. In the succeeding years till 2003, on-station research was discontinued due to farmers' limited interest in the crop. In 2005, the pigeonpea program was revitalized and new cultivars of different types (short, medium and late varieties) from ICRISAT were tested in MMSU Ilocos Norte. To date, testing was spread towards other regions such as parts of Regions 1, 2, 3, 4 and the Cordillera Administrative Region.

Sri Lanka

Geography

Sri Lanka is in the north-equatorial tropical zone, an island just off the southern tip of India (Figure 70), (between coordinates of 5°57' N to 9°37' N latitude and 79°6' E to 81°44' E longitude; 432 km North to South; 224 km West to East) on an area of 65,610 km² (land area - 62,705 km²; inland water 2,905 km²). Most of the country consists of plains between 30 and 200 masl. In the south-west, where 60% of the land make up the dry zone area, ridges and valleys rise gradually to merge with the Central Highlands, giving a dissected appearance to the plain. The coastal belt, about 30 masl, surrounds the island (en.wikipedia.org/wiki/Geography_of_Sri_Lanka).

The climate is tropical with high humidity and temperature, which varies with altitude. Seasons are not determined by change of temperature, but by the rainfall distribution influenced by convectional precipitation and two monsoons. The northeast monsoon in November–February is locally called 'Maha' season and the south-west monsoon from May–September 'Yala' season. Topography plays a major role in the pattern of rainfall distribution. While the northeast monsoon rains are island wide, the mountains intercept the southwest monsoon. Thus the country can be divided into three climatic zones: a) The highlands and the south-west receiving both monsoons are the 'Wet zone.' This is the most intensively exploited zone with 67% of its area under permanent agriculture; b) The Northern and Eastern lowlands receiving only the Northeast monsoons are the 'Dry zone.' This zone covers two thirds of the island. It is the most favored area with regard to radiation levels. But lack of rainfall during February - September is a major constraint to crop production. With irrigation, yield potential for field crops is high in the zone; and c) A narrow strip of land fringing the highlands to the North and East lies between the two zones and is the 'Intermediate zone.' It is dominated by coconuts along the Western Coastal region, where dairy production has a long tradition (en.wikipedia.org/wiki/Geography_of_Sri_Lanka).

Agriculture

Sri Lanka's agriculture is one of the most important sectors of the economy and gives employment to at least 34% with a high degree of subsistence farming, and provided 18% of GDP in 2004 (Central Bank Annual Report 2004). The agriculture, forestry and fishing sector, which expanded by 1.6% in value added terms in 2003, contracted marginally by 0.7% in 2004 mainly due to the impact of inadequate rainfall on certain major crops. The relative importance of the agriculture sector continued to decline from 19% of the GDP in 2003 to 18% in 2004 owing to the low contribution from paddy production. However, production of other subsidiary food crops and vegetables improved, as farmers shifted from rice paddy production to ensure maximum use of available water. In fact the 'other agricultural crops' category, which includes, vegetables, subsidiary food crops, minor export crops, animal husbandry, sugarcane, tobacco and fruits, expanded by 3.2% in value added terms compared to 1.9% recorded in 2003, while the value added in the fishery sector recorded an improvement of 1.6%.

Agriculture in Sri Lanka mainly depends on rice production although plantations of tea, coconut, rubber and other tree crops and home gardens offer cover to a large area of land. According to Ibrahim (2000), in the peri-urban system, there is a wide variation but extensive in level of integration and intensification of crops and livestock. Consistent with Zemmelink et al. findings in 1999, in the village-based system, most smallholders are crop-livestock farmers, growing vegetables and paddy. Farms combine a homestead tree garden system with rice production. Farm or landholding on both systems averages 1.6 ha because farmers encouraged the adoption of more intensive feeding for livestock. Manure is a major product of their cattle, with milk often a secondary source of income. Manure is an important output for both systems and is marketed through private entrepreneurs who collect directly from farms and sell to market gardeners in the Nuwara-eliya area.

About pigeonpea

Legumes in Sri Lanka are mainly grown under rainfed conditions. Though the number of accessions present in the country is huge at 110, this is considered a minor crop for subsistence farming (Nene et al. 1989; Nyabyenda 1987; and van der Maesen 1983, 1986). Pigeonpea provides much-needed vegetable protein to a significant portion of the population who abstain from consuming animal proteins. Low-income groups depend on grain legumes to substitute for the more expensive meat and fish products. According to Saxena et al. (1992), pulses play an important role in dryland crop production systems in Sri Lanka. The major cultivated pulse crops are cowpea, mungbean, blackgram, and soybean. Red Lentil has become the most popular pulse in the country due to its high cooking quality and palatability. However, environmental conditions do not allow this crop to grow because the crop requires a cooler and drier climate. In this context, pigeonpea has been considered as the closest substitute for lentil.

A considerable amount of foreign exchange can be saved if local production of pigeonpea is promoted. In 1974 to 1979, pigeonpea in Sri Lanka was so popular when imports of lentil were curtailed. However, the cultivation of pigeonpea was neglected due to its susceptibility to pod borers. For 40 years, an attempt to intensify the production of pigeonpea has failed due to three factors, namely, difficulty in managing insect pest, the lack of suitable processing techniques, and lack of suitable varieties. Production of newly

tested cultivars has reached as high as 1.3 t/ha in 1974 but the insect pest (pod borer) brought pigeonpea cultivation to a decline (Karunatilake et al. 1996).

Although no longer grown as a field crop after 1979, long-duration and perennial pigeonpeas can still be found in home gardens and backyards in Sri Lanka. However, the extent of this practice still needs to be documented (Saxena et al. 1992). In 1990-1992, a new beginning for pigeonpea production was initiated. A total of 158 demonstrations covering an area of 48 hectares were conducted in three dry zone districts. Yields were promising as farmers harvested more than 1 t/ha to as high as 3.7 t/ha. The strategy to obtaining high yield was through insecticide spraying to as much as three to four times during the cropping. Even with the additional expense for insecticide and labor, the average profit per hectare was estimated at Rs 6,160, an indication that pigeonpea can compete with traditionally grown pulse crops in Sri Lanka. Besides providing a good income, the production of pigeonpea can generate employment wherein an estimated cultivation of 1,000 hectares would provide employment equivalent to 187,000 labor days during the 'maha' season. In addition, if 50% is ratooned, another 15,000 labor days in the 'yala' season will be realized (Karunatilake et al. 1996).

In 1994–1998, the on-farm trials were extended to 746 ha. During the 1997/98 cropping seasons, pigeonpea was yielding at a range 0.6 to 2.7 t/ha. In the post rainy 'yala' season trials, adaptation of pigeonpea was successfully demonstrated in fallow paddy lands wherein variety ICPL 88039 yields over 2 t/ha. ICPL 2, a short-duration indeterminate cultivar, considered to be best for the 'Maha' season, was released as 'Prasada' in 1997 in the dry zone. Other promising lines are ICPL 87, ICPL 84045, ICPL 87115 and MPG 537. Pigeonpea cultivation in Sri Lanka during the 'Maha' (rainy) season became economical with net profits of Rs 10,612–13,572/ha and Rs 16,707–20,795 in the 'yala' (postrainy) season. For the first time, pigeonpea lines with high levels of *Maruca* resistance were developed. These new lines are being used in breeding programs in India. A processing machine was also designed and fabricated during that year (Saxena 1998).

The Ministry of Agricultural Development and Research of the Government of Sri Lanka places emphasis on developing high yielding varieties of different maturity groups to fit diverse rainfall patterns. Early seedling vigor, tolerance to drought and major pests and diseases and good eating quality

are considered sought-after varietal characters. Research is also underway to develop crop management packages for legumes in rice-based cropping systems.

Taiwan

Geography

Taiwan is a medium-sized archipelago in East Asia, located at 21°56' N to 25°14' N latitude, 119°55' E to 121°48' E longitude with the Tropic of Cancer passing through its center. It makes up the majority of the territories effectively under the administration of the Republic of China (commonly known as 'Taiwan'). The country is shaped like a tobacco leaf with the total area nearly 36,000 km² (Figure 70). The climate on the island is generally marine and varies widely by season in the northern part and the mountainous areas. The south, however, belongs to the tropical belt and is warm and humid all year. From May to June it's rainy season, with almost daily showers. From July to October typhoons are most likely to strike, on average about four direct hits per year. In the northern part of Taiwan, cloudiness is persistent and extensive during the year; in the south, however, the rainy days are always in the summertime, and 90% of the annual precipitation falls during this period. The annual rainfall is usually more than 2,500 mm, close to 5,000 mm in some eastern regions (en.wikipedia.org/wiki/Geography_of_Taiwan).

Agriculture

Generally, high yields, irrigation, terracing, multiple cropping, intertillage and extensive use of fertilizers characterize Taiwanese agriculture. Farms are small, averaging 1.1 ha of cultivable land per farm family. Mechanization, once confined largely to sugarcane and rice production, is increasing rapidly as a result of government subsidies and other incentives. Since there is an oversupply of rice, the government has encouraged farmers to grow soybeans, wheat and corn, which are more profitable. The growing scarcity of land on Taiwan is causing serious disagreements over land resources between agricultural, industrial and housing interests. About 24% of the land is under cultivation. Although still important as both an export earner and a domestic food source, agriculture has fallen far from the pre-eminent position it long held in the Taiwan economy. From 1973 to 1987, the crop production growth rate increased on average only 0.1% per year. In 2001, agriculture

accounted for 2% of GDP. About 8% of the labor force was employed in agriculture. High production costs and low returns have driven much of the agricultural work force away to industry. In 1997, there were some 780,000 farm households, down from 822,395 in 1993. Part-time farming households have accounted for over 80% of all farming households since 1980.

In 2004, 721,418 households were farming about 835,507 ha of land, an average of only 1.16 ha per household. Most vegetables produced in Taiwan are for domestic consumption. In 2004, about 165,338 ha of land were devoted to vegetable cultivation. Bamboo shoots, watermelons, leafy vegetables, cabbages and vegetable soybeans were the leading vegetables in terms of area planted. By value, the most important vegetable crops were bamboo shoots, watermelons, shiitake mushrooms, cabbages, leafy vegetables, scallions, tomatoes and Chinese cabbages. Currently, more than 100 kinds of vegetables are grown in Taiwan. Radishes, Chinese cabbages, leaf mustard and garlic thrive in northern Taiwan's cooler climate, while in southern Taiwan, cauliflower, bamboo shoots and beans are cultivated. In 2004, 2.73 MT of fruit were grown in Taiwan on a total planted area of 218,650 ha. Over 30 types of fruits are cultivated in Taiwan. Such deciduous varieties as apples, pears, and peaches thrive at high elevations, while citrus fruits, bananas, pineapples, lychees, longans, mangoes, papayas, persimmons, loquats and guavas are grown in the lower plains and undulating slope lands. The main crops are citrus fruits, mangoes, cantaloupes, lychees, bananas, pineapples, wax apples and oriental pears (GIO 2006).

About pigeonpea

In Taiwan, pigeonpea is cultivated as a minor crop as revealed by Nene et al. (1989), Nyabyenda (1987) and van der Maesen (1983, 1986). Though the country has identified three accessions of pigeonpea, ILDIS (2005) revealed that the crop has been introduced in the country.

There are 13 indigenous tribes living in Taiwan and one of them is the Bunun. The Bunun's traditional agricultural method is slash-and-burn, and they cultivate pigeonpea as an annual yellow herbal plant. Their principal food is millet, corn and sweet potatoes. Non-staple food is very rare in everyday life. Presently, rice and sweet potatoes compose the staple diet of the Bunun. Edible wild herbs and mushrooms are their additional food supply, particularly pigeonpea. Soups prepared with pigeonpeas and pork ribs are

the most common in the Bunun tribes' diet (Taiwan Indigenous Cultural Park 2008). Moreover, the peas are roasted and salted, and eaten as a snack (TripAtlas.com 2008).

Thailand

Geography

Thailand is situated 5°42' N to 20°28' N latitude and 98°5' E to 105°28' E longitude in the heart of south-east Asia and is the gateway to Indochina (Figure 70). Thailand covers an area of nearly 513,115 km². Thailand has a tropical wet and dry or savanna climate according to the Köppen climate classification, while the south and the eastern tip of the country have a tropical monsoon climate; countrywide, the temperature normally ranges from an average annual high of 38°C (100°F) to a low of 19°C (66°F). The temperature rises dramatically to over 40°C in the second half of March until mid April. Southwest monsoons that arrive between May and July (except in the south) signal the advent of the rainy season (*ridu fon*), which lasts into October but the high humidity is experienced as 'hot and sticky'. November and December mark the onset of the dry season and temperatures begin to rise in January and night temperatures on high ground can occasionally drop to a light frost. The dry season is shortest in the south because of the proximity of the sea to all parts of the Malay Peninsula. With only minor exceptions, every area of the country receives adequate rainfall, but the duration of the rainy season and the amount of rain vary substantially from region to region and with altitude (countrystudies.us/thailand 2008).

Agriculture

Agriculture is the main occupation in Thailand and it plays an important role in the economic development of the country. Only 20% of the total agricultural land area is under irrigation. The rest constituting rainfed area has relatively lower crop yields. The rainfed area faces the problem of soil erosion and reduced soil productivity. Improper soil management has caused the infertility of the soil (Tongpoonpol et al. 2005).

Thirty four percent of the total land area of 511,770 km² are arable land, of which, 6% and 2% constitute the permanent crops and pasture, respectively. The well drained, loose sandy alluvium of the Mekong flood plain is very

fertile; the main crops being grown on an industrial scale are rice, maize, cassava, tobacco and pineapples. Cash crops such as sugarcane and manioc are cultivated on a vast scale, and to a lesser extent, rubber. Silk production is an important cottage industry and contributes significantly to the economy. During the winter months in the mountainous north, the temperature is cool enough for the cultivation of fruits such as lychees and strawberries. Traditionally, these natural features made possible several different types of agriculture, including wet-rice farming in the valleys and shifting cultivation in the uplands (countrystudies.us/thailand 2008).

Average farm size is 4.2 ha household (Kreethapon 1994). Of 20 M ha designated as farmland, 18 M ha (93%) is used for cropping and can be divided into paddy rice (55%), field crops (34%), vegetables and permanent crops (11%). Only 0.7 M ha is classified as grassland or idle land. Real GDP in 1996 was US\$2,750 per capita with 8.8% growth including 3.2% in agriculture (Shelton and Chaisang 2003).

In 2006, agriculture, forestry and fishing contributed less than 10% of gross domestic product (GDP) but employed about 39% of the workforce. Thailand is the world's leading exporter of rice, canned pineapple, and a major exporter of shrimp. Other agricultural products include coconuts, corn, rubber, soybeans, sugarcane and tapioca. In 1985, Thailand officially designated 25% of the nation's land area for protected forests and 15% for timber production. In 2000, roughly 49% of Thailand's labor force is employed in agriculture and in 2006, agriculture, forestry and fishing employment was reduced to about 39%. The agriculture at that time only contributed to less than 10% of the countries total GDP (en.wikipedia.org/wiki/Economy_of_Thailand 2007).

About pigeonpea

Legume crops are important components of farming systems in Thailand, but cereal crops, particularly rice, dwarf their production. Generally, statistics for pulse crops (leguminous crops excluding soybean and peanut) are available only as a group. Thus it is difficult to determine the actual planted areas and productivity for pigeonpea crops. Pigeonpea in Thailand is a popular backyard garden for its green seeds or tender pods. The green seeds or tender pods are cooked whole, roasted and salted, and eaten as a snack (TripAtlas.com 2008). In some parts of Thailand, pigeonpea has been traditionally grown as

a green manure crop at high plant populations prior to planting sugarcane. In this system, pigeonpea is sown in May and ploughed back into the soil by September (Sukarin et al. 1987).

Pigeonpea is a minor legume crop grown countrywide in all regions of the kingdom, local name *Tua Mahae* in the north, *Tua Mae Tay* in the central region and *Tua Rad* in the south. Pigeonpea is a non-commercial crop produced for local consumption and an animal feed component. There is no significant statistics on national planted area and production. The alternative use of pigeonpea in this country is for soil fertility improvement. Pigeonpea is now popularly used as green manure in sugarcane plantations, especially in the northeast. A pigeonpea variety, ICPL304, introduced from ICRISAT was released in 2003 as *Khon Kaen*. It is well adapted to be grown in Thailand as a high biomass variety. In 2003, about 10 t of seed of variety *Khon Kaen* were entirely sold for green manure in sugarcane fields. At present, the constraints to pigeonpea growing are the amount of seed availability and high seed cost (THDA 2003).

Although there are 41 accessions identified in the country (Nene et al. 1989; Nyabyenda 1987; and van der Maesen 1983, 1986), pigeonpea is not grown commercially in Thailand because it is an introduced crop (ILDIS 2005). The plant and its products are not significant traditional components of human or animal diets. In general, legumes are less important than are cereals, such as rice, maize and sorghum. The adoption of pigeonpea as a non-traditional food or animal feed product will highly depend on the following: suitability of the crop for culture in specific farming systems, the acceptability of the crop and its products, the socio-economic factors and other unforeseen variables. Locally produced pigeonpea could be used domestically or exported as is done by Myanmar.

The influence of variables such as soil, climate, fertility and temperature on the suitability of the environment for pigeonpea in Thailand can be considered. Cropping patterns will be influenced by the timing and duration of the wet season and its influence on the growing season. From this brief review of the soils and climatic constraints on pigeonpea production in Thailand, Wallis et al. (1988) concluded that two potential areas for production exist. The first is the northeast region of drier, well-drained soils with low fertility where upland cropping systems prevail. The second is part of southern Thailand where the rainfall is high, but there is a distinct dry season for post-wet season crops in some production systems (eg, intercropped with rubber).

In a recent development, the Phase 1 Research Project between Thailand and ICRISAT in Pigeonpea Improvement clearly indicated a potential for pigeonpea, which has been found to be an excellent perennial cover crop in young rubber plantations to control weeds, especially in the northeast of Thailand and as an intercrop in rubber plantations in the southern part of the country (Persley 1988). Growth is possible for three years until the mature canopy reduces light intensity. Approximately 50,000 ha/year are replanted to rubber, providing a potential of 150,000 hectares for intercropping. This situation has the potential to provide a low-cost production system for pigeonpea.

Research on Pigeonpea in Thailand

In Northeastern Thailand, where pigeonpea grain production remains insignificant, the research was able to demonstrate the important traits of pigeonpea such as drought tolerance and its potential use as green manure, which are essential attributes in the area. (Janboonme et al. 2007). The conduct of research for this crop started in 1983 at the Khon Kaen Field Crops Research Center and in 1984 at the Field Crops Research Institute, Department of Agriculture. The research involved implementation of a series of research activities, which include pigeonpea improvement and production of early pigeonpea cultivars. The research activities were classified under five categories: (1) varietal tests (yield trials), (2) field tests, (3) population density and sowing time, (4) fertilizer rates, and (5) climatic adaptation. Table 24 shows the result of research conducted from 1984 to 1990.

Likewise, farm experiments were established in 20 farmers' fields in two villages near Khon Kaen in 1998. This pigeonpea produces a standing biomass of up to 15 tons dry matter ha when supplied with sufficient phosphorous (www.esap.org).

Table 24. History of pigeonpea research in Thailand (1984 to 1990).

Year	Research Activity	Result
1984	Genotypic Evaluation	A study on genotypic evaluation of pigeonpea in northeastern Thailand was carried out at Khon Kaen in 1984, when 19 cultivars were determined and classified into 2 groups; early-maturing cultivars (76- 86 days) and medium-maturing cultivars (115-128 days). Grain yields of 3.9 t/ha and 3.8 t/ha were obtained from QPL 58 and ICPL 155, 43% higher than the local variety (NORMAN). Maruca testulalis and fusarium wilt caused grain yield reductions of 25%.
	Population Density (early-maturing cultivars)	The highest grain yields of 1.96 t/ha and 3.1 t/ha were obtained from Hunt and QPL 412 with a density 200,000 plants/ha (50x10 cm). The mean annual rainfall in Khon Kaen over 10 years was 1,200 mm, starting in February and ending in November with the peak of 240 mm in September.
	Population Density (medium-maturing cultivars)	A study on optimum density of medium-maturing cultivars (145-155 days), cv ROYES and ICPL 295, was carried out at Khon Kaen. Grain yields of ROYES did not significantly differ with the population densities between 100,000 to 200,000 plants/ha with an average of 2.0 t/ha .The highest grain yield of ICPL 295 was 3.2 t/ha with the density of 100 000 plants/ha at the planting date of late August, and 2.2 t/ha with the density of 200,000 for the planting date in early October.
	Serial Sowing Trial	A study on pigeonpea climatic adaptation was carried out at Khon Kaen using 17 varieties sown at 2 week intervals from August 1983 to August 1984. Among those NORMAN, HUNT, QPL 42, 412, 1605, ICPL 1, ICPL 6, ICPL 26, PANT-A 3 and TC-F 6-2-7 were photoinsensitive varieties. Seven photosensitive varieties (ROYES, C 322, BDN 1, ICPL 227, ICPL 265, ICPL 270 and ICPL 304) sown during late August to early January reached 50% flowering 70-90 days after emergence, but when sown during late January to April it required 170 to 280 days from emergence to reach 50% flowering.

Continued

Table 24. History of pigeonpea research in Thailand (1984 to 1990) continued.

Year	Research Activity	Result
1985	Genotype X Sowing Time Trial	This study was carried out at Khon Kaen (KK), Ubon Rachatanee (UB), Chiang Mai (CM) and Rayong (RY) in 1985, using pigeonpea varieties QPL 17, QPL 42, QPL 130, QPL 58 and HUNT. Three plantings were done at monthly intervals, beginning in mid June at KK, UB and in late May at CM and RY. Planting in mid July at KK and UB and planting in late June at CM and RY gave the highest grain yields. QPL 130 gave the highest grain yields of 2.3 and 3.7 t/ha at UB and CM, QPL 58 gave 1.6 t/ha at KK and QPL 17 gave 1.32 t/ha at RY. HUNT produced the lowest grain yield of 1.37 t/ha. The mean of this experiment was 1.66 t/ha.
	Population Density	Early-maturing cultivars, HUNT and QPL 42, were grown at Khon Kaen using three population densities: 160,000, 330,000 and 660,000. Days to flowering, maturities (113 days) and grain yields did not differ among densities. QPL 42 gave a higher grain yield (1.2 t/ha) compared with HUNT (0.96 t/ha). Medium-maturing cultivars, ROYES and ICPL 265, were grown at Khon Kaen using three population densities: 50,000, 100,000 and 200,000. The densities of 100,000 and 200,000 gave higher grain yields than that of 50,000. Days to flowering and maturity (167 days) did not differ among densities. ICPL 265 was less damaged by insects and diseases than ROYES.
1987	Preliminary Yield Trial (early cultivars), Group I	Eighteen pigeonpea cultivars were sown in a field trial at Khon Kaen in the late rainy season of 1987. The highest yielding cultivars (>2 t/ha) were ICPL 86008, ICPL 83009 and QPL 1070. The 100-seed masses ranged from 8.92 g (QPL 1086) to 13.30 g (QPL 1082). ICPL 83009 showed the outstanding determinate type and no shattering characteristic. Days to maturities ranged from 125 to 138 days.
	Preliminary Yield Trial (early cultivars), Group II	Ten pigeonpea cultivars (135 days) were sown in a field trial at Khon Kaen in 1987. ICPL 8324 gave the highest grain yield of 2.4 t/ha, 43% higher than HUNT (control). The 100 seed masses ranged from 5.8 g (ICPL 4) to 15.2 g (ICPL 8324).

Continued

Table 24. History of pigeonpea research in Thailand (1984 to 1990) continued.

Year	Research Activity	Result
	Preliminary Yield Trial (pest resistance)	Nine medium-maturing pigeonpea cultivars (196 days) were evaluated without pest control at Khon Kaen in 1987. ICPL 332 (Heliothis-resistant line from ICRISAT) gave the highest grain yield (2.1 t/ha), 86% higher than ICPX 79083-NDT 2 (a susceptible line). ICPL 265, which was the high-yielding cultivar under pest control, produced 1.5 t/ha of grain yield. However, the insect population that year was not serious.
	Standard Yield Trial	Fourteen early pigeonpea cultivars were compared in field trials at four locations. Grain yields ranged from 1.2 t/ha in cv OPL 566 to 1.8 t/ha in cv QPL 17 at Khon Kaen, from 0.5 t/ha in cv QPL 734 to 1.4 t/ha in cv QPL 652 at Ubon, from 0.3 t/ha in cv QPL 42 to 0.9 t/ha in cv QPL 702 at Rayong, and from 0.7 t/ha in cv QPL 58 to 1.1 t/ha in cv QPL 827 at Chiang Mai. QPL 637 was the highest-yielding cultivar on average of four locations (1.2 t/ha) and was a well-adapted cultivar.
	Standard Yield Trial (pest resistance)	Eight medium pigeonpea cultivars (188 days) were evaluated under pest control at the economic level. ICPL 265, which gave 1.9 t/ha of grain yield did not significantly differ from ICPL 332 (Heliothis resistant line), 1.85 t/ha. ICPX 79083-NDT 2 (susceptible line) gave the lowest grain yield of 1.2 t/ha.
	Standard Yield Trial (vegetable pigeonpea)	Six pigeonpea cultivars (107-139 days) were tested in field trials at three locations. Fresh pod yields ranged from 5.5 t/ha in cv ICPL 211 to 8.25 t/ha in cv ICPL 8324 at Khon Kaen, from 1.22 t/ha in cv ICPL 7035 to 1.88 t/ha in cv ICPX 79083-NDT 2 at Rayong, and from 2.67 t/ha in cv ICPL 211 to 3.96 t/ha in cv ICPL 7035 at Chiang Mai. ICPL 7035 was suitable for fresh pod consumption based on edible quality and high fresh pod yield on the mean of three locations (3.96 t/ha).

Continued

Table 24. History of pigeonpea research in Thailand (1984 to 1990) continued.

Year	Research Activity	Result
	Fertilizers	In a field trial at Khon Kaen in 1987, pigeonpea cv QPL 42 was grown on infertile soil (OM = 0.36%, available P = 13 mg kg and exchangeable K = 20 mg kg). Nine treatment combinations of 3 rates of P and K (37, 56 and 75 kg/ha) were applied. Grain yields increased with P applications from 1.56 t/ha up to 1.83 t/ha. Increasing K increased seed size and grain yield. Both P and K had no effect on days to 50% bloom, plant height or plant dry weight at 100 days after sowing.
1988	Fertilizers	In a field trial at Khon Kaen in 1988, pigeonpea cv ICPL 83024 was grown on infertile soil (OM = 0.37%, available P = 7.5 mg/kg and exchangeable K = 10.0 mg/kg). Sixteen treatment combinations of four rates of P and K (0, 37, 56 and 75 kg/ha) were used. Grain yields increased from 1.18 t/ha with no P application up to 1.57 t/ha when applied with P at 37 kg/ha and from 1.16 t/ha with no fertilizer application up to 1.62 t/ha when applied with K at 37 kg/ha. Increasing K increased seed size, but both P and K had no effect on days to flowering, days to maturity and plant height.
	Population Density (green manure)	In a field trial at Khon Kaen in 1988, pigeonpea cv ICPL 83024 was grown on infertile soil (OM = 0.37%, available P = 7.5 mg/kg and exchangeable K = 10.0 mg/kg). Sixteen treatment combinations of four rates of P and K (0, 37, 56 and 75 kg/ha) were used. Grain yields increased from 1.18 t/ha with no P application up to 1.57 t/ha when applied with P at 37 kg/ha and from 1.16 t/ha with no fertilizer application up to 1.62 t/ha when applied with K at 37 kg/ha. Increasing K increased seed size, but both P and K had no effect on days to flowering, days to maturity and plant height.
	Regional Yield Trial	Twelve pigeonpea cultivars were compared in field trials at four locations. The highest yielding cultivars were QPL 637 (1.86 t/ha) at Rayong, QPL 702 (2.41 t/ha) at Chiang Mai, QPL 652 (1.76 t/ha) at Ubon and ICPL 86008 (2.67 t/ha) at Khon Kaen. QPL 637 gave the highest grain yield of 2.0 t/ha as a mean of four locations.

Continued

Table 24. History of pigeonpea research in Thailand (1984 to 1990) continued.

Year	Research Activity	Result
	Locational Yield Trial	Eight medium and four early pigeonpeas were sown at Khon Kaen in 1988. ICPL 270 gave the highest yield of 1.85 t/ha (170 DAE), ICPL 151 harvested at 130 DAE was the highest yielding cultivar among early pigeonpea (1.40 t/ha). Plant heights ranged from 1.41.7 m among medium cultivars and 0.901.20 m among early cultivars.
	Field Test	In a field test in 1988, QPL 42 was sown with a density of 300,000 at two locations in Khon Kaen. Grain yield on the average of two locations was very low (0.8 t/ha) due to damage by Maruca (<i>testulalis</i>) <i>vitrata</i> (Geyer) and Helicoverpa (<i>Heliothis</i>) <i>armigera</i> (Hubner) in the flowering period. Farm costs were high, up to 15,708 baht/ha, with 33% of total cost being insecticide applications.
1989	Field Test	In a field test in 1989, QPL 42 was sown with a density of 400,000 plants/ha at two locations in Khon Kaen. Grain yield harvesting at 133 DAE for the mean of two locations was 1.97 t/ha. Farm cost was 15,347 baht/ha, 34% of total cost being insecticide applications.
1990	Field test	In a field test in 1990, ICPL 83009 was sown with densities of 300,000 and 400,000 plants/ha at two locations in Khon Kaen. Grain yield harvesting at 131 DAE for the mean of two locations was 1.33 t/ha and did not differ among densities. Farm cost was 14,580 baht/ha, 30% of total cost being insecticide applications.

Source: Janboonme et al. 2007.

Impact of pigeonpea in northeastern and northern Thailand

The usefulness of pigeonpea in the farming systems of Thailand is in crop rotation and green manuring in sugarcane producing land holdings. It is not significant for its dry seeds as green vegetable. Green manuring of pigeonpea in sugarcane cropping systems was found common in the provinces of Khon Kaen and Udon Thani in the upper regions of northeastern Thailand. Sugarcane is one of the most important crops in the northeast regions of Thailand. It occupies the third largest area grown to field crops, following cassava and corn. The area grown to sugarcane more

than doubled from 53,404 hectares in 1985 to 119,213 hectares in 1996. In this region, sugarcane is mainly harvested from October to March and the land left fallow until the end of the rainy season (October). Pigeonpea can be planted at the beginning of the rainy season (May) and ploughed down after four months in August, after which it is left for at least a month to decompose before the sowing of sugarcane, which is considered the main crop (Janboonme et al. 2007).

The survey data from northeastern Thailand indicates that there were two categories of people who adopted pigeonpea: (1) large-holder farmers who allocated more than 10 hectare for sugarcane production; and (2) smallholder farmers, who allocated less than 10 hectare for sugarcane production. Large-holder farmers comprised 27% of cane farmers in northeast Thailand (Pramanee et al. 1997), and achieved a higher rate of adoption of pigeonpea as a green manure than small-holder farmers. Cane farmers who owned more than 200 ha of sugarcane land were usually found to grow pigeonpea for green manure as well as for seed multiplication. Extra seed is sold mainly to nearby farmers. Smallholder farmers prefer to buy seed every year. Although some seed producers multiply pigeonpea mainly for seed sale, the seed has remained insufficient for the seed buyers. The Khon Kaen Field Crops Research Center produces and distributes, on an average, 1 ton of foundation seed a year. Likewise, it was revealed that farmers of Chiang Mai intercrop pigeonpea with *Leucaena spp.* as a hedgerow to reduce soil erosion in sloping lands. The Land Development Department Region 6 (LDD6) produces 10 tons pigeonpea seed per year in an area of about 800 hectares to supply farmers who grow it as hedgerow. The multiple cropping center at Chiang Mai University, after evaluating a number of different legume crops, also established that pigeonpea is the only legume that could grow well and improve the soil nutrients of the poor soils in the area (high acidity and low phosphorus levels). This finding is very significant considering that farmers in the highlands who cultivate upland rice obtain only 1.2 t/ha even after leaving their land fallow for a year (Janboonme et al. 2007).

Soil improvement has been the first priority for research and development by the LDD. Research at LDD and CMU indicates that among many green manuring crops, pigeonpea is accepted as one of the most appropriate crops in the uplands of northeastern Thailand. In addition, cultivation of pigeonpea as hedgerows in the sloping highlands enhances soil conservation. The pigeonpea leaves can be used as forage for animal feed, and the stems for fuel wood.

Aside from green manure, the crop grown for 2-3 years serves as an important host to the scale insect that produces *lac* and the leaves are used to feed silkworms (Nene et al. 1990). During 1988-89, a trial on using perennial pigeonpea for rearing *lac* insects was conducted. The crop was planted in May with the onset of rains and *lac* was introduced on the branches in December. The *lac* was allowed to grow for a year and harvested with an average yield of 2,500 kg/ha. The total production period for *lac* was 18 months.

Trading

In the export market, Thailand would have a potential advantage over traditional suppliers (Malawi and Tanzania) as a result of the lower cost of freight to India. Interestingly, Thailand has tried exporting to India 85 tons of pigeonpea during the period 1984/85 (Directorate General of Commercial Intelligence and Statistics 1987). However, no definitive studies on the potential of pigeonpea as an export crop have been completed. This is a serious deficiency, which must receive a high priority for future investigation.

Russia

Geography

The area formally known as the Soviet Union is situated at 42°1' N to 77°50' N latitude, 59°10' E to 170°9' W longitude, and occupies the eastern portion of the European continent and the northern portion of the Asian continent (Figure 70) with a total area of approximately 22.4 M km². Due to the sheer size of the state, the climate varied greatly from subtropical and continental to sub-arctic and polar. Eleven percent of the land was arable, 16% was meadows and pasture, 41% was forest and woodland, and 32% was declared 'other' (en.wikipedia.org/wiki/Geography_of_Soviet_Union).

Agriculture

Agriculture in the Soviet Union was organized into a system of state and collective farms, known as sovkhozes and kolkhozes, respectively. Organized on a large scale and relatively highly mechanized, the Soviet Union was one of the world's leading producers of cereals, although bad

harvests (as in 1972 and 1975) necessitated imports and slowed down the economy. However, despite immense land resources, extensive machinery and chemical industries, and a large rural work force, Soviet agriculture was relatively unproductive, hampered in many areas by the climate (only 10% of the Soviet Union's land was arable), and poor worker productivity. Conditions were best in the temperate black earth belt stretching from Ukraine through southern Russia into the west, spanning the extreme southern portions of Siberia (en.wikipedia.org/wiki/Agriculture_in_Soviet_Union). In addition, the 2-3% of arable land allotted as private plots does not include the large area allocated to the peasants as pasture for their private livestock; combined with land used to produce grain for fodder, the pasture and the private plots total almost 20% of all Soviet farmland (www.usm.maine.edu/eco/joe/works/Soviet). It has also been claimed that private farming also turns out to be relatively inefficient, taking roughly 40% of all agricultural labor to produce only 26% of all output by value. Finally, such claims tend to discuss only a small number of consumer products and do not take into account the fact that the kolkhozy and sovkhozy produced mainly grain, cotton, flax, forage, seed and other non-consumer goods with a relatively low value per unit area. The most important crops grown are wheat, barley, maize, rice, cotton, pea, chickpea, melon, tomato, sugar beet, lentil, alfalfa, soybean, grapes, pomegranate, apple, apricot, pistachio, haricot and persimon (en.wikipedia.org/wiki/Agriculture_in_Soviet_Union).

About pigeonpea

There are 2 accessions of pigeonpea identified in Russia (Upadhyaya 2007). However, Nene et al. 1989; Nyabyenda 1987; and van der Maesen 1983, 1986 found that the country is a minor producing region of pigeonpea as subsistence crop to smallholder farm families.

Vietnam

Geography

Vietnam is located on the eastern margin of the Indochinese peninsula with coordinates of 8°40' N to 23°14' N latitude, 102°7' E to 109°9' E longitude (Figure 70) and occupies about 331,688 km², of which about 25% was under cultivation. Vietnam's climate is amazingly varied, but this is due to the vast range of latitudes and altitudes in the country. The average temperature in

the north is about 81°F (27°C) and in the south a nice 70°F (21°C) and is generally humid. Two monsoons control the weather, one is considered to be a dry monsoon, which occurs mainly in the north from about October/November to March. The other brings wet, warm weather to the entire country, with the exception of the mountainous areas, from April/May to October. July and August are considered to be the hottest and most humid months (AsianInfo.org 2000).

Agriculture

Agricultural production, the backbone of Vietnam's development strategy, varied considerably from year to year following national reunification in 1975 (LCFRD 1987). Over 40% of the GDP comes from agricultural production. The principal field crops are rice, maize, sweet potato and cassava. Industrial crops like coffee, rubber, tea, groundnut and cashew contribute to export earnings. Most of the legumes, vegetables and fruits (except for banana) are grown for domestic consumption (FAO International Technical Conference on Plant Genetic Resources 1995). Vietnam's agriculture is projected to grow annually by more than 4% over the next 20 years. There is very little land to increase the area under cultivation and growth must be achieved through intensification (Mutert 1999).

In 2004, agriculture and forestry accounted for 21.8% of gross domestic product (GDP), and during 1994-2004 the sector grew at an annual rate of 4.1%. However, agricultural employment was much higher than agriculture's share of GDP; in 2005 about 60% of the employed labor force was engaged in agriculture, forestry and fishing. Agricultural products accounted for 30% of exports in 2005. The relaxation of the state monopoly on rice exports transformed the country into the world's second or third largest rice exporter. Other cash crops are coffee, cotton, peanuts, rubber, sugarcane and tea (LCFRD 2005).

Of the total land area of 33 M ha in Vietnam, 75% is hilly or mountainous. About 21% of the total land area, or 6.9 M ha, is used for agriculture, of which 5.3 M ha is used for annual crops, while 42%, or 13.8 M ha, has been abandoned or is left fallow. Phien and Tu Siem (1996) stated that "as a direct consequence of planting upland rice and cassava for food self-sufficiency, more than one million ha have become eroded skeleton soils with no value for agriculture or for forestry". Similarly, ISRIC (1997) reports that of the 38.6

M ha of total land area in Vietnam, 8.6 M ha (22%) are suffering from various degrees of water erosion, while 5.0 M ha (13%) from fertility decline.

About pigeonpea

In mountainous or hilly areas of Vietnam, cropping systems, which combine trees and crops, favor sustainable production in agriculture and forestry. By using such methods, soil erosion and soil degradation can be avoided. Band Cultivation of Trees and Crops (greening band) protects land from erosion, increases the fertility of soil, and provides green manure and fodder. Leguminous crops, such as pigeonpea (*Cajanus cajan*) are used for this purpose. The optimum distance between bands is from 5 to 10 m, depending on the gradient of the slope. The width of each band is usually about 1m. Before planting, soil in the band should be well ploughed for better seed germination and better growth of plants. The space between greening bands can be used for annual or perennial crops. Annual crops may include upland rice, maize, sorghum, millet, cassava, peanut and sesame while perennial crops are tea, cocoa or coffee (DAFE and MARD 2001).

Since no accessions have been identified in the country, the crop has been introduced for testing as mentioned by ILDIS in 2005. Exotic plant species are playing a significant role in Vietnam's rural economy and provide basic needs of food, fuel and shelter. Pigeonpea is considered an exotic crop by Vietnam. This crop will continue to be a feature of the landscape in Vietnam and local people will rely on a blend of indigenous and exotic trees to meet basic needs of food, fuel and shelter. Products from planting this crop will help reduce harvesting pressure on Vietnam's declining natural forests (Midgley et al. 1996).

Several crop combinations, including pigeonpea, peanut and soybean proved suitable at the research sites in Vietnam. These rotations improved soil fertility, reduced weed populations, and also provided additional income to farmers (www.irri.org).

Potential Growing Area in Middle East

United Arab Emirates (UAE)

Geography

Situated in the strategic location along the Hormuz strait, which is one of the vital crude oil transit points, United Arab Emirates is an important destination in southwest Asia. The precise location of UAE is in the border area between the Gulf of Oman and the Persian Gulf, between Oman and Saudi Arabia (Figure 70). The United Arab Emirates lies between 22°40' N to 25°43' N latitude and 51°35' E to 56°15' E longitude. Such is the Geography of UAE, that it shares a 530 km border with Saudi Arabia on the western side, southern side, and southeastern side. It also shares a 450 km border with Oman on the southeast and northeast. UAE's total area is surveyed approximately 77,700 km² (www.holidayshub.com/uae/geography).

The climate of the UAE is generally hot and dry. The hottest months are July and August, when average maximum temperatures reach above 48°C (118°F) on the coastal plain. Average minimum temperatures in January and February are between 10°C (50°F) and 14°C (57°F). The average annual rainfall in the coastal area is fewer than 120 mm, but in some mountainous areas annual rainfall often reaches 350 mm. Rain in the coastal region falls in short, torrential bursts during the summer months, sometimes resulting in floods in ordinarily dry *wadi* beds. The region is prone to occasional, violent dust storms, which can severely reduce visibility (Nazzal 2009).

Agriculture

Agricultural achievements in the United Arab Emirates are among the most significant and commendable feats of the country. Agriculture plays an important role in the economic growth of the country and this is primarily attributed to the climatic and ecological formation of the country. It is a landmark achievement as it helped the UAE to counter the harsh weather, scarcity of water and rainfall and turn the desert into a fertile soil that produces thousands of tons of fruit, vegetables and flowers for export around the world. The UAE economy continues to grow rapidly due to high oil prices and due to success of other sectors including manufacturing, real estate and tourism. Agriculture production stands at more than Dh2 billion per year. An

average crop season yields more than 600,000 t of crops such as tomatoes, cucumbers, aubergines, lettuce, cabbage and animal feed. At present, UAE exports its vegetable and fruit products to Japan, Indonesia, Malaysia and many other countries. Despite the climatic conditions, UAE's cultivated area now extends to more than 364 ha and the country is self-sufficient in dates, dairy products and fish (www.freshplaza.com/2005/10aug/2_uae_agriculture).

The promise of pigeonpea

Crop diversification is the key to sustainable agricultural productivity. In the UAE, where soils are nutrient-poor, only a limited number of crops can be grown successfully. Among the new crops tried on the ICBA farm over the past year, pigeonpea [*Cajanus cajan* (L.) Millsp.] was particularly promising. Pigeonpea holds great promise for crop diversification in the UAE. Its multiple uses as food, animal feed and fuel make it a truly high-value crop. Further studies are warranted, particularly to identify genotypes adapted to the local environment and to develop suitable agronomic and management practices for commercial production. Recently, ICBA acquired the minicore germplasm collection (a limited set of accessions chosen to represent most of the genetic diversity held in the global collection) consisting of 137 accessions from ICRISAT, India. These were sown in mid November and the crop was irrigated with drip system using fresh water of about 3 dS/m salinity. Compost was incorporated into soil before planting, and during crop growth a single dose of urea one month after planting and three split doses of NPK were applied by banding alongside the rows. Vegetative growth became luxuriant with the onset of warm weather. Considerable variation was also observed among the accessions for traits such as leaf shape, flowering pattern, and flower and seed color. This was not unexpected as the minicore collection represents the variation existing in the world collection of about 13,000 accessions conserved in the ICRISAT genebank (Rao and Shahid 2007).

Africa

Africa is a continent comprising 62 political territories (including 59 countries), representing the largest of the great southward projections from the main mass of Earth's surface (Figure 71). It includes an area of 30.4 M km², including the adjacent island. Africa is divided into 4 main parts: 1) Northern Africa - predominantly Muslim, Arabic with dry and arid/semi-arid climate conditions; mainly French speaking; 2) Western Africa - mixed Christian/Muslim population with higher level of precipitation on average than North Africa; 3) Eastern Africa - mixed Christian/Muslim population, very attractive for tourism (especially Kenya, Tanzania, Burundi and Mozambique); and 4) Southern Africa - majority of the population are Christian with the Republic of South Africa being the center of tourism. Separated from Europe by the Mediterranean Sea and from much of Asia by the Red Sea, Africa is joined to Asia at its northeast extremity by the 130 km wide Isthmus of Suez (which is transected by the Suez Canal). For geopolitical purposes, the Sinai Peninsula of Egypt – east of the Suez Canal – is often considered part of Africa. From the most northerly point, Ras ben Sakka in Tunisia, in 37°21' N, to the most southerly point, Cape Agulhas in South Africa, 34°51'15" S, is a distance approximately of 8,000 km; from Cape Verde, 17°33'22" W, the westernmost point, to Ras Hafun in Somalia, 51°27'52" E, the most easterly projection, is a distance approximately 7,400 km. The length of coast-line is 26,000 km and the absence of deep indentations of the shore is shown by the fact that Europe, which covers only 10,400,000 km², has a coastline of 32,000 km (en.wikipedia.org/wiki/Geography_of_Africa).

In sub-Saharan Africa (SSA), over 80% of the people derive their livelihood from small-scale agriculture. Predominantly, rainfed agriculture and farming systems depend largely on the broad ecological zones based on the disparity in the amounts of the rainfall. Crops and livestock production are both important parts of the farming system. Crop production takes place under extremely variable agro-ecological conditions, with annual rainfall ranging from 250 to 4,000 mm. Different farming systems have been identified based on climate, vegetation types and land use practices, and different cropping pattern have also been identified within these farming systems. Agricultural production has particularly stagnated or declined in important food crops such as cereals, tubers and legumes. Crop yields in most African countries are about the same as 20 years ago at around 1 t/ha (World Bank 1996).



Figure 71. Map of Africa.

Pigeonpea is no longer an exotic crop in eastern and southern Africa because it has been there too long. Reports indicate that it is grown in 37 African countries at altitudes ranging from sea level to 2,050 m. Pigeonpea is mainly produced by smallholder farmers together with maize, sorghum, cotton, finger millet and other legumes such as beans. In most parts of Africa, pigeonpea is grown as a multi-purpose grain legume, eaten as grain or as a vegetable (Kimani 2001). Pigeonpea in Africa is usually served as stew (www.gracefoods.com/site/gungopeas). But now the crop is becoming more important to farmers than ever before, and its importance is increasing every year, particularly because of the monetary benefits. Farmers are tired of being poor and many of them view pigeonpea cultivation as their best bet for prosperity (The Future Harvest Centers of the CGIAR, 2001).

Pigeonpea is an amazingly versatile crop where scientists and farmers keep finding new uses for it. The crop can simultaneously satisfy needs for food, feed and fuel. In the southern and eastern parts of Africa, where the importance of pigeonpea is growing rapidly, the crop plays a vital role in food security, balanced diet and poverty alleviation.

Pigeonpea is fast emerging as a cash crop and it is cultivated on over 400,000 ha across the semi-arid areas of eastern and southern Africa. It is essentially a smallholder crop, grown on poor soils in drought-prone areas (Monaco 2006). Pigeonpea is a source of income where surpluses are traded in both local and international markets, and export demand outstrips supply. Pigeonpea grains are mostly consumed whole in southern and eastern Africa. Kenya, Malawi, Mozambique and Tanzania export pigeonpea as whole grain (dried pods) to India. Kenya and Malawi have a well-developed processing industry and export dehulled split peas to the Far East, Europe and the Americas. The crop is an important staple food in northern Uganda and it is also grown in small quantities in Burundi, Sudan and Zaire with possibilities for extending its cultivation to Swaziland, Zambia and Zimbabwe. The crop is also grown in the drier belts of Senegal, Ghana, Togo and Nigeria.

Although pigeonpea breeding has been carried out in Eastern and Southern Africa for over two decades, its production has remained static. A major producer such as Malawi only manages an average yield of 450 kg/ha, which is less than 25% of the potential yield. Although ICRISAT in collaboration with various national programs have developed improved varieties, farmers continue to grow traditional landraces due to ineffective seed distribution

channels (Jones et al. 2001). A study on the adoption of a modern variety in Kenya indicated that the demand for seed is higher than supply, meaning the deficit could be met by the formal sector (Jones et al. 2000). However, there is little interest from seed companies to market pigeonpea seeds.

Pigeonpea is widely, but often informally, traded within Africa, for instance between Mozambique and Malawi and between Tanzania and Kenya. Regional trade flows are driven by both domestic and export market opportunities. In northern Tanzania most of the pigeonpea produced is sold in Kenya, where it is very popular among the Indian community (van der Maesen 2006). Given these limitations of the domestic market, export markets are the key outlets for pigeonpea commercialization in Africa. India is by far the most important market aside from Europe, the Americas and the Middle East (Monaco 2003).

Area

Between 1972 and 2003, pigeonpea recorded an increase in area by 66% from 0.26 M ha to 0.42 M ha with an increase in production by 96% from 0.13 MT to 0.26 MT. The leading producers in Africa are Kenya (164,000 ha), Uganda (113,000 ha), Malawi (110,000 ha), Tanzania (33,000 ha) and Mozambique (Kimani 2001). In 2005, pigeonpea in Africa is cultivated in an area of 485,520 ha (Table 25), which is second to Asia, doubling the area cultivated in the 70s and 80s. Production of this crop in Kenya, Malawi, Tanzania and Uganda shot up 46% between 1980 and 1997 with an average annual growth rate of 3% (mainly due to expansion in the area). But according to Kay (1979), the reported figures for area cultivated and production could be low by a factor of two to three times, because the crop is grown extensively in village compounds and kitchen gardens. The crop is essentially for small-scale farmers, grown in poor soils in drought prone areas where its ability to tolerate dry spells and harsh conditions is a key factor in household food security. Traditional varieties are generally intercropped with food crops such as maize, sorghum, cowpeas, beans and non-food crops such as cotton (Monaco 2006).

Table 25. Area (ha) of pigeonpea in Africa (1961-2005).

Country	Area (ha)					
	1961	1965	1970	1975	1980	1985
Burundi	2,371	2,371	3,878	5,665	2,524	2,577
Comoros	-	-	-	-	-	352
Congo	4,960	4,960	5,565	9,360	3,423	6,400
Kenya	-	-	-	-	-	95,272
Malawi	82,540	111,111	118,044	182,266	113,823	114,286
Tanzania	14,493	9,425	28,340	39,409	35,570	72,464
Uganda	15,315	18,018	67,453	62,808	54,370	25,225
Total	119,679	145,885	223,280	299,508	209,710	220,952

FAOStat 2008.

Table 26. Pigeonpea production (t) in Africa (1961-2005).

Country	Production (t)					
	1961	1965	1970	1975	1980	1985
Burundi	2,300	2,300	2,300	2,630	2,500	2,400
Comoros	-	-	-	-	-	250
Congo	3,100	3,100	3,300	3,800	4,000	4,000
Kenya	-	-	-	-	-	81,000
Malawi	52,000	70,000	70,000	74,000	76,000	72,000
Tanzania	10,000	6,503	16,806	16,000	22,000	50,000
Uganda	17,000	20,000	40,000	25,500	26,000	28,000
Total	84,400	101,903	132,406	121,600	130,430	156,500

FAOStat 2008.

Production

Since the 60s, pigeonpea production has expanded across the country (Table 26 and Appendix 3). The increase started during the 80s but hurdled in 2000-2005. According to Monaco (2006), the production of pigeonpea in Africa in 1980 till 2001 was dominated by Malawi as the largest producer in the region with more or less 80,000 t annually. Since then, from 2002 until 2006 (Appendix 3), Kenya occupied the position as the major producer of this crop in the region with an annual production of 105,000 t as compared to Malawi's stagnated production of 79,000 t. Other important producers are Burundi, Congo, Tanzania and Uganda. Although the production in Mozambique is barely mentioned in official statistics such as the FAO, the cultivation of this crop is widespread across its northern territory, with production unofficially estimated at around 40,000 t (Technoserve 1998a). Pigeonpea is an important export crop of Kenya, Tanzania, Malawi, Uganda and Mozambique (www.icrisat.org/PigeonPea/PigeonPea).

As mentioned by Joshi et al. (2001), production of pigeonpea was highest in Tanzania (2.6%) and Uganda (6.1%) per year mainly due to the combination of yield gains and expansion of planted area. But this was not the case in a report by FAO in 2008 where Kenya was the dominant country in terms of production at 65,604 t (23.71%) in 2000 and an increase in production of 105,000 t (32.33%) in 2006 as gleaned in Table 25 compared with Tanzania and Uganda where they have a decreasing trend.

Taking into account the major producing countries in Africa for area cultivated and production of pigeonpea (not to include the minor producing countries), Kenya registered as the highest producer with 41.20% (area) and 32.29% (production) in 2006 followed by Malawi, Uganda, and Tanzania. The least producer during the period 2000-2006 cropping season was Comoros (Table 27).

Table 27. Percent of area cultivated (ha) and production (t) in Africa (2000-2006).

Africa	Area cultivated and Production (%)						2005			2006		
	Area	Prod.	2000	2001	2002	2003	Area	Prod.	Area	Prod.	Area	Prod.
Burundi	0.38	00.65	00.44	00.63	00.44	00.58	00.38	00.57	00.42	00.55	00.41	00.55
Comoros	00.09	00.10	00.10	00.10	00.09	00.10	00.09	00.10	00.09	00.10	00.09	00.10
Congo	01.84	01.91	02.11	01.88	01.72	01.62	01.74	01.58	01.66	01.54	01.65	01.54
Kenya	41.34	23.68	34.09	25.60	37.91	30.13	39.72	30.96	41.43	32.51	41.20	32.29
Malawi	27.10	28.52	30.25	27.53	27.02	25.54	26.11	24.89	25.35	24.33	25.34	24.30
Tanzania	14.60	16.97	16.28	16.38	14.81	15.52	14.14	15.44	13.74	15.10	14.01	15.38
Uganda	14.64	28.16	16.73	27.88	18.01	26.51	17.82	26.46	17.31	25.87	17.30	25.84

FAOStat 2008.

Table 28. Pigeonpea productivity (kg/ha) in Africa (1961-2005).

Country	Productivity (kg/ha)					
	1961	1965	1970	1975	1980	1985
Burundi	970	970	593	406	1042	970
Comoros	-	-	-	-	-	710
Congo	625	625	593	406	1110	625
Kenya	-	-	-	-	-	850
Malawi	630	630	593	406	668	630
Tanzania	690	690	593	406	618	690
Uganda	1110	1110	593	406	478	1110
Total	805	805	593	406	783.20	805

FAOStat, 2008

Productivity

Low productivity is a major hindrance to improved trade prospects. Since 1980s, the average yield across the region stagnated at around 600 kg/ha. Under smallholder management, yields of local pigeonpea varieties have been found to be significantly lower at 350 kg/ha than the regional average of usable seed weight and inconsistent across areas and seasons (Ritchie et al. 2000). Grain yield on farmers' fields in Eastern Africa average 450-670 kg/ha, compared to 2.6-4.3 t/ha reported from research trials in Kenya (Rubaihayo and Onim 1975, Onim 1984). However, in 2005 and 2006 cropping season, the average mean yield of pigeonpea in the region has stagnated to 736.28 kg/ha as shown in (Table 28 and Appendix 4) (FAOStat Data, April 2008). Pigeonpea has not achieved its productivity potential largely due to limited use of appropriate inputs and crop management practices (Smith et al. 2001) and also the lack of efficient seed system, which hampers adoption of new, higher-yielding varieties (Jones et al. 2000). A number of biotic and abiotic constraints contribute to this gap between potential and actual yields (Kimani 2001).

Data Inconsistencies

The FAO database reports for 2006 (FAOStat 2008) and 2002 (as cited by ICRISAT for pigeonpea grown in Eastern and Southern African region) have inconsistencies in the figures gathered for area, production and productivity. Except the yield records of Malawi, Tanzania and Uganda for 1980–1982 season, production records of Burundi, Malawi, Tanzania and Uganda for 1980–1982 and 1990–1992 seasons and Burundi during the 2000-2002 cropping season, as shown in Appendix 4 and 5.

African Cropping Systems

Pigeonpea in Africa is usually grown in mixed stands with other crops, the most frequent companion crops are maize, sorghum and cassava. Results show that individual farmers grow an average of six to seven different companion crops, with a range of one to 15 crops. Only 25% of the fields were planted to a single crop. Rice, yam and cassava were the crops grown often as sole crops (IITA 1997). This was collaborated with the FAO findings wherein pigeonpea is intercropped with sesame or *Eleusine coracana* (Uganda), with maize (Malawi) or rotated with maize-groundnut-tobacco-

pigeonpea in Uganda and Mauritius. Likewise, pigeonpea performs well as an intercrop with 2 rows of cereals (millet, sorghum), cotton or groundnut. After the intercrop is harvested, pigeonpea continues to grow, produce, and protect the soil (www.fao.org/WAICENT/FAOINFO/AGRICULT/AGP/AGPC/doc).

In East Africa, long duration pigeonpea is sown with cereals or short duration grain legumes such as cowpea. After the grain crop is harvested, pigeonpea grows to its full height and pods are used as a green vegetable or pulse. In the following year, pigeonpea is either ratooned and the cereals are planted, or it is allowed to dominate the field for pod production. In the second year, cereals are rarely planted among un-ratooned pigeonpea because it is too competitive. Animals are not allowed to graze fields after cereals because they easily browse the pigeonpea (Omanga and Matala 1987).

Pigeonpea Limitations and Market Potentials

African farmers have not been able to fully exploit the potential of pigeonpea over time due to the following reasons: a) local varieties are low yielding and susceptible to pests and diseases; b) most of the available varieties are small seeded and do not meet market requirements; c) market linkages for dryland farmers are largely underdeveloped; and d) available market and farmer-preferred varieties do not reach farmers due to poor input and technology delivery systems. These factors have made African smallholder farms difficult to benefit from the large export market. India alone imports an average of 1.5 to 2 Mt of pigeonpea per year, but Africa supplies only less than 5% of this requirement. Likewise, there are similar high value niche markets for exporting to European and American markets. However, the domestic demand for pigeonpea has been growing substantially over the last few years (ICRISAT 2009a).

The Role of ICRISAT

ICRISAT and partner institutions (private and public sector) have been working to develop suitable varieties and institutional innovations to help African dryland farmers benefit from the pigeonpea. This began with the development of large seeded, cream colored and fusarium wilt resistant varieties to address limitation in output marketing and utilization. This has catalyzed a process of livelihood transformation for many dryland farmers in Kenya, Malawi, Mozambique, Tanzania and Uganda. In Tanzania, ICRISAT

has a long and fruitful collaboration with the Ilonga Research Station in Kilosa and the Selian Agricultural Research Institute (SARI) in Arusha for breeding to cover the Northern Zone. Improved varieties like ICEAP 00040 and ICEAP 00053 have increased adoption in the Babati District to the level of 60% in which pigeonpea alone contributes more than 50% of cash income for smallholder farmers. Realizing the huge demand for improved seeds, the agrovets (local agro-dealers) sign up with trained farmers to grow high quality seeds. The produce is marketed through producer marketing groups (PMGs) that allow smallholders to benefit from collective action. It is noticeable that ICRISAT-developed varieties dominate the fields and have huge impacts on the livelihood of smallholders farmers (ICRISAT Brochure 2009a).

In Kenya, the ICRISAT-led consortium awakened the pigeonpea revolution, which brought together parties like Technoserve, Catholic Relief Services (CRS), Kenya Agricultural Research Institute (KARI) and private sector processors and exporters. Successive projects for legume commercialization stimulated local seed production and agro-dealer networks for distribution and marketing. The PMGs facilitated community seed production, local distribution and market access, and managed to increase local produce prices by 20-25% in Nairobi and Mombassa after linking to wholesaler the main revolution came about through introduction of medium-duration varieties (ICEAP 00040 and 00053) that give two crops a year. The improved varieties reached Emali village (Makueni District, Kenya) in 2003 through field days held at ICRISAT/KARI research station in Kiboko. Farmers have also realized the potential of fresh vegetable in the domestic market at prices almost twice that of the dry grain aside from the crop as a buffer when food reserves are very low to stave off hunger (ICRISAT Brochure 2009a).

Major Pigeonpea Producing Countries in Africa

Burundi

Geography

Burundi, as a landlocked country, is located in central Africa, to the east of the Democratic Republic of Congo with coordinates of 4°10' S to 2°17' S latitude and 29°00' E to 30°05' E longitude, and occupies an area equal to 27,830 km² in size, of which 25,650 km² is land (Figure 71). Eighty percent of the country's total area of 28,000 km² consists of an undulating plateau

situated between 1,600 m and 2,000 masl. Burundi has an equatorial climate, and is sited on a high plateau with considerable altitude variation, from 772 m to 2,670 m. The average annual temperature varies with altitude, from 23°C to 17°C, although it is generally moderate as the average altitude is approximately 1,700 m. The climate is of a temperate tropical type with two rainy seasons. The average annual rainfall is about 1,500 mm, with wet seasons from February to May, and from September to November. Dry seasons are from June to August, and December to January (www.wikipedia/burundi.com).

Agriculture

Agriculture is the mainstay economy of Burundi and accounted for 58% of the GDP in 1997. Burundi is overwhelmingly rural and agriculture supports more than 90% of the labor force, the majority of who are subsistence farmers. In the 1970s and 1980s, agriculture was already in decline, and the situation worsened with the start of the 1993 conflict. Although Burundi is potentially self-sufficient in food production, the ongoing civil war, overpopulation and soil erosion have contributed to the contraction of the subsistence economy by 25% in recent years (en.wikipedia.org/wiki/Economy_of_Burundi).

Burundi is a net food importer, with food accounting for 17% of imports in 1997. Beans are the staple food and the main cash crop of Burundi is coffee, which accounted for 78.5% of exports in 1997. Coffee is the largest state-owned enterprise and the dependency on coffee has increased. Other principal exports include tea and raw cotton while banana is the largest market in Africa. Although food production is the dominant activity, coffee and tea are the nation's biggest earners. They accounted for 8% of agricultural production but for no less than 90% of export earnings before the civil war started. The collapse of the international coffee and tea markets in the 1990s has added a heavy burden to the economy. These external factors were compounded by the destruction by armed rebels of about/half of the country's coffee washing stations, the destruction of one tea factory and serious damage to other factories. Violence also affected other agro-industrial facilities in the cotton, palm oil and sugar sub-sectors (www.ruralpovertyportal.org/english/regions/africa/bdi/geography). Common cropping practices are primarily based on crop associations, most frequently beans, sorghum, cassava, millet and maize. Almost without exception, farms also include livestock, mainly small animals.

Pigeonpea Area, Production and Yield

In Burundi, pigeonpea is a traditional crop grown extensively in the rural areas with little or no improved cropping techniques. However, little attention is given to this crop by any agricultural project or research institute. Statistical data are difficult to calculate due to mixed cropping practices (Godderis 1992). Burundi's production and area cultivated with pigeonpea is the second least among the major producing countries in Africa. The crop is grown in small quantities integrated with sorghum, millet, maize and cassava or planted as live fences along borders of farms and homestead. Based on statistics derived from FAOStat (2008), in 2000 season, the area cultivated was registered only at 1,729 ha with annual production of 1,800 t with an average yield of 1,041 kg/ha for green pods, the second highest among the major producing countries in the region (Tables 25, 26, 27). While in 2006, area cultivated increased to 2,000 ha with annual production of 1,800 t (Appendix 2, 3). Average mean yield has substantially decreased to 900 kg/ha (Appendix 4). Production was observed stagnant from year 2000 to 2006 at 1,800 t (Appendix 3).

Pigeonpea is grown on a small subsistence scale throughout the country. The bulk of pigeonpea is grown in the semi-arid regions of Bugesera, Kumoso and Buragane near the Tanzania border. Rarely grown as a sole crop, pigeonpea is most often cultivated as an intercrop with sweet potato, cowpea and cocoa yam or as mixed crop with sorghum and maize or with crops such as bananas and beans. Most farmers grow this crop as an annual crop and they occasionally prefer ratooning. Farmers grow either of the two long-duration type of cultivars, namely *Isega* and *Itenda*. The said varieties mature in 8-11 months, are tall and indeterminate. Sowing starts at the onset of monsoon (September to November) with little or no fertilizer applied. Farm plots vary from 0.25 to 0.35 ha with average yield range of 300 to 700 kg/ha. Major losses are cause by insect pests and diseases. Harvesting takes place when the pods reach maturity between July and September (Godderis 1992). Most varieties grown by farmers were introduced (source unknown), with Burundi farmers adopting them where they proved adaptable. Farmers distinguish two maturity groups: long and short duration (Kimani 2001).

Research activity

Most varieties grown by farmers were introduced and distinguished two maturity groups, the long and short duration (Kimani 2001). The

pigeonpea improvement program started with germplasm introduction from ICRISAT and neighboring countries. Pure lines such as NPP610, RK101, TRT201 were identified for cultivation (Onim 1981). However, no genetic improvement work on this crop has been done in recent years (Ntukamazina and Nzimenya 1987). The Institut des sciences agronomiques du Burundi (ISABU) in collaboration with ICRISAT started the first varietal trials on pigeonpea in 1990/91. Due to financial constraint, research is maintained only at an inappropriately low level. Four short-duration varieties (ICPL 87B, ICPL 87W, ICPL 87102 and ICPL 151) were compared with one medium-duration variety (ICPL 87051). ICPL 87W (1002 kg/ha) and ICPL 87B (969 kg/ha) yielded the most (Baert 1992).

Utilization and Marketing

Pigeonpea in Burundi is mainly grown for local consumption and sold only in small quantities measured in cups. The farmers love the taste of its dry, cooked seeds and do not need much cooking time, which they prefer to that of phaseolus bean. In 1992, a cup of pigeonpea seeds cost 0.10-0.25 USD and during off-season it fetches upto 0.30 USD (Godderis 1992).

Comoros

Geography

The Comoros officially the Union of the Comoros is an island nation in the Indian Ocean, located off the eastern coast of Africa with coordinates of 11°54' S to 11°23' S latitude and 43°6' E to 43°43' E longitude on the northern end of the Mozambique Channel between northern Madagascar and northeastern Mozambique. The nearest countries to the Comoros are Mozambique, Tanzania, Madagascar and the Seychelles (Figure 71). At 2,235 km², the Comoros is the third smallest African nation by area (en.wikipedia.org/wiki/Comoros).

The Comoros is formed by Ngazidja (Grande Comore), Mwali (Mohéli), Nzwani (Anjouan), and Mahoré (Mayotte), the major islands in the Comoros Archipelago, as well as many minor islets. The interiors of the islands vary from steep mountains to low hills. The climate is generally tropical and mild, and the two major seasons are distinguishable by their relative raininess. The climate is marine tropical, with two seasons: hot and humid from November

to April, the result of the northeastern monsoon, and a cooler, drier season the rest of the year. Average monthly temperatures range from 23°C to 28°C along the coasts. Although the average annual precipitation is 2,000 mm, water is a scarce commodity in many parts of Comoros (Ottenheimer and Ottenheimer 1994).

Agriculture

Comoros is one of the poorest countries in the world. Economic growth and poverty reduction are major priorities for the government. With a rate of 14.3%, unemployment is considered very high. Agriculture, including fishing, hunting and forestry, is the leading sector of the economy. High population densities, as much as 1000 km² in the densest agricultural zones, for what is still a mostly rural, agricultural economy may lead to an environmental crisis in the near future, especially considering the high rate of population growth. The Comoros' real GDP growth was a low 1.9% in 2004 and real GDP per capita was continuing to decline annually in 2004. These declines are explained by factors including declining investment, drops in consumption, rising inflation, and an increase in trade imbalance due in part to lowered cash crop prices, especially vanilla (Ministry of Planning and Regional Development 2005).

Agriculture, involving more than 80% of the population and 40% of the gross domestic product, provides virtually all foreign exchange earnings. Plantations engage a large proportion of the population in producing the islands' major cash crops for export: vanilla, cloves, perfume essences and copra. Comoros is the world's leading producer of essence of ylang-ylang, used in manufacturing perfume. It is also the world's second-largest producer of vanilla, after Madagascar. Principal food crops are coconut, bananas and cassava. Foodstuffs constitute 32% of total imports. The country is not self-sufficient in food production; rice, the main staple, accounts for the bulk of imports.

Pigeonpea Area, Production and Yield

Although considered as a major producing country by the FAOStat (2008), pigeonpea in Comoros is grown as a mixed crop in small plots, around homesteads and bordering the farms, and serve as live fences to almost all households. In 1991, IFAD launched a project called the Nioumakéle Small Producers Support Project, which enabled small farmers to organize

themselves around intensive development sites, then introduced the system of contouring to combat erosion, encouraged mixed cropping and promoted the use of improved plant varieties. Apart from introducing live fencing by planting pigeonpea, the project also organized milk producers, thus making it easier for Agence Française de Développement to launch a local milk processing plant in 2002. In this region, populated essentially by poor farmers, the results of the live fence technique have been spectacular. In 20 years, the landscape of the poorest region in the archipelago has been transformed. According to Mariame Anthony, an agricultural expert and head of the region's agricultural training centre, before the implementation of the project, "the land was very severely degraded," and "erosion was very pronounced and productivity was low" (IFAD 2007).

Like most of the farmers in the region, Yssouf Mdigo and his wife Kurashia Budube own several plots, widely scattered and each no larger than 0.4 hectares. They are all enclosed with hedges, like those of their neighbors, and they have one cow, which meets their fertilizer needs. "Before we adopted the live fence and tethered cow technique, we grew nothing but upland rice. Today we have cassava, sweet potato, taro, banana and pigeonpea. In good harvest years, we have even been able to sell some," says Yssouf Mdigo. The Mdigo family also sells fodder and milk. However, apart from a clear improvement in land productivity and in income, which made the installation of live fences such a success, the technique also had an unexpected effect on the division of farm labor between men and women. "When we grew rice, only the woman could work the land," says Yssouf Mdigo – for rice-growing is an occupation exclusively reserved for women. "Since we changed crops with the introduction of live fences, the man can work without embarrassment." He thus works to clear undergrowth, install contouring and help his wife with the heaviest tasks (IFAD 2007).

Based on FAOStat (2008), Comoros carved its name as one of the major producing countries of pigeonpea in Africa in 1990. Although the country is the smallest among the major producing countries in Africa, the area cultivated to this crop is slowly increasing from 352 ha in 1990 to 440 ha in the 2006 cropping season (Appendix 2). The production obtained from the 2006 season was recorded at 320 t with an average productivity of 727 kg/ha (Appendix 3, 4).

Republic of the Congo (Congo-Brazaville)

Geography

Congo, lying astride the equator with coordinates of 5°12' S to 3°36' N latitude and 10°59' E to 17°45' E longitude, is located in West Central Africa. It is bounded by Gabon to the west, Cameroon to the northwest, Central African Republic to the north, Democratic Republic of the Congo (Zaire) to the south and east as well as Angola and the Atlantic Ocean to the southwest (Figure 71). Dense grasslands, mangroves and forests cover much of Congo. Major cities are Brazzaville, Pointe-Noire, Loubomo and Nkayi. Land uses compose the following: forested 62%, pastures 29%, agricultural-cultivated 1%, and others 8% (www.atlapedia.com/online/countries/congo). The Congo has a tropical climate characterized by high temperatures with humidity around 80% and little seasonal variation. The wet season is between April and late October while the dry season is from November to March. Violent winds and squalls are also common in the wet season. Average annual precipitation varies from 1,250 to 1,750 mm while it is heaviest in the north and decreases towards the Atlantic Coast in the south. Average temperature ranges in Brazzaville are from 17 to 28°C (63 to 82°F) in July to 23 to 33°C (72 to 91°F) in April (www.atlapedia.com/online/countries/congo).

Agriculture

Domestic agriculture is the main source of food supply and cash income for the majority of the population. Although the country is rich in agricultural potential, the deterioration of the agricultural services since independence has led to a re-growth of subsistence agriculture and a collapse of market production. Foodstuffs such as cereals and fish are imported in increasing amounts. Coffee is the chief agricultural export; palm oil, rubber and cotton, once mainstays of the export economy, have become almost negligible (www.britannica.com/eb/article-40800/Congo).

In the humid equatorial region, cassava (manioc) and rice are the basic food crops. Peanuts (groundnuts), oil palms and fruit trees are also important, while robusta coffee is the main cash crop. In the eastern highlands, yams, beans and sweet potatoes are used as food crops, while arabica coffee and tea are export commodities. Vegetable growing is widespread throughout

Congo whereas on the southern plateaus, corn (maize) is of major importance for the urban populations.

Pigeonpea Area, Production and Yield

Pigeonpea is cultivated in small quantities as subsistence crop to smallholder farmers. The crop is planted as backyard garden or as fences on homestead, along rice bunds and intercropped with coffee, maize or cassava. As documented by FAOStat (2008), Congo was third as the least major producer of pigeonpea in the region. It was found that 1.91% or 5,296 t was produced in 2000 in an area of 8,340 ha or 1.84% (Tables 24, 25, 26), respectively, while in 2006, area of cultivation and production slightly decreased to 8,000 ha and 5,000 t, respectively. The average annual mean yield was at 625 kg/ha in 2006. Furthermore, from 2000–2006, the average annual mean yield was documented not below 600 kg/ha (Appendix 2, 3, and 4).

Kenya

Geography

Kenya is still the primary focus of all adventure travel in Africa. It is one of the finest and undoubtedly the most famous safari destination in the world. Located on the east coast of Africa, Kenya with an area of 582,646 km², is situated astride the equator with coordinates of 4°39' S to 4°49' N latitude and 33°50' E to 41°55' E longitude, transect from north to south by the Great Rift Valley (Figure 71). While much of northeastern Kenya is a flat, bush-covered plain, the remainder of the country encompasses pristine beaches and the magnificent Mount Kenya. Mount Kenya, with its snow-capped summit, lies on the equator (en.wikipedia.org/wiki/Geography_of_Kenya).

Eighty percent of Kenya's total land area, which is characterized by low and unreliable rainfall, is under the arid and semi-arid lands (ASALs). The ASALs are spread over the seven provinces, covering 33 districts with over 20% of the total human population, 50% of livestock herds and 5% of agriculture output (Government of Kenya 2002). All 13 districts in eastern Kenya are ASALs and are categorized as agro-ecological zones 3 to 7 based on the classification of Braun (1982).

Although Kenya's varied environments experience a wide variety of climate conditions, the temperature remains comfortably warm year-round. The northern three-fifths of the land is arid, semi-desert to desert. The south is temperate, dominated by a high, mountainous central plateau, which levels out to a series of highlands and plains to the east and west. Much of Kenya experiences heavy rainfall from March through May and, to a lesser extent, from October through December.

Agriculture

The arid and semi-arid areas cover 82% of Kenya's land area and have a mean annual rainfall ranging from 200 to 800 mm and moisture index of (-)30 to (-)57. Over 95% of the production of this crop is in the semi-arid districts of Eastern province of Kenya. These areas experience frequent food shortages and famine relief food is supplied to deal with the food insecurity almost every year (Olubayo et al. 2002). Farmers have traditionally relied on food staples such as sorghum, and in drier parts, pearl millet, generally grown in mixed stands with a range of legumes, including beans, cowpea, green gram and pigeonpea. These crops are used both for consumption and sold for cash in local markets. The farming systems are relatively complex because of the high rainfall variability typical of the semi-arid tropics (Nagarajan and Smale 2007).

The livelihood of the inhabitants of Kenya is mainly small-scale subsistence-based agriculture. Crops and livestock production are both important parts of the farming system and form the main sources of food and income of over 90% of the population. Farm size varies between 2 and 7 ha per household, the size increasing as one moves to drier zones. The cropped family land ranges from 30% to 50%, again depending on the zones, leaving the rest of the land for livestock grazing. In the subsistence agriculture common in the ASALs, farmers produce a broad range of crops and varieties to meet their basic needs and avoid total crop failure (that may result from the many existing abiotic and biotic stresses). Major crops grown include cereals (maize, sorghum and millet) and grain legumes (beans, pigeonpea, cowpea and green gram). Cotton, cassava, sweet potatoes, sunflower, *Dolichos lablab*, castor, gourds and chickpeas are also grown as part of the common mixed farming system. The major cause of low agricultural productivity in the country is drought that accounts for low and poor distribution of rainfall (Omanga and Rissiter 2003).

The evolution of pigeonpea

In Kenya, pigeonpea research started at the University of Nairobi in 1975 and the National Dryland Farming Centre, Katumani in 1979. The breeding activities were centered on collection, evaluation and selection from pigeonpea germplasm. The first early variety released in Kenya was NPP670 and was developed through hybridization (Onim 1981). Scientists in Kenya also initiated some research on population improvement by using partially out-crossing nature of the crop with moderate success.

During the last 20 years, improved long (9 months), medium (6 months) and short (4 months) duration pigeonpea cultivars were developed and released in Kenya by University of Nairobi (UoN), Kenyan Agricultural Research Institute (KARI) and International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) (Kimani 1991). Although these varieties showed high potential under research environment, their performances under farmer conditions are poorly documented.

In eastern Kenya, about 20% of the farmers have adopted new pigeonpea varieties (Saxena 2008a). Most of the farmers plant traditional varieties that take up to 11 months to mature, while improved varieties are less common. These late maturing genotypes produce rather low yields (between 300 to 500 kg/ha) and are generally intercropped with cereals (maize, sorghum, millet) and other food legumes (bean and cowpea) (Omanga et al. 1996). Farmers have also started adopting new medium maturing pigeonpea varieties like ICEAP 00554 and 00557 both for grain as well as green vegetable purposes. About 77% of farmers in Makueni and 31% in Mbeere plant at least one improved cultivar. In Thavu and Karaba, about 31% and 57% grow simultaneously traditional and improved early maturing pigeonpea varieties, respectively (Mergeai et al. 2001).

Pigeonpea Cropping System, Area, Production and Yield

Pigeonpea in Kenya is a perennial shrub that is commonly grown as an annual crop in an elevation as high as 600 masl. It has very slow initial development (up to 2 months after planting). With a deep taproot, the pigeonpeas are able to take up nutrients and water from lower subsoil layers. Therefore, in crop mixes, they hardly compete with the companion crops. This crop grows and yields well under conditions of low rainfall and poor soil (Mergeai et al. 2001).

Pigeonpea is important in the local farming systems and as a secondary crop, is intercropped or strip cropped with cereal crops (generally maize) and other crops such as beans, cowpeas, cassava, green grams and 'dolichos' beans (Mergeai et al. 2001, Mwang'ombe et al. 1998). Pigeonpea is produced as a vegetable and an important export grain crop in Kenya. The crop is the third most widely grown pulse legume, which is planted by almost every farmer in the country, and it is one of the fastest growing cash crops with an annual growth rate of 3% in the last decade. In terms of land allocation and yield, the main crop is mostly intercropped with the other crops and pigeonpea constitutes the second most important crop in terms of land allocation. However, in Thavu region, pigeonpea is the main cash crop, followed by cotton, bean, cowpea, green gram and sorghum. In Karaba, green gram is the most important cash crop, followed by pigeonpea and dolichos lablab (Mergeai et al. 2001).

In the dry Ukambani plains of Kenya, the varieties cultivated took one year to reach maturity. These varieties are sown during the short rains from November to December. The crop grows slowly through the short, but intensely hot season from January to March, reaching maturity during the long rains from March to June. Pigeonpea flower during the long rains and are harvested in July or August. Due to the uncertainty of rainfall in arid and semi-arid Africa, these varieties do not reach proper maturity, and so do not give good yields when rains in one of the seasons is inadequate (Khalil-Timamy 2002).

In some cases, pigeonpea is grown as a trap crop. In Ngethu, Thika, Kenya, the Ngethu farmers intercrop pigeonpea with passion fruit. This system distracts insects from invading the passion, especially during the flowering stage (New Agriculturist On-Line 2006). There is also the potential of using pigeonpea in the control of *Striga* (*Striga* spp.) weed, which is a major problem in Africa. Rotation with pigeonpea in *Striga* infested soils of western Kenya showed pigeonpea as one of the most productive crops with a remarkable decrease of *Striga* populations in maize planted after pigeonpea (Oswald and Ransom 2001).

Intercropping pigeonpea with sorghum and maize are the most common intercrops combination. After harvest of the main crop, long-duration pigeonpea continues to grow and protects the soil. However, due to its high demand, there is a tendency to move away from traditional intercropping to

monocropping just like in Ukambani and the coastal strip of Kenya where the crop is grown commercially in large plots (Snapp et al. 2003). As revealed by Mergeai et al. (2001), in Makueni, local pigeonpea varieties are mainly planted in strip-cropping or in mixed intercropping with cereals and other legumes. In Mbeere district, where the area grown with pigeonpea is lower, traditional varieties are predominantly planted in pure-stand (54%). Likewise, main cropping system for improved pigeonpea varieties is planted as pure stand (monocrop) in Karaba (63%) while the proportion of monocrop (46%) and intercrop (54%) fields is more balanced in Thavu. Ratoon cropping is mostly practiced in pigeonpea producing areas in Kenya. After harvest the stems are cut back to facilitate re-growth and a second crop is harvested in the subsequent season.

With more than 150,000 ha under cultivation, mostly located in the dry regions of the Eastern part of the country, Kenya is the main producer of pigeonpea in East-Africa and the second highest producer in the world, after India (Johansen et al. 1993). However, according to FAOStat (2008), in 1993, the area cultivated with this crop was officially recorded at 77,593 ha. In spite of the discrepancies in figures in the two literatures, even to date, there has been no actual measurement of the land used by pigeonpea because crops planted mostly by small-scale farmers in kitchen gardens (backyard), as fences on homesteads or as field boundaries are not recorded.

Moreover, as shown in Table 25, cultivated area of this crop soared to 187,440 ha in 2000 season and reached its peak at 200,000 ha in 2006 (Appendix 2) or 41.23% of total area cultivated among the major producing countries in Africa (FAOStat 2008). The annual production of pigeonpea was recorded highest in 2004-2006 at an average of 105,000 t or 32% of total production in Africa (Appendix 3). The average mean yield is 525 kg/ha (Appendix 4). Yields calculated from farmer and on average pigeonpea producing plots are rather low (200 to 500 kg/ha). The low grain yield was partly because a significant part of the production is consumed before pod maturity, and very high losses due to pest incidence. On an average, about 25% of the whole pigeonpea production was harvested before pod maturity. Almost/half of the farmers do not produce enough pigeonpea dry grain to cover the needs of their family (Mergeai et al. 2001).

Consumption and Marketing

In Kenya, pigeonpea is one of the fastest growing cash crops with an annual growth rate of 3% over the last 15 years (Freeman et al. 1999). Pigeonpea is an important food legume, cultivated commercially for dry seed and as a green vegetable. In a study conducted by Mergeai et al. (2001), most pigeonpea producers in Kenya sell only a portion of their harvest, about 25% of the local production is consumed as green pods, 15% is eaten as dry grain and the rest (about 60%) is sold. They usually eat a part of the production as green pod and sell the dry grain surplus. Green pods of early maturing varieties are available in April–July while long duration local cultivars produce green pods in August–September. The main outlets for pigeonpea green pods are local markets, shopkeepers and neighbors. Nairobi market is the center for trading. For local markets, brokers from Nairobi buy regularly the green pods and dry pigeonpea grains. An expanding world market is providing this opportunity wherein the whole grain and processed grain is exported to the Indian diaspora, and vegetable products to Europe, Asia, and the Caribbean (Jones et al. 2002, Snapp et al. 2003), while the dry grain is also an important export commodity in several African countries like Malawi, Mozambique, Tanzania and Uganda (Minja et al. 1999). However, in a report by FAOStat (2008), there was no reported export trading that occurred during the 60s to mid 20s.

Pigeonpea Seed System

Formal sector breeders, from the private and public, remain relatively insignificant. In the Machakos area of Kenya, commercial seed accounts for less than 2% of the cowpea and pigeonpea seed used by the average farmer, neighbors and local markets supply over 17% and the rest is saved by the farmer (Gordon 2000). Most of these seed breeders are women, and they produce 70% of the food for use in the region. They carefully select those seeds that respond to various soil types and growing conditions and that carry particular traits such as stability, disease resistance, drought tolerance, palatability and storage quality (FAO 1995b).

Uses

As a multiple purpose drought-tolerant crop, it provides many benefits to resource-poor families: protein-rich grain, fuel, fodder, fencing material, improved soil fertility and control of soil erosion (Siambi et al. 1992).

Pigeonpea is well balanced nutritionally and an excellent source of protein. It is eaten as a vegetable (immature pods or green pea) or as dried grain (cooked and eaten as *dal*, dry split cotyledons). Green pods are picked over a long period in home gardens or hedge crops. Processing includes *dal* making, either wet (after sprinkling heaps of seed) or dry, by milling. The crop has many other uses: the wood is used as fuel, and the leaves and husks provide livestock feed.

Pigeonpea is useful as tall hedges on dry soil and on the bunds of paddy fields. In some areas where poor soil or loss soil is prevalent, pigeonpea are planted as hedgerows as contour bunds to serve as soil erosion buffer and at the same time as source of fodder/forage for livestock (Annen 2001). The branches and stems can be used for baskets and firewood. It is often grown as a shade crop, cover crop or windbreak. After establishment, pigeonpea improves the soil by its extensive root system. The bacterium *Rhizobium* that lives on the roots of the pigeonpea is able to fix nitrogen and thus to improve soil fertility. Fallen leaves are used as mulch. Traditional uses as medicine are many, eg, young leaves are applied to sores, herpes and itches.

In a report by CGIAR News in 1999, an estimated 30% of children under age 5 in sub-Saharan Africa are underweight, mainly due to a deficiency of energy and nutrients. A women's organization locally known as the 'Ivuso ya Manyatta' that was started in Kenya has proven to be a very effective vehicle for introducing improved crop technologies into poor communities by playing a key role in raising public awareness in the drought-prone Makindu district, and has successfully promoted improved varieties of pigeonpea for fighting malnutrition.

Armed with this new knowledge, Ivusos first aim was to improve nutrition by increasing pigeonpea consumption among the local communities. The women baked and sold cakes and biscuits containing a high proportion of pigeonpea, sorghum and millet flour instead of the conventional wheat. Malnourished children have benefited from eating pigeonpeas as they contain more minerals and 10 times more fat than ordinary peas, as well as five times more vitamin A and three times more vitamin C. The peas are 28% cheaper than meat and an equally good source of protein, making them an ideal supplement to traditional cereal- or tuber-based diets. Diana Nzomo, the association founder was justifiably proud when she claimed, 'we have improved the quality of food eaten here'. So striking are their achievements

that several similar associations have sprouted up in the district (www.worldbank.org/html/cgiar/newsletter/sept99/peas).

Research Breakthrough

The marginal area of the Lake Victoria falls within LM3 and LM4 agro-ecological zones (Jaetzold and Schmidt 1982). The annual rainfall is erratic and low: 700-1000 mm. The soils are infertile and can only support low production of cereals and legumes like maize and bean, respectively. Crops like pigeonpea (*Cajanus cajan*) that withstand low rainfall and low soil fertility can be suited to this region. Pigeonpea is an important pulse crop that performs well in semi-arid tropics where moisture availability is unreliable or inadequate (Reddy et al. 1993). The crop can withstand low moisture conditions and perform well in areas receiving less than 1000 mm of rainfall annually. Rao and Willey (1981) state that pigeonpea can contribute about 40 kg N/ha through leaf fall and roots. This biological source of N is valuable to smallholder farming systems where resource-poor farmers cannot afford inorganic fertilizers. The grain of the crop is rich in protein and good for the rural communities whose diet is cereal based. The protein content of pigeonpea, especially the dry split (*dhal*) and green grains ranges between 24-26% (Singh and Diwakar 1993). In 1997 pigeonpea was introduced in the Lake Victoria region through an on-farm study and the objectives were: a) to assess the adaptability of improved pigeonpea varieties, b) to involve farmers in bulking the seed for sustainability and, c) to involve the farmers in the evaluation process and to promote the utilization of the crop as a protein rich food.

Seven varieties of pigeonpea, categorized into short, medium and long maturity types were obtained from ICRISAT, Nairobi for this trial. They were three long maturity varieties, ICPL 9145, ICEAP 00040 and ICEAP 00020; two medium maturity varieties, ICEAP 00068 and ICP 6927; and two short maturity varieties, KAT 60/8 and ICPL 87091. The varieties were planted in lower Nyakach and East Karachuonyo in Nyando and Rachuonyo districts, respectively. Twenty-one farms were planted in Karachuonyo and 12 in Nyakach in 1997 and 1998. Two varieties of different maturity periods were planted in each farm. The trials were farmer managed while researchers took data on crop vigor, pest and disease incidence. At the end of the seasons, the farmers were involved in pre-harvest and post-harvest evaluation of the crop, using their own criteria.

Evaluation by the farmers gave both long and medium maturity varieties higher ranking than the short maturity types. The former two were more tolerant to pests and had longer harvesting periods. The short maturing varieties were more susceptible to pests such as pod sucking bugs. Another drawback to the short maturity types was the short/harvesting period. The average yield for each variety was below expected potential yield. While the expected yield ranged from 500 to 1,500 kg/ha, the yield in the region ranged between 150 and 300 kg/ha. This drastic reduction was mainly due to poor crop management by the farmers, especially delayed weeding. Other factors were high pest and disease incidence, livestock damage and flooding in some fields in Nyakach site. (Okoko 2000). Recently, over 10,000 ha of medium-duration pigeonpea varieties resistant to wilt were cultivated by farmers two times a year in Eastern Kenya (CGIAR 2008).

Pigeonpea, A Savior Crop

Maize has been traditionally the main crop of poor smallholder farmers. Unfortunately, the maize crop fails in three out of five years, leaving families to rely on pigeonpea, which the local people call 'our dryland coffee' and 'our beef'. To date, pigeonpea is widely considered a lifesaver and guarantor of livelihoods in these drought prone areas of Kenya. The commercialization of pigeonpea allows farmers to own valuable assets from mobile phones to productive land and livestock, and is opening viable pathways to move out of poverty. The increased income also allows families to improve food security and increase expenditures on other basic needs to improve the quality of life (ICRISAT Brochure 2009a).

Malawi

Geography

Malawi is a landlocked tropical country with Zambia to the west, Mozambique to the south and east, and Tanzania to the north and east with latitude of 17°3' S to 9°52' S and 32°57' E to 35°51' E longitude (Figure 71). The national borders encompass Lakes Malawi and Chilwa, which cover 2,440 km² leaving a land area of 9,408 km². The Northern region covers 2,690 km², the Central region 3,559 km² and the Southern region 3,176 km². The total area of the country is 118,480 km², but this includes 24,400 km² of water surface, mainly composed of Lake Malawi, but there are other sizeable lakes, such

as Lake Malombe, Lake Chilwa and Lake Chiuta. The land area is 94,080 km² ([wikipedia.org/wiki/Geography_of_Malawi](https://en.wikipedia.org/wiki/Geography_of_Malawi)).

Malawi's climate is generally tropical. It changes from semi-arid in the Lower Shire Valley, semi-arid to sub-humid on the plateaux and sub-humid in the highlands. The rainy season runs from November to April. There is little to no rainfall throughout much of the country from May to October. It is hot and humid from September to April along the lake and in the lower Shire Valley, with average daytime maxima around 27° to 29°C. Lilongwe is also hot and humid during these months, albeit far less than in the south. The rest of the country is warm during those months with a maximum temperature during the day around 25°C. From June through August, the lake areas and south are comfortably warm, with daytime maxima of around 23°C, but the rest of Malawi can be chilly at night, with temperatures ranging from 10°C–14°C (50°F–57°F). High altitude areas such as Mulanje and Nyika are often cold at night (around 6-8°C) during June and July. Karonga in the far north shows little variation in temperature with maximum daytime temperature remaining around 25 to 26°C all year round but is unusual in that April and May are the wettest times of the year due to strengthening southerly winds along the lake. Frost may occasionally occur in lower lying land on the plateaux, but is not a significant limiting factor in pasture production ([wikipedia.org/wiki/Geography_of_Malawi](https://en.wikipedia.org/wiki/Geography_of_Malawi), Moriniere and Chimwaza 1996).

Agriculture

Eighty percent of Malawi's population is highly dependent on their own agricultural production to meet their household needs for food and income. The majority of rural smallholder farmers cultivate between 0.5 and 1.0 ha of land. While 70-80% of the agricultural landscape is devoted to maize, the staple crop, smallholder farmers' average maize yields are in decline. This is primarily due to nutrient-related soil constraints and farmers economic inability to invest in external inputs for soil improvement. There is a strong relationship between soil fertility, agricultural productivity, crop diversity and malnutrition. To improve food security and the nutritional status of their families, Malawian farmers need to understand these relationships and learn ways of cultivating their land both more sustainably and intensively (McKnight Foundation Collaborative Crop Research Program 2008).

Malawi's total cropped area including field and tree crops is about 2.2 to 2.5 M ha and 40% of the total land area is suitable for agriculture, of which more than 90% is in small farms. The country's share of world or regional markets for other agricultural goods is small enough to allow for massive expansion if and when production and trade respond. Yields for other export crops (eg, rice at 1.4 t/ha; pulses at 370 kg/ha; groundnuts at 440 kg/ha) are far below yields in other developing countries at similar latitudes. Farm level prices are also low, suggesting poor trade links to world markets (www.malawi.gov).

In the early 1980s, Malawi was one of the showcases of economic growth in Africa, fueled by rapid growth in tobacco production by the estate sector and by the introduction of fertilized hybrid maize in the smallholder sector. The promising overall agricultural sector performance, with the growth rate in agricultural GDP averaging 4.7% annually over the decade, was primarily export growth in which small farmholders played a minor role (Hardy 2000).

By the late 1980s, over 56% of households were on holdings of less than 1 hectare, and a further 20% on 1.0 to 1.5 ha. Because of pressure on land there is little opportunity for fallow and rotation to restore soil fertility, and small farmholders have expanded their cultivation to marginal, less fertile soils often on hill slopes, which are not suitable for intensive cultivation, leading to woodland depletion, soil degradation and erosion. Rainfed agriculture predominates, dependant on a single rainy season between November and April. The growing season varies in length from less than 120 days to over 210 days. Only 10,000 ha of land is currently irrigated, 5% of the potential irrigated area, largely on sugar estates. Other irrigated crops include rice and vegetables (Moriniere and Chimwaza 1996).

The per capita food production has been falling, moving from an index of 100 in 1978-81 to 75 by 1991, reaching only about 87% of the recommended minimum daily calorie consumption. Maize is the main staple of the Malawian diet, covering 76% of smallholder farmland. In the late 1960s, intercropping was found on 94% of the maize area, but this had fallen sharply by 1980 (Heisey and Smale 1995). Other food crops include rice, sorghum and millet while legumes, beans, pigeonpea and groundnuts are traditionally grown by smallholder farmers. Cassava, potato and sweet potato are more locally based. The area planted to cassava, often intercropped with maize, has increased sharply over the past 10 years particularly in densely populated southern areas. Tobacco is the dominant cash crop, providing 71% of

export earning from both large scale and small scale farming sectors. Other cash crops include cotton, sugar, tea and coffee (Moriniere and Chimwaza 1996).

Malawi's deteriorating food security situation threatens to undo completely the impressive progress made in laying the policy framework for growth. Despite real substantial technological promise in food production, events are rising downwards. The only realistic and practical way to reverse this spiral and simultaneously to restart economic growth is to use the best bet technology Malawi's scientists have established for all smallholder farmers. This would simultaneously improve the food security of all food-deficit smallholder farmer households, and sharply increase the marketed surplus available to urban consumers (Hardy 2000).

Pigeonpea Cropping System, Area, Production and Yield

Pigeonpea production in Malawi is geographically concentrated. Two long-duration cultivars have been released and pigeonpea seed is now included in the country's subsidy program (CGIAR 2008). The major production areas are in the south, mainly because of the low prevalence of animals. In the major growing areas, 90% of farmers grow the crop, and 70% are "commercial", selling over half their production. In Ekwendeni, 94% of farmers grow pigeonpea in association with groundnuts and mucuna while in Kasungu, a few farmers are currently growing this crop with the new cropping system (McKnight Foundation Collaborative Crop Research Program 2008).

Pigeonpea fits well in a rotation with maize in the cropping system of Malawi. Moreover, a successful combination of intercropping is maize with pigeonpea (promising drought-tolerant legume that thrive on residual moisture). The crop can be successfully cultivated with maize, without significant compromise on yield. While both crops are sown simultaneously, the legumes start to grow only after the maize is harvested. Research in Malawi shows that pigeonpea and maize can grow sequentially in the same row, rather than in separate rows. The combination of legumes with cereals also shows increased fertilizer-nitrogen use efficiency (Mapfuno and Giller 2001).

Pigeonpea area, yield, and production began to increase in 1985/86 following the availability of seed of the ICP 9145 variety. However, area and productivity increased rapidly in 1993 following the entry of private traders. Nationally,

area planted with the crop increased from 113,000 ha in 1996/97 to 140,000 ha in 2001/02, an increase by about 24%. Total production likewise increased over that period, from 73,000 t to 105,000 t. The computed average yield in 1996/97 and 2001/02 cropping season was 646 kg/ha and 750 kg/ha, respectively (USAID 2003). However, during these periods, pigeonpea projections by FAOStat (2008) were substantially low for areas planted and production. The calculated area was estimated at 101,892 hectares with a production rate of only 70,000 t in 1996/97 and 123,000 hectares with a measly annual production of 79,000 t during 2001/02 cropping season (Appendix 2, 3).

USAID (2003) also reported that the projected area planted with pigeonpea is about 9% of the area cultivated to maize and is heavily concentrated in the Blantyre, Machinga and Shire Valley. In Blantyre, about 36% of the area planted is pigeonpea as compared to maize, while in Machinga it is 13%, and in Shire Valley, about 9%. These three locations accounted for approximately 86% of the expanded area planted and in addition, Karonga and Salima accounts for an additional 10% of the increase. Average yield over the period increased from 643 kg/ha in 1997 to 753 kg/ha in 2002. The district of Machinga reported the highest yields, with 869 kg/ha. But FAO estimates on the same periods, was 687 kg/ha and 642 kg/ha, respectively.

In 2006, the annual production was recorded by FAO at 79,000 t (Table 26) over 123,000 ha (Table 25) with an annual mean yield of 642 kg/ha (Table 28). The high productivity observed for the 2005-2006 cropping season is indicative of improved management practiced by smallholder farmers.

Uses

In the southern region, planting of pigeonpea has increased over recent years. Although there are relatively few cattle, the presence of a long season crop in the field requires protection from free grazing animals. Benefits to soil fertility of incorporation of crop residues depend on C:N ratio in the residue. In the short term, the incorporation of low N material adversely affects fertility through utilization of free N in soil for bacterial growth. However, high N residue is the most valuable for animal feed. For most smallholder farmers in Malawi, soil fertility (and hence crop yield) is more important than animal feed. This will only change when a market develops for the sale of animal feed, which will probably be dependent upon consumer demand for

meat and milk and their ability to pay farmers an attractive price for livestock products (Reynolds 2000).

Marketing

Market development for pigeonpeas is quite advanced in the three cited districts, where an export industry is developing for processing the crop into mashed pigeonpeas, or *dal*, to be exported for the Indian market. One of the reasons cited for the limited area planted to pigeonpeas in the central and northern regions is the lack of marketing infrastructure. However, pigeonpeas are not common in the diet of families outside of the south. This lack of consumer demand may be one of the principal factors explaining the lack of market development (USAID 2003).

In a report by the FAOStat (2008), Malawi consistently exported pigeonpea since the 60s with a total of 147,507 t (Table 8). Ever since, the trend for exporting this crop was dropping with a record of only 304 t during the 2004 season.

Tanzania

Geography

Tanzania is immediately south of the Equator between 11°36' S to 1°8' S latitude and 29°37' E to 40°9' E longitude, entirely within the tropics. The mainland is bordered on the south by Mozambique, Malawi and Zambia; on the west by Zaire, Burundi and Rwanda; on the north by Uganda and Kenya; and on the east by the Indian Ocean (Figure 71). Tanzania is the largest of the East African nations, and it possesses geography as mythic as it is spectacular. The nation is divided into 25 regions; twenty on the mainland, three on Zanzibar Island and two on Pemba. The country has a total area of 945,087 km² comprising land and water, which is 886,037 km² and 59,950 km², respectively (Sarwatt and Mollel 2000). Land use represents the following: arable land, 3%; permanent crops, 1%; permanent pastures, 40%; forests and woodland, 38%; and others, 18% (en.wikipedia.org/wiki/Geography_of_Tanzania", May 2008).

The diversity of topography and other factors give rise to a range of average rainfall from 200–2,000 mm per annum. Most of the country receives less than 1,000 mm, except highlands and parts of the extreme south and west

where 1,400–2,000 mm can be expected. In the central arid areas 200–600 mm falls on average. Rainfall is unimodal north of the central railway line, while to the south it is bimodal (Sarwatt and Mollel 2000).

Agriculture

Agriculture is the backbone of the Tanzanian economy. Smallholder farms using traditional cultivation methods where crop production is determined by rainfall dominate the sector. Tanzania's climate and growing conditions are favorable for a wide variety of fruit, vegetables and flowers. The major fruit potential is pineapples, passion fruit, citrus fruit, mangoes, peaches, pears and bananas, while vegetables include tomatoes, spinach, cabbage and okra. Both tropical and non-tropical varieties of flowers are grown. There is good potential to export these products to neighboring countries, the Middle East and Europe.

The main staples include maize, sorghum, millet, rice, wheat, pulses, cassava, potatoes, bananas and plantains. The major export crops include coffee, cotton, cashew nuts, tobacco, sisal, pyrethrum and tea. Export crop marketing has been liberalized, as has the supply of agricultural inputs and prices. The robust growth of the agricultural sector in 2004 was attributed to good weather experienced in most parts of the country in the 2003/2004 cropping season. As a result the crops sub-sector, which accounted for about 75% of the agricultural sector, grew by 6.2% in 2004 as compared to 3.6% recorded in 2003 (www.sadcreview.com/country_profiles/tanzania/tan_agriculture).

The birth of pigeonpea research

In Tanzania, pigeonpea research started in the early 1960s, when varieties collected from Ukariguru (Tanzania) were grown in observation plots at the Agricultural Research Institute (ARI), Ilionga in 1962/63 to screen for wilt resistance. This work was discontinued following the departure of scientists involved in crop research, but resumed in 1974/75 when the National Grain Legumes Research Program (GLRP) was started at ARI-Ilionga. Sixty lines, including six dwarfs, short-duration genotypes from ICRISAT, were evaluated that season. Pure lines such as NPP610, RK101, TRT201 were identified for cultivation (Onim 1981). These lines formed few or no branches, podded profusely on the main stem, and the best lines gave grain yields of up to 2 t/ha. The next phase began in 1986/87 when a Pigeonpea Germplasm

International Trial was conducted jointly with ICRISAT scientists at ARI-Ilonga, Gairo (Kilosa district), and the Sokoine University of Agriculture. The most promising lines flowered in 55-60 days and matured in 110-115 days. Although the data are limited, it appears that early-maturing pigeonpea has potential under Tanzanian conditions (Singh 1991).

Pigeonpea Research and Development

A number of studies revealed that in Tanzania, pigeonpea production was not growing as fast as other pulses (Mligo 1994, Lyimo and Myaka 2001, ICRISAT 2004). In fact, in some areas, pigeonpea production is declining rapidly mainly due to fusarium wilt (soil borne fungal disease that is devastating for the crop) that even farmers are abandoning pigeonpea cultivation (Reddy et al. 1993). The high yielding local variety "Babati White" was devastated by fusarium wilt and most of the farmers harvested only stems for firewood (ICRISAT Flyer 2010). In order to address this, in 1991, ICRISAT initiated a regional breeding program to ensure that the varieties developed were adapted to the growing conditions in east Africa. This was made possible in collaboration with NARS in the region. The research aimed at developing varieties that are resistant to fusarium wilt, able to meet end-user preferences (farmers and markets), and adapted to agro-climatic conditions. In terms of market traits, the focus was on varieties with large white/cream seeds (fast cooking grains with aroma), and early maturing type so that farmers can avoid terminal drought. Long duration varieties were targeted for medium and high altitude areas of northern Tanzania and medium and short duration types were targeted for low and medium elevation areas. The collaboration was expanded to include development partners (TechnoServe and the CRS) who provided significant contributions in developing farmer and market-preferred pigeonpea varieties. By 1997, the effort resulted in the development of 21 varieties of long, medium and short duration types (Shiferaw et al. 2005). Improved varieties like ICEAP 00040 and ICEAP 00053 are becoming very popular especially in the Babati district. The huge impacts have been made possible because of the committed partnership of Tanzania's Department of Research and Development, the Ilonga Research Station in Kilosa and the Selian Agricultural Research Institute (SARI) in Arusha that covers the Northern Zone of Tanzania, for breeding improved pigeonpea varieties. About 50% of the farmers in Babati district adopted new varieties and pigeonpea production area expanded to reach the neighboring districts of Karatu and Mbulu (ICRISAT Brochure 2009a; ICRISAT Flyer 2010).

Pigeonpea Cropping System, Area, Production and Yield

Pigeonpea (*Cajanus cajan*) is an important grain legume in the semi-arid regions of Tanzania. Pigeonpea grown in Tanzania is mainly exported in raw form to India, Kenya and other Asian countries. Only a small portion is locally consumed. The crop is a nutritious foodstuff and also a vital cash earner for the poor in different parts of the country. In the major growing areas, 90% of farmers grow the crop, and 70% are “commercial”, selling over half their production. About 14 districts are primary producers mainly located in the southern and northern zones of the country. The major growing areas are Lindi and Mtwara regions in the southern zone; Kilimanjaro, Babati, Arusha and Manyara regions in the northern zone; Shinyanga region in the Lake Zone; and Kondoa in the central region. The crop is also grown along the coast, Dar es Salaam, Tanga and in Morogoro regions in the eastern zone where it is used mainly as a vegetable (green peas). In these districts, pigeonpea is mainly harvested and consumed or sold as dry grain. With the secondary production, pigeonpea is harvested at the green stage and consumed as a vegetable (green peas). In the northern zone districts including Babati, pigeonpea is mainly grown as a cash crop. Traditionally, the farmers in the northern zone prefer to consume other legumes such as beans and cowpeas while in the southern zone districts, due to lack of beans and cowpeas, the farmers use a larger share of their pigeonpea produce for home consumption. The quality of pigeonpea from the northern zone districts especially the large and white colored grains grown in Babati is also considered to be superior and hence more suited for the export market (Shiferaw et al. 2007).

The entry of private traders in Tanzania following liberalization of agricultural markets increased pigeonpea area, yield, production and export. For example, in Kondoa district in Tanzania, pigeonpea is now a major cash crop, following an expansion of research and extension and private traders over the last five years (Table 29). Farmers used to grow pigeonpea on a small scale (in backyards, along fences and as intercropped plant), then production expanded when they adopted the white-seeded *Kombowa* (ICPL 87091) and crop management methods developed by ICRISAT and Selian Agricultural Research Institute. Because of increased availability of *Kombowa* grain, traders came in from the neighboring Babati district, where pigeonpea was already highly commercialized. Farmers found they could earn high incomes from pigeonpea, and expanded production further,

attracting even more traders. Farmers have become much more receptive to new technology, adopting improved crop management practices especially farmyard manure, inorganic fertilizers, pesticides and ox-drawn ploughs and rippers to incorporate crop residues into the soil to increase fertility and this is seen with doubling of average grain yields in 2001 and 2002 seasons.

Table 29. Pigeonpea situation in Kondoa district, Tanzania (1998-2001).

Particulars	Year				
	1998	1999	2000	2001	2001
Cultivated Area (ha)	6,000	6,000	3,000	14,000	32,000
Yield (kg/ha)	200	90	200	500	500
Production (t)	3,000	1,000	1,000	7,000	16,000

Source: District Agricultural Extension Office, Kondoa.

Along with FAO statistics (2004), pigeonpea accounted for about 11% (44 t) of the total annual production of pulses in an average area cultivated around 62,900 hectares in the country between 1992 and 2000.

Production level of Tanzania recorded in 2006 is 50,000 t in an area of 68,000 ha. In northern Tanzania alone, two long-duration varieties, which are high yielding, having white bold grain and resistant to wilt are being grown in over 50,000 ha (CGIAR 2008). The trend in area cultivated and production is around 66,000 ha to 68,000 ha and 47,000 t to 50,000 t during 2000 to 2006 cropping season (Appendix 2, 3). Considered as one of the major producing countries in the world, Tanzania ranks 4th in area cultivated and production of pigeonpea in the region. The productivity calculated by FAO has increased from 710 kg/ha in 2000 to 735 kg/ha in 2006 cropping season (Appendix 4).

Uses

The crop offers multiple benefits – protein rich seed (approximately 21% protein), fuel, fodder, fencing material, improved soil fertility and erosion control. It ranks third among the pulses (after beans and cowpea) in total national production (Mligo 1994, Lyimo and Myaka 2001). Since local varieties take long to cook, many consumers prefer fast cooking grains with good aroma.

Marketing

Time series trade data for pigeonpea production in the country are very difficult to find from the official national trade statistics. In several trade statistics, pigeonpea is lumped together with peas, pulses or legumes. Although the export figures shown may not fully reflect the total volume of pigeonpea exported from Tanzania, the data shows that it is an important pulse crop that earns foreign exchange for the country (Table 29). If the productivity and the quality of production can be improved, pigeonpea can be an important legume in the agricultural economy of Tanzania and a valuable source of cash, nutrients and livelihoods for small producers (Shiferaw et al. 2007).

Table 30. Production, Area, Yield and Export of pigeonpea in Tanzania (1992-2001).

Year	Production (t) ¹	Area (has) ¹	Yield (kg/ha) ¹	Export (t) ²
1992-93	38,000	55,000	690	23,390
1993-94	34,000	50,000	680	22,800
1994-95	42,000	60,000	700	27,690
1995-96	55,000	79,000	700	34,610
1996-97	41,000	60,000	680	25,690
1997-98	45,000	65,000	690	27,130
1998-99	47,000	65,000	720	28,580
1999-00	47,000	66,000	710	29,410
2000-01	47,000	66,000	710	30,290

¹FAOStat 2004; ²Estimates compiled from various sources (this data was not available from FAO Statistics).

Masawe (2001) said that a strong non-government organization (NGO) known as TechnoServe was helping/assisting rural entrepreneurs of Tanzania to develop growth-oriented businesses linked to the local and global economy. After conducting a pigeonpeas sub-sector analysis in 1998, TechnoServe identified a number of constraints that were hindering these pigeonpea farmers from fully attaining the potential benefits of the valuable pigeonpeas grown in their district. Some of these were lack of reliable markets & market information, inadequate extension services, and poor yields and product quality. TechnoServe partners with the private sector, developing commercial linkages to all stages of industry (production, processing, distribution, marketing and financial institutions) to stimulate sustained investment and growth in rural areas. TechnoServe's pigeonpea program operates in Babati district where the world-famous Babati white pigeonpeas are grown.

The NGO's one area of intervention in helping small-scale pigeonpea farmers is through marketing. The NGO has assisted in organizing the farmers into marketing groups and linked them to large-scale exporters of pigeonpeas. In 1998/99, TechnoServe assisted these farmers to sell their peas in niche markets in Europe for significantly higher prices than in their traditional Indian market. In the 2000/01 year, the NGO had secured an order in the Netherlands for Babati white pigeonpeas and exported 40 t with a substantial price of US\$450 per ton as compared with the average price of \$250/t paid in India, the major market and consumer of pigeonpeas.

Uganda

Geography

Uganda lies astride the Equator between 1°3' S to 4°2' N latitude and 29°37' E to 33°55' E longitude, and is a landlocked country with no access to the sea. The country is located in Eastern Africa, west of Kenya and east of the Democratic Republic of the Congo (Figure 71). Uganda has a total land area of 241,548 km², and is administratively divided into 39 districts. More than 75% of the country (over 18 M ha) is available for both cultivation and pasture (Mwebaze 1999).

Despite being on the equator, Uganda is more temperate than the surrounding areas due to its altitude. Temperatures are in the range of 15°–30° C. More than two-thirds of the country is a plateau, lying between 1,000–2,500 masl. Precipitation is fairly reliable, varying from 750 mm in Karamoja in the Northeast to 1,500 mm in the high rainfall areas on the shores of Lake Victoria, in the highlands around Mt. Elgon in the east, the Ruwenzori Mountains in the south-west and some parts of Masindi and Gulu. The country is mostly plateau with a rim of mountains. This has made it more suitable to agriculture and less prone to tropical diseases than other nations in the region. The climate is tropical; generally rainy with two dry seasons (December to February, June to August). It is semi-arid in northeast near Sudan and approaching the Sahara (en.wikipedia.org/wiki/Geography_of_Uganda).

Agriculture

About 80% of the country's total land area is arable, although it is estimated that only 30% is being productively utilized. The southern parts of Uganda mainly cultivate perennial crops that include coffee and green bananas, while livestock farming is practiced in the drier areas of northern and western Uganda. Agriculture is the backbone of Uganda's economy; 95 percent of the population farms (both crops and livestock) on small farms for food and cash income, and on fairly large farms including ranches, of an average size of 1,200 ha and crop farms (5-20 ha). Agriculture contributes over 40% to the Gross Domestic Product (GDP) and over 90% to the country's foreign exchange earnings. It also contributes over 60% to total government revenue in addition to employing more than 80% of the total labor force and providing over half of the total income for the bottom three-quarters of the population (MFPED 1996).

Agriculture contributes to over 70% of Uganda's export earnings and provides the bulk of the raw materials for most of the industries that are predominantly agro-based. Agricultural output primarily comes from about 3 M smallholder subsistence farmers, who own an average farmland area of 2.5 ha. The agricultural sector is dominated by the production of food crops, but cash crops, livestock, fishery and forestry are also important. Food crops accounted for 72.4% of agricultural GDP in 1985, falling to 65.3% in 2000 (www.fao.org 2005).

In Uganda it is common to combine crop and livestock production; the two enterprises are complementary. Crops are the main agricultural activity. The average farm size is small, about 1–5 ha. Livestock are kept for draught, milk and/or meat for sale. Mixed farming is the commonest smallholder dairy system in the South-west, Central and South Eastern parts. Exotic and crossbred dairy animals are kept, usually in fenced units, to facilitate control of tick borne diseases and for pasture management. Agropastoralists are sedentary farmers who grow food crops both for subsistence and sale, while keeping some livestock that graze on communal land, fallows and on crop stubble after harvest. Livestock is used for draught, savings and milk. Shifting cultivation is common. Agropastoralists have little control over the feed resources, common grazing land and crop residues. Milk production fluctuates with seasonal availability of feed. Nowadays, with the increase in population and land pressure, this system often evolves into mixed farming (Mwebaze 1999).

The main food crop is banana, which accounted for 28% of the total cropped area in 2000, followed by cereals, root crops, pulses and oilseeds with 25, 17, 14 and 8% of the area, respectively. Despite the dominance of food crop production, only one-third is marketed. Cash crops, livestock, fish and forestry accounted for 4.5, 16.5, 4.0 and 2.6% of agricultural output in 1985, and 8.9, 6.9, 4.6 and 4.3% in 2000, respectively. Although Uganda is able to meet its domestic food needs, food products like wheat and rice are imported to cater to the urban population (www.fao.org 2005).

Pigeonpea Area, Production and Yield

Pigeonpea, an important staple food in northern Uganda, is grown in the drier areas with mean annual rainfall ranging from 768–1,115 mm in the north-east and north, and 1,065–1,670 mm in the wetter areas of the north-west of the country. Pigeonpea as a grain legume forms an important part of the diet in these regions (Acland 1986). The Sasakawa-Global (SG) 2000 Program has established seed banks to encourage rotations and the intercropping of legumes with cereals. Collaboration with the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) has broadened the range of legumes to include pigeonpeas. More than 40 t of pigeonpea seed were available, largely for eastern Uganda. Nearly 700 ha of pigeonpea were sown in 2003, as part of the program involving ICRISAT, NAADS, Catholic Relief Services, TechnoServe, and other NGOs. In 2002, the program registered an average yield of improved cultivars of pigeonpea at 2,300 kgs/ha as compared to the traditional cultivars at 900 kgs/ha of green pods involving 15,839 farmers (Breth and Dowswell 2003).

Pigeonpea is regarded as a good plant for restoration of fertility and is used in rotation with crops such as maize, groundnut, tobacco, pigeonpea for three to four years in Uganda. One of the advantages of pigeonpea is the increased growth of the grass interplant with it. The main pigeonpea cultivars in the country are landraces, which take 6-10 months to mature. The crop is judiciously intercropped in alternate rows with sesame or African finger millet (*Eleusine coracana* L. Gaertn.) and sorghum (*Sorghum bicolor* L. Moench) (Silim et al. 1994, www.infonet-biovision.org - Pigeonpea 2008). In traditional cropping system, actual pigeonpea yields on-farm are very low, 0.3-0.6 t/ha. However, in experimental conditions, pigeonpea yields as high as 1.4 t/ha (Obuo et al. 1996). Low yields obtained at the farm level are attributed to numerous constraints, particularly poor management of the intercropping

systems with respect to plant population, spatial arrangement, unimproved cultivars, and heavy insect damage.

In the data calculated from FAOStat (2008), since the recording in 1961, pigeonpea production per unit area for green pods was the lowest at 406 kg/ha in 1975 and highest at 1,176 kg/ha in 1999 to 2001 cropping season (Appendix 4). In some cases where there are no data from green pods, yield for dry pods are recorded at around 400 kg/ha. The yield shown in both type conforms the findings made by Obuo et al. in 1996.

Research and Development

The first pigeonpea breeding program in south and east African region started in 1968 at Makerere University, Uganda. The main objective of this program was to breed grain type varieties with short maturity (Khan and Rachie 1972). The crop improvement activities at this station started by evaluating 5,400 germplasm collected from India, the Caribbean, the Philippines and identifying promising single plants for head-to-row selection. The progenies were primarily grouped on the basis of plant type and spreading and compact types were selected respectively for low and high density cropping systems. However, the pigeonpea research program was adversely affected by civil conflict between 1973 and 1986 (Saxena 2008a).

Research information on pigeonpea in Uganda is very scanty. Of seven promising cultivars in Uganda, 'CIVE1' yielded 889 kg seed/ha with a grain/straw ratio of 0.318; 16, on the other hand, with the highest seed yield of 1,225 kg/ha had a grain/straw ratio of only 0.224 (Khan and Rachie 1972). On crop diversification, pigeonpea+millet intercropping is a remarkable element in the Uganda cropping systems, information on the scientific management of intercropping is limited. The only data reported was the study conducted by Osiru and Kibira (1981) at Kabanyolo on sorghum. They stated that sorghum+pigeonpea intercrop gave 28% more yield than sole sorghum crop.

Marketing

The generally low production prices set by the government and the problem of delayed payments for produce prompted many farmers to sell pigeonpea at higher prices on illegal markets in neighboring countries.

Minor Pigeonpea Producing Countries in Africa

Angola

Geography

Angola is located on the South Atlantic Coast of West Africa. It is the second largest country in sub-Saharan Africa. It covers an area of 1,246,700 km² and lies between 4°23'S to 18°8'S latitudes and 11°41' E to 23°54' E longitudes (Figure 71). Rainfall is the main climatic influence. The southwest and littoral areas are strongly influenced by the cold Benguela current, with cool arid conditions in the SW extreme. The entire coastal belt experiences arid to semi-arid climate; the Escarpment Mountains and interior plateau are much more humid with rainfall ranging between 900 and 1,700 cm per annum (Castanheira 1993, FAO 1996).

Like the rest of tropical Africa, Angola experiences distinct, alternating rainy and dry seasons. It is semi-arid in the south and along the coast to Luanda; the north has a cool, dry season (May to October) and a hot, rainy season (November to April). In the interior, above 1,000 m, the temperature and rainfall decrease. In general, precipitation is higher in the north, but at any latitude it is greater in the interior than along the coast and increases with altitude. Temperatures fall with distance from the equator and with altitude and tend to rise closer to the Atlantic Ocean. The average annual temperature is about 26°C. Two seasons are distinguished - the cool, from June to September; and the rainy, from October to May. The heaviest rainfall occurs in April, and is accompanied by violent storms (en.wikipedia.org/wiki/Agriculture_in_Angola; worldfacts.us/Angola-geography).

Agriculture

Agriculture in Angola is primarily subsistence agriculture, with the average size of plot cultivated per family at around 2 ha. In 1999, the estimated arable land was figured at 2.41% of total land area with 0.4% with permanent crops. Over half the small farmers use some form of shifting agriculture, which to some extent by-passes the problems of lack of fertilizers and pesticides. Agriculture is a major economic activity in the country. In 1975, Angola was self-sufficient in production of maize, sorghum, millet, beans, cassava, coffee, potatoes, sugar, bananas; it was also a significant exporter of coffee

(fourth in the world), cotton, tobacco, sisal, palm oil, bananas, rice and maize (World Bank 1991).

In 1991 there has been a slight increase in the number of small (mainly horticultural) commercial enterprises near major urban areas, but commercial farms still account for less than 5% of overall agricultural activity. In spite of the war between 1990 and 1992, 73% of the workforce was employed in agriculture. Considering the variety of physio-climatic zones, with the ample water resources available in much of the country, Angola has one of the greatest agricultural potentials in sub-Saharan Africa (en.wikipedia.org/wiki/Agriculture_in_Angola; worldfacts.us/Angola-geography; World Bank 1991).

Agricultural production has continued to fall over the past two years, more than ever due to rural insecurity and particularly to the presence of landmines. A comparison of cereal production between the 1992-93 and 1993-94 harvests shows a drop of 27% in maize production, 33% in sorghum/millet and 14% in rice, an overall fall in cereal production of 19% (FAO 1995).

About pigeonpea

Pigeonpea in Angola is an important vegetable cultivated in the kitchen garden because of its high nutritive value and as it is rich in vitamins. According to Chicapa-Dovala (1995), some pigeonpea is grown in isolated maize fields and the crop is not well known in the country. The type of pea grown is landraces and they are grown as subsistence crop for small-scale farmers. There have not been many rigorous studies of the significance of wild or under utilized crops of pigeonpea in Angola; however, this crop plays a considerable role in the diet of the rural population (FAO 1996), although Upadhyaya (2007) states that only 1 accession has been identified.

Commonly known as Angola pea, the crop is one of the oldest food legumes in Angola and is considered as a minor crop (Nene et al. 1989; Nyabyenda 1987; and van der Maesen 1983, 1986). Pigeonpea is normally grown as an annual shrub, but is a short-lived perennial tree that may reach 4 m in height, has trifoliate leaves, clusters of yellow flowers and flattened pods generally containing four seeds (www.grainlegumes.com). The pea when young and properly cooked is not very inferior as a green vegetable to English peas and likewise, when matured is an excellent ingredient in soups (www.henriettesherbal.com).

Benin

Geography

The Republic of Benin with geographic coordinates of 6°24' N to 12°17' N latitude and 0°52' E to 3°46' E longitude is located in Western Africa, bordering the Bight of Benin, between Nigeria and Togo (Bradshaw 1997) (Figure 71). With an area of 112,622 km², is mostly flat plains of 200 masl. Benin's climate is hot and humid. Benin has two rainy and two dry seasons. The principal rainy season is from April to late July, with a shorter less intense rainy period from late September to November. The main dry season is from December to April, with a short cooler dry season from late July to early September. Temperatures and humidity are high along the tropical coast. In Cotonou, the average maximum temperature is 31°C (88°F); the minimum is 24°C (75°F). Variations in temperature increase when moving north through a savanna and plateau toward the Sahel. A dry wind from the Sahara called the harmattan blows from December to March. Grass dries up, the vegetation turns reddish brown, and a veil of fine dust/hangs over the country, causing the skies to be overcast. It is also the season when farmers burn brush in the fields (www.theodora.com/wfbcurrent/benin/benin_geography).

Agriculture

Benin is predominantly an agricultural country. About 55% of the economically active population was engaged in the agricultural sector in 2000, which accounted for 38% of GDP. Most of Benin's population is engaged in agriculture, whether it is for cash crops or to feed their families (Bradshaw 1997). Small, independent farmers produce 90% of agricultural output, but only about 17% of the total area is arable land (2000 estimate) and 1% is cultivated with permanent crop (1998 estimates), much of it in the form of collective farms since 1975. Despite its growth, the economy of Benin still remains underdeveloped and dependent on subsistence agriculture. In 2007, the arable land has been reduced to 13% but increased in permanent crops to 4%. Cotton accounts for 40% of GDP and roughly 80% of official export receipts. There also is production of textiles, palm products and cocoa. Corn, beans, rice, peanuts, cashews, pineapples, cassava, yams and various other tubers are grown for local subsistence. Real economic growth for agriculture in 2007 was 4.2% (www.usa.gov 2008).

About pigeonpea

Although there are no accessions identified in the country, Nene et al. (1989), Nyabyenda (1987), van der Maesen (1983, 1986), and Versteeg and Koudokpon (1993) considered Benin as a minor producer of pigeonpea. The crop production system of cassava in Benin is usually grown in mixed stand with other crops wherein the frequent companion crop amongst others is pigeonpea (IITA 1997).

Southern Benin is characterized by a high population density, as well as a market-oriented but low external input agriculture. Cropping systems based on natural fallow have already vanished in the peri-urban south and are set under high pressure in the cotton growing central belt. The possible options exist by improving annual fallow using pigeonpea and have been tested on-farm, which might help farmers to develop sustainable intensive cropping systems. Farmers' technology choice differs strongly according to the applied farming systems. On the degraded areas of *Terres de barre* (northern part of the Allada plateau), pigeonpea had been proposed as a component of a mixed cropping system but was soon discontinued due to stem borers in sorghum. However, according to farmers, pigeonpea as an annual fallow helps reduce fertilizer costs on cotton fields (simultaneous in stripes or as a rotational fallow) (Floquet 2000).

Botswana

Geography

Botswana with geographic coordinates of 17°53' S to 26°54' S latitude and 19°57' E to 29°10' E longitude is a landlocked country located in southern Africa, north of South Africa. Botswana occupies an area of 600,370 km², of which 585,000 km² is land. Botswana has land boundaries of combined length 4,013 km of which the constituent boundaries are shared with Namibia, for 1,360 km; South Africa 1,840 km; Zimbabwe, 813 km and Zambia, less than 1 km (Figure 71). Much of the population of Botswana is concentrated in the eastern part of the country. Botswana is semi-arid, due to the short rainy season. However, the relatively high altitude of the country and its continental situation gives it a subtropical climate. The country is remote from moisture-laden air flows for most of the year. The dry season lasts from April to October in the south and to November in the north where, however,

rainfall totals are higher. The south of the country is most exposed to cold winds during the winter period (early May to late August) when average temperatures are around 14°C. The whole country has hot summers with average temperatures around 26°C. Sunshine totals are high all year round although winter is the sunniest period. The whole country is windy and dusty during the dry season (en.wikipedia.org/wiki/Geography_of_Botswana).

Agriculture

More than half of Botswana live in rural areas and are dependent on subsistence crop and livestock farming, together with money sent home by relatives in urban areas. Agriculture meets only a small portion of food needs and contributes just 2.8% to GDP -- primarily through beef exports -- but it remains a social and cultural touchstone. Cattle raising dominated Botswana's social and economic life before independence (en.wikipedia.org/wiki/Agriculture_in_Botswana).

The basic agricultural system (with a number of variations) is for people to live in villages and to grow crops in fields (lands or masimo), which may be near the village or further away (in the latter case necessitating people temporarily living at their fields during the growing season). Fields are ploughed by animal traction or tractor and most crops are broadcast, although row planting has been encouraged in recent years and is reported to give higher yields and to be on the increase. Few people use fertilizer, although some use animal manure, and weeding is important to obtain a good crop. Sorghum is the main crop, with maize, beans, groundnuts, millet, sunflowers and water melons also grown, often mixed in the same field. Yields vary enormously with rainfall but on average are extremely low at about 300 kg/ha. Most families do not grow enough to last them throughout the year (Whiteside 1997, www.ducksters.com/geography/country.php?country=Botswana).

About pigeonpea

According to Amarteifio et al. (2002), cultivation of pigeonpea has also been reported in Botswana. Moreover, the Botswana College of Agriculture (BCA) initiated an evaluation of pigeonpea. This is a collaborative, multidisciplinary project involving agronomists, entomologists and nutrition specialists. The BCA's Research and Publications Committee funded it. The main objective of the project is to investigate the potential of pigeonpea production in

Botswana. This research is important because pigeonpea is a multipurpose crop that can improve soil fertility and is utilized as food and yet can also provide fuelwood for farmers and its seeds can be fed to livestock. The research has evaluated seven pigeonpea varieties obtained from the SADC Regional Pigeonpea Research and Development Programme based in Malawi. The studies conducted so far have included assessment of growth and yield characteristics of the varieties; determination of effects of planting dates on their growth and yield parameters; evaluation of relative susceptibilities of the varieties to major pests; assessment of yield losses caused by pests and assessment of the impact of indigenous natural enemies on major pests of the crop. The nutritional composition of seeds of each variety has also been estimated. Research has also been initiated on the potential use of pigeonpea as a livestock feed and as a source of fuelwood (www.bca.bw/CSP/research_projects/pigeonpea).

This study investigated the composition of pigeonpeas grown at Sebele, Botswana. The raw seeds of six varieties were analyzed for dry matter, crude fat, protein, fiber, and ash, using Association of Official Analytical Chemists procedures. Major minerals, Calcium (Ca), Potassium (K), Phosphorus (P), Magnesium (Mg), Sodium (Na) and trace minerals, Copper (Cu), Iron (Fe) and Zinc (Zn) were also assessed. The range of nutrient contents obtained were: dry matter 86.6–88.0%, crude protein 19.0–21.7%, crude fat 1.2–1.3%, crude fiber 9.8–13.0%, and ash 3.9–4.3%. Minerals ranges (mg/100 g dry matter) were: K 1845–1941, P 163–293, Ca 120–167, Mg 113–127, Na 11.3–12.0, Zn 7.2–8.2, Fe 2.5–4.7 and Cu 1.6–1.8. The values obtained for the dry matter, crude protein, fat, ash, Ca, Cu, Fe and Mg were similar to those in pigeonpeas grown elsewhere, while those for crude fiber and Zn were higher. In general, the composition of pigeonpeas compared favorably with those of other legumes such as Bambara groundnut (*Vigna subterranea*). The levels of crude protein, crude fiber, K, Ca, P and Mg indicated that pigeonpeas could be valuable in the diet of the people of Botswana. This crop would positively contribute protein in the diet and the diversification of agricultural produce (Amarteifio et al. 2002).

The Government of Botswana is evaluating genotypes for tolerance and escape of drought through research programs on cereals, oilseeds and legumes. Breeding activities also concentrate on associated traits such as early flowering and maturity, which are considered to be escape mechanisms for drought. Other exotic crops of dry regions, such as cassava, pigeonpeas

and sweet potatoes, are being studied for potential adaptation to Botswana's conditions (Government of Republic of Botswana 1997).

Burkina Faso

Geography

Burkina Faso formally known as Upper Volta is a landlocked country in West Africa covering about 274,000 km². It lies between 9°42' N to 14°51' N latitudes and 5°32' W to 2°17' E longitudes and is surrounded by the Republic of Mali in the north and west; Cote d'Ivoire in the south-west; Ghana, Togo and Benin in the south; and Niger in the east (Figure 71). The country lies in the Sudano-Sahelian zone, where the climate and natural environment are harsh (Ouedraogo et al. 2006, www.theodora.com/wfbcurrent/burkina_faso/burkina_faso_geography).

Burkina Faso has a dry tropical climate. The dry season is characterized by the harsh harmattan winds that blow from the north-east to the south-west from October to March. April is the month of humid winds or trade winds bearing monsoons. The rainy season, from May/June to September is characterized by humid winds. Over the whole country, the seasonal rainfall is monomodal. The mass of humid air of Atlantic origin goes up the Gulf of Guinea and reaches Burkina from the south-west where the rains start in April. At first sporadic, they gradually cover the whole country from June onwards. August is the wettest month for the whole country. The rains cease from the end of September. October is when the dry harmattan winds blow (Ouedraogo et al. 2006). The duration of the rainy season decreases progressively from the south-west to the north. The rainfall is very erratic and its volume also decreases from the south-west to the north. There are large seasonal variations in temperature and high ranges at night, particularly in the north of the country (Some and Sivakumar 1994).

Agriculture

Agriculture and livestock farming traditionally dominate the economy in Burkina Faso. Agriculture employs nearly 90% of the manpower. However, this agriculture, livestock farming and husbandry are reliant on poor amounts of rainfall. Therefore, output can vary from one year to another. Crops grown are dominated by growing grains, sorghum and early millet. Other staple

crops include maize, groundnut, cassava, yam and rice. Some subsistence crops are exported such as cashew nut, shea nut and butter nut, sesame seed, groundnut and hibiscus flower. Other cash crops include fruits and vegetables. The following are grown mostly in dry seasons in urban suburbs: green beans, tomatoes, mangoes, peppers. The livestock and husbandry sector generates sub products such as skin and leather, horn, milk, eggs, etc. With 25% of the overall exports, it is the second source of income after cotton (www.burkina_faso_Agriculture.com).

Around 30% (10 M ha) of the soils are suitable for crop production in Burkina Faso. Of this potential area, only one third (3.5 M ha) is actually cultivated per year. About 40% of GDP comes from agricultural activities (crops 25%, livestock 12% and forestry and fishing 3%), which are the main sources of the county's economic growth. Burkina agriculture is a subsistence agriculture based on cereal growing (sorghum, millet, maize, fonio and rice), which takes up 88% of the cultivated area per year and constitutes the staple diet of the majority of the population. It is an extensive agriculture and not highly productive, dominated by small-scale family farming from 3-6 ha on an average. Its development is hampered by major natural constraints such as drought and desertification, overgrazing, soil degradation and deforestation. These physical and climatic constraints make Burkina agriculture vulnerable, as crops are essentially rainfed. Vulnerability due to climatic hazards, the inadequate growth of productivity and the poor diversification of incomes are the reasons why economic and food insecurity persist in the rural households. The climatic hazards, which affect the stability of agro-pastoral production and export incomes, are weakening the country's economy (Ouedraogo et al. 2006).

About pigeonpea

Nene et al. (1989), Nyabyenda (1987) and van der Maesen (1983, 1986) identified Burkina Faso as a minor producer of pigeonpea. Pigeonpea is grown in backyards and sometimes intercropped with cereals and cassava as a subsistence crop for small-scale farmers. The nutritional value of diets in this country is enhanced by traditional vegetables like pigeonpea because of its protein content (FAO 1997).

Cameroon

Geography

Cameroon, with geographic coordinates of 1°55' N to 12°17' N latitude and 8°36' E to 16°5' E longitude, is located in Western Africa bordering the Central African Republic, Chad, and Republic of the Congo, between Equatorial Guinea, Gabon and Nigeria (Figure 71). The country is sometimes referred to as the hinge of Africa. Cameroon has a total area of 475,400 km² with only 6,000 km² water. The nation's climatic condition varies with terrain, from tropical along coast to semi-arid and hot in the north (CIA 2004).

Agriculture

Agriculture is the mainstay of Cameroon's economy. About 75% of the active population is involved in agricultural production, which accounts for 50% of total exports. Cameroon has great agricultural potential. The climate, ranging from humid to semi-arid, allows growing a wide variety of crops and the loss of soil fertility is not as serious as in the other parts of Africa. With decreasing land availability, in areas where traditional shifting agriculture is still practiced, fallow periods have been reduced or are non-existent. Thus, soil fertility in the cleared land cannot recover to optimal levels and thus slash-and-burn farming systems are becoming unsustainable. In some areas of Cameroon, this process is contributing to deforestation. The prevailing land tenure system is another factor that, coupled with an increase in population, is a constraint to food production, especially because it places women and poor farmers at a disadvantage. Women are the main producers of food crops but according to traditional custom, cannot own land. Moreover, average farm size is less than 1 hectare for many families. The small size of these landholdings makes it difficult to feed the family throughout the year (Gehrke 1997).

Producers fall into three categories according to the size of their holdings and the land tenure system: Small farm producers found in all zones are family farmers, who are involved in fair-trade and produce pineapples, papayas, pepper, avocados, coffee, cocoa, mangoes and various food crops. The farm size ranges from a few acres to one or two hectares; the farm size of commercial farm producers ranges from two to ten hectares. Crops grown are pineapple, papaya, cocoa, coffee and plantain. These producers

can be found mainly in the central and coastal provinces. The farm size of producers of cash crops ranges from five to more than 100 ha. These producers have turned to organic agriculture. The main crops grown are cocoa, coffee, palm trees, pineapple, papaya and plantain. These holdings are primarily located in the coastal, southern, western, north-western and south-western provinces. Other products exported as organic are plantain, yam, rambutan, mangosteen, basil, tubers (sweet potato, potato, macabo, taro), various fruits (corossol, coconut, sagou), various stimulating plants (cocoa, coffee, cola nut, bitter cola, pepper), legumes (peanuts, soy, beans) and medicinal plants (citronella, methyl chavicol basil, linalol basil, camomile, rosemary, ginger, peppermint, eucalyptus globulus, voacanga). Pineapple, mango, avocado, plantain and papaya represent the largest exported quantities (FAO 2001, CIA 2004).

About pigeonpea

Pigeonpea in this country is grown as a minor crop for small-scale farmers as acknowledged by Nene et al. (1989), Nyabyenda (1987), and van der Maesen (1983, 1986). Through the initiative of ICRAF, pigeonpea research was given the emphasis for improving soil fertility aside from its nutritional value. Food crop production in highly populated areas of the African humid tropics such as Cameroon is increasingly faced by problems of soil fertility with declining crop yields and higher incidence of weeds. Between 1988 and 1998, ICRAF has developed the improved fallow technology using a farmer participatory approach. A shrub fallow was designed, using pigeonpea in a relay cropping system. Farmers' response to this technology was positive. Benefits reported were higher crop yields, easier clearing of pigeonpea fallows, and the shading out of weeds by the shrubs. Women particularly appreciated the technology for its low labor demand and because these shrubs can be planted on land with less secure tenure. Economic analysis of pigeonpea fallows compared to natural fallows projected over 6 years demonstrates the profitability of the technology in the humid lowlands of Cameroon (Degrande 2001).

In a study conducted by Degrande et al. (2007), pigeonpea planted during the fallow period increases total maize production per hectare over the six-year phase by 200% and groundnut by 350%. In addition, relay cropping pigeonpea into maize greatly reduces the extra establishment and weeding requirements. However, total labor requirement in pigeonpea is 3 times higher

than that in natural fallows, because pigeonpea plots are cropped every year. The net present values per hectare for pigeonpea are 3 times higher than for natural fallows. In summary, pigeonpea fallows can be a profitable alternative to natural fallows for households that do not have enough land to practice the long natural fallows, required to restore soil fertility (Degrande et al. 2007).

Cape Verde

Geography

The Republic of Cape Verde with geographic coordinates of 14°51' N to 17°13' N latitude and 22°25' W to 25°2' W longitude is a group of islands located in the North Atlantic Ocean, west of Senegal, covering 4,033 km² (Figure 71). Cape Verde is classified as a medium human development country and a Low-Income Food-Deficit Country (LIFDC) (Gibb 2003). The archipelago includes 10 islands and 5 islets, Three islands—Sal, Boa Vista and Maio—generally are level and very dry. Mountains higher than 1,280 m are found on Santiago, Fogo, Santo Antão and São Nicolau. Sand carried by high winds has created spectacular rock formations on all islands, especially the windward ones. Sheer, jagged cliffs rise from the sea on several of the mountainous islands. Natural vegetation is sparse in the uplands and coast, but interior valleys support denser growth (www.state.gov. 2008).

Climate is temperate (warm, dry summer; precipitation meager and very erratic). Rainfall is irregular, historically causing periodic droughts and famines. The average precipitation in Praia is 240 mm/yr. During the winter, storms blowing from the Sahara sometimes form dense dust clouds that obscure the sun; however, sunny days are the norm year round (en.wikipedia.org/wiki/Geography_of_Cape_Verde).

Agriculture

Cape Verde suffers from a poor natural resource base, including serious water shortages rebated by cycles of long-term drought. The country's economy is service-oriented, with commerce, transport and public services accounting for almost 71.6% of GDP. Although nearly 70% of the population lives in rural areas, the share of agriculture in GDP in 2001 was only 11%. About 82% of the food is imported (CIA 2000). The principal foods consumed

locally in Cape Verde include maize, bananas, rice, beans, wheat, coffee, vegetables, sugarcane, vegetable oil and livestock products. Maize is grown on all nine of Cape Verde's inhabited islands. It is the only cereal produced in the country in any significant quantity. Cape Verde's food deficit is structural and the country will need to continue to import food for the foreseeable future (Gibb 2003, en.wikipedia.org/wiki/Geography_of_Cape_Verde).

About pigeonpea

About 80% of subsistence farmers have cultivated pigeonpea in Cape Verde but from those a minimum number cultivates pigeonpea as single crop (Baptista and Querido 2001). Based on documents provided by Gibb (2003), pigeonpea production in Cape Verde varies from a small fraction of consumption needs to a small surplus. The crop has been part of the food system of the country as revealed in Table 31. Production of pigeonpea for the years 1997 to 2001 was erratic, as high as 1,976 mt in 1998 to as low as 396 mt in 1997. The 5-year productivity level was 949 mt. Although pigeonpea has been grown in the country, Cape Verde still imports pigeonpea — from as high as 1,454 mt in 1998 to as low as 382 mt in 2000. The 5-year average of imported pigeonpea was recorded at 833.2 mt.

Table 31. Annual pigeonpea production and import in Cape Verde (1997-2001).

Particulars	Calendar Year (MT)					5-Year Average
	1997	1998	1999	2000	2001	
Production	396	1,976	782	1,000	593	949.0
Commercial Imports	1,038	1,454	1,292	382	833	833.2

Sources: CNASA/DSSA and GEP of the Ministry of Agriculture and Fisheries, Customs, INE), FAO and WFP. (Year 2001 data is from the Ministry of Agriculture's Annual Agriculture Study for the 2001/2 season)

According to Baptista and Querido (2001), the traditional corn-bean system that characterizes rainfed farming in Cape Verde requires certain agricultural practices that result in significant soil loss from the more severe slopes. The various National Development Plans (NDP) since 1986 have called for the substitution of the traditional corn-bean intercrop on rainfed lands for pigeonpea, but adoption is not widespread yet. Based on the orientation of the NDP, some soil conservation projects have strongly promoted the technology on the more severe slopes. In some regions farmers have introduced pigeonpea either intercropped among the corn plants or in

separate stands. They likewise reiterated that the crop is a perennial legume, well adapted to semi-arid conditions and provides a wide range of usable outputs in the farming system including food, animal fodder, fuelwood and soil conservation. As a perennial pigeonpea, the plant provides more permanent vegetative cover and is recommended from a sustainability perspective. Except for the annual cultivars, the crop reaches maximum production levels in its third year and continues to produce for up to five years or more. The more mature plants require little attention other than the harvesting of beans and the pruning of woody branches for fuelwood. It tends to be cultivated on the steeper, less fertile soil, where the traditional corn-bean intercrop is less productive.

Pigeonpea has also been integrated in local diets both dry and fresh, being the fleshy harvested green seeds particularly relished. Though fully cognizant of the potential advantages of pigeonpea, the rural population so far have been reluctant to substitute the corn-bean mix to any large extent. In the past ten years or so, attempts have been made through several projects like IFAD, Inter-CRSP, SAFGRAD, and by distributing pigeonpea seeds to farmers, particularly on Santiago Island, to increase acceptance of the legume in the farming system as a substitute for corn which is planted over more than 35% of the mountain slopes. In 2000 and 2001 seeds from India's germplasm collection were distributed to more than sixty farmers before the rainy season as part of InterCRSP activities to promote adoption of an alternative crop, which is less erosive and more productive, to substitute for a corn-bean system.

Côte d'Ivoire (Ivory Coast)

Geography

Côte d'Ivoire (the Ivory Coast) is a sub-Saharan nation in southern West Africa located at 4°23' N to 10°34' N latitude and 2°32' W to 8°15' W longitude. The country is shaped like a square and borders the Gulf of Guinea in the north Atlantic Ocean to the south and five other African nations on the other three sides, with a total of 3,110 km of borders: Liberia to the southwest (716 km), Guinea to the northwest (610 km), Mali to the north-northwest (532 km), Burkina Faso to the north-northeast and Ghana to the east (668 km) (Figure 71). In total, Côte d'Ivoire comprises 322,460 km², of which 318,000 km² is land and 4,460 km² is water, which makes the country about

the size of Germany. The climate of Côte d'Ivoire is generally warm and humid, ranging from equatorial in the southern coasts to tropical in the middle and semi-arid in the far north. There are three seasons: warm and dry (November to March), hot and dry (March to May), and hot and wet (June to October). Temperatures average between 25 and 30°C and range from 10 to 40°C. Rainfall is heavy, particularly in the low coastal region; the rainy season is from May to October (en.wikipedia.org/wiki/Geography_of_Côte_d'Ivoire).

Agriculture

Agriculture is the main economic activity of Côte d'Ivoire. One of the most important crops for countries like Côte d'Ivoire and Ghana is cacao, which is grown in the fertile soil of the wet areas. Eight percent of the country is arable land. Agricultural activities are undertaken almost completely on small-scale farms with an average area of 4 ha. The techniques used on the farms are traditional, as most (72%) of the farm heads are illiterate; only 0.95% of farms use tractors, 4.4% use animal traction, and 18% of these farms are run by women. Irrigated land represents only 2% of the total cultivated land (Minagra 1999).

Maize and yams are consumed and produced predominantly in the north, yam in the central regions and cassava and plantain in the south. Rice is consumed in all regions, but half of the 600,000 t national consumption is imported. Small-scale family farms are the rule for traditional cocoa and coffee export crops, whereas large plantations are dominant in bananas, rubber, palm oil and pineapple, but the share of plantation agriculture is relatively small. Coffee and cocoa dominate the country's agriculture. Although Côte d'Ivoire does not have the reputation of being an animal-raising country, 40% of its farms combine agriculture and some animal raising. Animal production is concentrated in the north with 85% of total cattle (Hiey 2003).

About pigeonpea

Although pigeonpea is cultivated as a minor crop by farmers in Côte d'Ivoire (Nene et al. 1989; Nyabyenda 1987; and van der Maesen 1983, 1986), most upland rice farmers in West Africa cultivate pigeonpea as weed-suppressant nitrogen-fixing legume as fallow after rice harvesting in slash-and-burn systems of the humid forest zone. Pigeonpea was able to slow the yield

decline of rice and suppress weed growth in rice fields. Moreover, pigeonpea as fallow crop will improve water infiltration and N retention in the upland vegetation of Côte d'Ivoire (Bognonkpe 2004). Likewise, the combination of pigeonpea with rock phosphate application and with the use of the modern upland rice cultivar WAB 56-50 was able to maintain the yield of upland rice at 3.0 t/ha (Cuero 2006).

In addition, pigeonpea was found to suppress dicot weeds, with a 6 months fallow established in an intercropping system, and was able to increase the yield of upland rice by up to 67% (Akavou et al. 2002). The use of weed suppressing cover legumes as short-duration fallow offers the potential to sustain rice yields under intensified cropping. The farmers involved in various participatory technology evaluations in Côte d'Ivoire expressed interest in using fallow legumes such as pigeonpea in their own upland rice-based systems in the forest zone. They selected the legume species on the basis of labor considerations such as ease of land clearing and weed suppression, but also on the basis of yield effects (WARDA 1999).

Pigeonpea as a fallow crop improves water infiltration and N retention in the upland vegetation (Bognonkpe 2004). The pigeonpea cultivar IDESSA-red of Côte d'Ivoire is a strongly branching red-seeded perennial shrubby type that can reach 3-4 m in height. It develops a deep and strong root system with well-developed lateral roots in the surface soil layer and is nodulated by the cowpea group of rhizobium. Pigeonpea seeds were dibble-seeded at 1-2 seeds/hill at 25x25 cm spacing into the interspaces of the stubbles, 2-5 days after rice harvest (Cuero 2006).

Egypt

Geography

Situated in the north-eastern corner of Africa, bounded by the Mediterranean Sea on the North and the Red Sea on the East, with the Sinai Peninsula constituting a link to Southwest Asia, Egypt enjoys a unique, strategic location at the crossroads between Africa, Middle East and Europe. Egypt, with geographic coordinates of 22°1' N to 31°21' N latitude and 24°52' E to 35°46' E longitude, is located in the northern part of Africa, covering 1 M km² of land. However, it includes the Sinai Peninsula, which is considered part of Southwest Asia. Therefore, Egypt is located in both North Africa and

Southwest Asia. It borders Libya to the west, Sudan to the south, and the Gaza Strip and Israel to the east (Figure 71). The Geography of Egypt can be split into two general sections, the ‘black land’ and the ‘red land’. The ‘black land’ was the fertile land on the banks of the Nile. The ancient Egyptians used this land for growing their crops. This was the only land in ancient Egypt that could be farmed because a layer of rich, black silt was deposited there every year after the Nile flooded. The ‘red land’ was the barren desert that protected Egypt on two sides (en.wikipedia.org/wiki/Geography_of_Egypt).

Agriculture

Egypt is predominantly desert. An area of only 35,000 km² — 3.5% of the total land area — is cultivated and permanently settled. Most of the country lies within the wide band of desert that stretches from Africa’s Atlantic Coast across the continent and into southwest Asia (en.wikipedia.org/wiki/Geography_of_Egypt). Agriculture is one of the main sources of income in Egypt where one third of the population is employed in the agro-sector. But many producers are living in the poorest areas of Upper Egypt, or in the desert and the oases, and are marginalized from the principal local and international trade channels (www.cospe-egypt.org/agriculture).

Practically all Egyptian agriculture takes place in some 25,000 km² of fertile soil in the Nile Valley and Delta. The land is worked intensively and yields are high. Cotton, rice, wheat, corn, sugarcane, sugar beets, onions and beans are the principal crops. The Egyptians likewise cultivate barley, chickpeas, flax and other types of vegetables, fruits, flowers and cotton for export. The most common traditional farms occupy 4,000 m² each, typically in a canal-irrigated area along the banks of the Nile (en.wikipedia.org/wiki/Economy_of_Egypt).

About pigeonpea

Nene et al. (1989), Nyabyenda (1987) and van der Maesen (1983, 1986) have identified pigeonpea in this country as a minor crop. At present, pigeonpea is still grown as a hedge crop by some farmers along the Upper Nile. Locally called gunga pea and gandule, pigeonpea landrace is yellowish brown in texture with a mildly pungent flavor and tough outer skin, and requires longer cooking time (www.naturalpedia.com/Egypt).

The place of origin of pigeonpea has been the subject of much speculation. Alphonne de Cadolie considered pigeonpea a native to tropical Africa. However, remains discovered in tombs testify to pigeonpea culture in Egypt between 2,200 and 2,400 BC. It is assumed that pigeonpea was carried by traders from India or Ceylon. Ancient Egypt had established trade relations with tropical Africa to the south and Syria to the east by 2,000 BC, exporting dried pigeonpeas (www.nhm.ac.uk/seeds).

In 1975, Habib et al. studied the phytochemical and nutritional component of pigeonpea (*Cajanus indicus* spreng.) cultivated in Egypt. In this study, pigeonpea contained 25.2 g protein, 170 mg calcium and 8.9 mg iron. The pigeonpea, whether raw or cooked was deficient in amino acids such as methionine, cystine and tryptophan while other amino acids were present in amounts higher than that given by the FAO provisional pattern. However, cooking pigeonpea increases threonine, leucine and isoleucine. It was also observed that cooking the seeds destroyed the trypsin inhibitors and haemagglutinins found in the seeds.

Ethiopia

Geography

The Federal Democratic Republic of Ethiopia (FDRE) is a landlocked country in the horn of Africa, bounded to the north by Eritrea, to the west by Sudan, to the south by Kenya and to the east by Somalia and Djibouti; it lies within the tropics between 3°52' N to 14°51' N latitudes and 32°57' E to 47°48' E longitudes (Figure 71). It covers 1.12 M km² in nine regional states, one City Council and one City Administration. The topographic diversity of the country has resulted in the formation of a multitude of agro-ecological zones and sub zones with varied farming systems. The main Ethiopian plateau is characterized by broad rolling uplands, immense cultivation with good soil. In June–September the landscape is green. In December, it is yellow-tan with ripe grain and stubble. In March, it is grey – black ploughed fields of traditional subsistence farms (Mengistu 2003).

Ethiopia, being near the equator and with an extensive altitude range, has a wide range of climatic features suitable for different agricultural production systems. The climate is temperate on the plateau and hot in the lowlands. At Addis Ababa, which ranges from 2,200 to 2,600 m, maximum temperature is

26°C (80°F) and minimum 4°C (40°F). The weather is usually sunny and dry with the short (belg) rains occurring February-April and the big (meher) rains beginning in mid-June and ending in mid-September.

According to FAO (1984a) rainfall in Ethiopia is generally correlated with altitude. Middle and higher altitudes (above 1,500 m) receive substantially greater rainfalls than do the lowlands, except on the western part of the lowlands where rainfall is high. Generally average annual rainfall of areas above 1,500 m exceeds 900 mm. In the lowlands (below 1,500 m) rainfall is erratic and averages below 600 mm. There is strong inter-annual variability of rainfall all over the country. Despite variable rainfall, which makes agricultural planning difficult, a substantial proportion of the country gets enough rain for rainfed crop production (FAO 1984b).

Agriculture

Agriculture in Ethiopia is the foundation of the country's economy, accounting for 41% of gross domestic product (GDP), 80% of exports, and 80-85% of the labor force is employed in agriculture, especially in farming. Livestock and their products account for about 20% of agricultural GDP. The dominant agricultural enterprises in all agro-ecological zones are small-scale subsistence farms in the highlands and livestock rearing in the lowlands. Crops and livestock production are an important recipe in the farming system of the country. Smallholders, the backbone of the sector, cultivate 95% of the cropped area and produce 90-95% of cereals, pulses and oilseeds. Subsistence agriculture is almost entirely rainfed and yields are generally low (Mengistu 2003). In 2006, GDP on agriculture has increased to 47%, likewise, its cultivated land has jumped to 17% of total national land area as compared to the data obtained in 2003 (Bureau of African Affairs 2008).

Of Ethiopia's total land area of 1.2 M km², 15% was under cultivation and 51% was pastureland. It was also estimated that over 60% of the cultivated area was cropland. Smallholder farmers cultivate 10 M ha (8%) and about 3.1 M ha are fallow. The total area of grazing and browse is estimated to be 61–65 M ha, of which 12% is in mixed farming and the rest in pastoral areas (Alemayehu 1998a, MoA 2000). Land holdings are small and often fragmented into many parcels. Farms of less than a hectare comprise more than 26% of agricultural land; almost 60% is in holdings of less than two hectares and the rest in holdings between 2–2.5 ha (Mengistu 2003).

Crop production by area is predominantly cereals (84.55%) followed by pulses (11.13%) and others (4.32%). Five crops account for almost all cereal production: maize (15.75%), teff (*Eragrostis tef*) (25.78%), barley (12.29%), sorghum (12.39%) and wheat (10.76%) (CSA 1999). The principal grains are teff, wheat, barley, corn, sorghum and millet. Exports are almost entirely agricultural commodities, and coffee is the largest foreign exchange earner. Ethiopia is Africa's second biggest maize producer and the livestock industry is believed to be the largest in Africa, and as of 1987 accounted for about 15% of the GDP (Thomas and Berry 1991).

Ethiopia's agriculture is plagued by periodic drought, soil degradation caused by overgrazing, deforestation, high population density, high levels of taxation and poor infrastructure (making it difficult and expensive to get goods to the market). Yet agriculture is the country's most promising resource. A potential exists for self-sufficiency in grains and for export development in livestock, grains, vegetables and fruits (en.wikipedia.org/wiki/Agriculture_in_Ethiopia).

About pigeonpea

Pigeonpea research in Ethiopia started early in the 1970s by the Institute of Agricultural Research (IAR) at Nazret National Horticultural Centre, with short-duration cultivars introduced from Makerere University, the Dominican Republic and later from Guyana, IITA and ICRISAT-India (Amare Belay, personal communication). The pigeonpea improvement program started with germplasm introduction from ICRISAT and neighboring countries. The main objective was to identify high yielding, disease and pest tolerant cultivars. Pure lines such as NPP610, RK101, TRT201 were identified for cultivation (Onim 1981). During 1973-77, the Welayta Agricultural Development Unit (WADU) in southern Ethiopia, Kobo in northern Ethiopia and Humera in northwestern Ethiopia tested the introductions of pigeonpea in nurseries, variety trials, and national yield trials at Nazret, Arekasa, Adam and Koko in Central Ethiopia. Yields were inconsistent in different years at most locations except at WADU and to some extent at Melkasa. Further evaluations of local and exotic collections from the Genetic Resources Unit of Ethiopia, International Livestock Centre for Africa (ILCA) and ICRISAT were conducted between 1986 and 1990. Most of these cultivars have yet to reach many farmers due to inadequate extension and seed production and distribution systems. Little information is available on the status of traditional Ethiopian

varieties, local preferences for seed size and color, and farmers' reactions to the new short-duration cultivars (Kimani 2001).

Importance and uses of pigeonpea

Pulses are the second most important element in the national diet and a principal protein source in Ethiopia. They are boiled, roasted, or included in a stew-like dish known as *wot*, which is sometimes a main dish and sometimes a supplementary food item. Pulses, grown widely at all altitudes from sea level to about 3,000 m, are more prevalent in the northern and central highlands.

In Ethiopia, pigeonpea is grown as a minor crop (Kamanga and Shamudzarira 2001; Nene et al. 1989; Nyabyenda 1987; and van der Maesen 1983, 1986) with 14 accessions (Upadhyaya 2007). Production systems of pigeonpea are as complex as the agro-ecological zones, and amplified further by the cultural diversity of people. Three factors contributed to the decline in the relative importance of this crop. First, the recurring droughts had devastated the main areas in the country where pigeonpea was produced. Second, because peasants faced food shortages, they gave priority to cereal staples to sustain themselves. Finally, although the production cost of pigeonpea continued to rise, the government's price control policy left virtually unchanged the official procurement price of this crop, thus substantially reducing net income from them. Subsequently, production of pigeonpea failed to improve, by 1988 the output index, whose base year was 1972 (100), was 85.3. Given the country's economic and political problem, there was little prospect of improvement.

Nevertheless, with the identified constraints, smallholder farmers have found pigeonpea an important crop because of its diverse characteristics. The country, which is occasionally confronted by drought, has found the crop to be a subsistence crop among smallholder farmers. As has already been mentioned, pigeonpea has multiple uses, the seeds are used for human food or for poultry production while the stover is used for fodder and the stem as fuel wood.

Pigeonpea is intercropped between rows of annual crops. They can be sown at the same time as the crop if they do not compete too strongly with its growth. If they do compete, the farmer may be prepared to cut them back and

feed as fodder to livestock during the early growing season, or, alternatively, may plant the legume two to four weeks after the cash crop. Perennial and late-maturing cultivars would then continue to grow after maturation of the main crop, producing additional fodder. Perennials, which can persist through the dry season, are particularly useful as they will produce some growth in response to any showers during the dry season and this growth can be grazed as standing hay or used for cut-and-carry fodder. In the following growing season the farmer will have a number of options in the management of his perennial legume (Lazier 2008).

In 2001, Annen stated that 200 hectares of pigeonpea contour hedges was established in Woldya, Ethiopia benefiting farmers from sale of forage, sale of seeds and use of pigeonpea seeds as food. Pigeonpea plays an important role in small farms for they can provide natural fencing, fuel, construction material, food and fodder. They may be planted around fields and houses in rows or broadcast in pastures, or in rows in cropped land (alley farming) where the leaves can be used as a fertilizer or mulch, cut and carried as feed, and grazed *in situ* during fallow periods (Lazier 2008).

Annen (2001) also stressed that pigeonpea-mounted contour soil bunds pass three key sustainability tests namely, providing forage and other visible benefits that include diminished soil erosion, increased plant residue left in the soil, and increased soil moisture retention that can contribute to increased productivity; avoiding the problem of rat infestation associated with stone bunds; and significantly lower costs of construction and maintenance as compared to stone bunds.

Lazier (2008) also revealed that pigeonpea is so diverse in utilization for the livestock industry because the crop can be used as pure sward grazed; grass-legume mixture grazed; reserve fodder; cut and carry; and food and fodder.

Eritrea

Geography

Eritrea is located in the Horn of Africa with geographic coordinates of 12°12' N to 17°48' N latitude and 36°23' E to 43°3' E longitude and is bordered on the northeast and east by the Red Sea, on the west and northwest by

Sudan, on the south by Ethiopia, and on the southeast by Djibouti (Figure 71). The country with a total area of 124,320 km² has a high central plateau that varies from 1,800 to 3,000 masl. Coastal plain, western lowlands and some 300 islands comprise the remainder of Eritrea's land mass. Eritrea has no year-round rivers. The climate is temperate in the mountains and hot in the lowlands. Maximum temperature is 26°C (80°F). The weather is usually sunny and dry, with the short (belg) rains occurring February-April and the big (meher) rains beginning in late June and ending in mid-September of up to 610 mm of rainfall annually (en.wikipedia.org/wiki/Geography_of_Eritrea).

Agriculture

Eritrea has 391,000 ha of arable land and 2,000 ha under permanent crops. Three-quarters of Eritrea's people are subsistence farmers dependent on unreliable rainfall to feed families that average seven children. Although these farmers have experienced relative peace and good harvests since May 1991, food production has not been able to keep pace with a rapidly expanding population. Harvests have been variable due to rainfall variations and pest infestations. Principal crops in 1999 included sorghum, millet, barley, wheat. Legumes, vegetables, fruits, sesame and linseed are also grown (www.nationsencyclopedia.com/Africa/Eritrea-AGRICULTURE).

About pigeonpea

Pigeonpea in Eritrea has been cultivated as a minor crop (Silim et al., 2001). In the Central Highlands, the great majority of producers have small land holdings (average 1 ha or less), and produce mainly wheat, barley, sorghum, teff (*Eragrostis tef*), peas (including pigeonpea), beans, chickpeas and linseed. The legume fodder shrubs have great potential as a source of protein and minor nutrients, to supplement diets of large and small ruminants normally fed nutritionally unbalanced and low digestibility roughage such as natural pasture, stubble and untreated crop residues. The shrub *Cajanus cajan* has a very great potential for use in both the Central Highlands Zones (CHZ) and in valley beds of the Western Lowlands, in areas with 600 mm and over of rainfall (Kayouli et al. 2006).

Gambia

Geography

The Gambia (the last country in Western Africa) is a very small and narrow country with the border based on the Gambia River. With geographic coordinates of 13°9' N to 13°45' N latitude and 13°58' W to 16°52' W longitude, the country is less than 48 km wide at its greatest width. Apart from its coastline, where the Gambia borders the Atlantic Ocean, it is an enclave of Senegal and by far the smallest country on the continent of Africa (Figure 71). The climate is tropical. It has a hot rainy season from June to November and a cooler dry season from November to May (en.wikipedia.org/wiki/Geography_of_The_Gambia).

Agriculture

About three fourths of the people live in rural villages that depend on crops and livestock for its livelihood. The main natural resource is the Gambia River. The country's soil is mostly poor and sandy, except in the swamps. The land is ideal for peanuts, which the economy depends on (Bradshaw 1997).

The Gambia's economy is characterized by traditional subsistence agriculture, a historic reliance on peanuts or groundnuts for export earnings. Agricultural products aside from peanuts are pearl millet, sorghum, rice, maize, cassava, palm kernels, cattle, sheep and goats. Agriculture accounts for 23% of gross domestic product (GDP) and employs 75% of the labor force. Within agriculture, peanut production accounts for 5.3% of GDP, other crops 8.3%, livestock 4.4%, fishing 1.8% and forestry 0.5%. The limited amount of manufacturing is primarily agriculture based (eg, peanut processing, bakeries, a brewery and a tannery) (en.wikipedia.org/wiki/Economy_of_the_Gambia).

About pigeonpea

The only documented literature on pigeonpea in Gambia are from Nene et al. 1989; Nyabyenda 1987; and van der Maesen 1983, 1986, where the plant is said to be grown as a minor and exotic crop for subsistence farmers.

Ghana

Geography

Ghana, once called the Gold Coast, is situated in south-central Western Africa, south of the Sahara and north of the Equator on the Gulf of Guinea. The country has an area of 238,530 km² and lies between 4°54' N to 10°55' N latitude and 0°42' E to 3°15' W longitude. It is bordered on the east, west and north by the Republics of Togo, Cote d'Ivoire and Burkina Faso, respectively. On the south it is bordered by the Atlantic Ocean (Figure 71) (Ghana Country Report 1996, Iddrisu and Telly 1999).

The mean annual rainfall in Ghana is 1,473 mm. The rainfall pattern is bimodal, the rainy season starts in March and ends in October, with a short dry spell in August with peaks in June and September (FAO-UNESCO 1990). It has two rainy seasons: March to July and September to November with a rainfall of 1,200–1,600 mm (Ghana Country Report 1996).

Agriculture

Agriculture in Ghana is predominantly on smallholder basis. About 90% of farm holdings are less than 2 ha, although there are large farms and plantations particularly for rubber, oil palm and coconut and to a lesser extent, rice, maize and pineapples. Agricultural production is still widely based on traditional farming practices such as slash and burn and shifting cultivation. Most food crop farms are intercropped. Monocropping is mostly associated with large-scale commercial farms. In the northern part of the country almost every crop farmer also keeps livestock (Adongo 2006).

Agriculture is vital to the overall economic growth and development of Ghana and it is the largest contributor to the Gross Domestic Product (GDP), accounting for about 55%. About 52% of the population live in rural areas and derive their income from agriculture and related activities. The agricultural sector consists of crops, livestock, fisheries and the cocoa sectors. One of the most important crops is cacao, which is grown in the fertile soil of the wet areas. About half of the country's total cultivated land area is under cocoa, followed by cereals (25%), and roots and tubers (20%). The bulk of farmers are smallholders who account for about 80% of the agricultural production. Average holding is less than 1.5 ha. Shifting cultivation is widely practiced and subsistence farming is common in the rural areas. In recent years a few

commercial farms have been initiated and have started exporting pineapples, mangoes, pepper and yams. Cocoa accounts for 18% of agricultural GDP and other crops for 62%, livestock for about 7%, fishing for about 3% and forestry about 7%. The principal food crops are maize, cassava, plantain, yam, cocoyam, rice, sorghum and millet. Maize accounts for 50–60% of the total cereal production. Vegetables include pepper, eggplant, tomato, okra and beans. The country's important cash crops are cocoa, oil palm, cotton, coconut, tobacco, groundnut and rubber. Productivity is low mainly because of low fertility of the land, limited use of available technical packages, non-timely delivery of inputs (particularly fertilizers), and poor credit availability (Ghana Country Report 1996, Bradshaw 1997, Afikorah-Danquah 2006, Adjei-Nsiah et al. 2006).

About pigeonpea

According to Upadhyaya (2007), there are 2 accessions of pigeonpea and introductions of these various crops are being tested and utilized in breeding programs to produce cultivars that are resistant to pests and diseases. Cultivated as a minor crop in the country (Nene et al. 1989; Nyabyenda 1987; and van der Maesen 1983, 1986), pigeonpea, a multi-purpose species, is extensively used as food grain and green manure crop for soil fertility amelioration in local cropping systems (Yeboah et al. 2000). But according to Berkel (2008), pigeonpea is amongst the main crops grown in Ghana.

There are, however, a few instances in West Africa, such as in Ghana, where the use of pigeonpea has become unpopular among farmers due to its low and variable yield as well as its inability to redress soil fertility sufficiently in the long-term (Juo et al. 1996). Scientists in West Africa have developed biological management practices, which have the potential to address the problem of low soil productivity in the region (Peoples and Craswell 1992, Sanchez and Salinas 1981). The native farmers of Ghana who own land tend to use rotations involving long-duration crops such as cassava and pigeonpea to improve their soils. Yield of maize without N application was higher after cassava and pigeonpea compared to that after speargrass fallow, cowpea or maize in both researcher and farmer-managed experiments (Adjei-Nsiah 2006).

Crop and livestock production in the Guinea savanna zone of northern Ghana has been declining over the past years as a result of increasing pressure on

land. To sustain soil productivity, pigeonpea, a leguminous perennial crop was evaluated for its potential as a short duration fallow crop for fodder and grain, and maize production. Considering the biomass of pigeonpea from pruning at 60 cm, pigeonpea seed yield and maize grain yield after the pigeonpea is the most promising regime for crop-livestock production systems (Agyare et al. 2002). In this same region, maize/pigeonpea intercropping in a 3:1 row ratio proportion proved to be ideal (Sharma and Sowley 1984).

Feeding has long been the most potent tool by which man manipulates productivity in his domestic animals and sheep/goats are no exception. Boundary planting of shrubby legumes (eg, pigeonpea) around homesteads and farms are used for cut and carry feeding for livestock (sheep and goat). Animal feeding constitutes one of the major constraints facing sheep and goat production in Ghana not in terms of scarcity of grazing area but the attitude of livestock farmers to the question of effective pasture utilization. Feeding trials conducted at the Techiman Sheep and Goat Diseases Investigation Farm confirmed the fact that pigeonpea is a valuable source of protein that can contribute greatly towards the improvement of nutritional conditions of sheep and goats in Ghana. From our investigations, pigeonpea proved to be the best solution that will benefit the farmer himself — it can be effectively incorporated in the diet of the animals as well as alleviate the problems of dry season feeding, since it has a very good drought resistant ability; the leaves, with a very high protein content, can be effectively used as animal feed and the farmer can consume or sell the seeds (Ockling 1987).

Guinea

Geography

Guinea with geographic coordinates of 7°11' N to 12°22' N latitude and 7°54' W to 15°7' W longitude is located on the Atlantic Coast of West Africa and is bordered by Guinea-Bissau, Senegal, Mali, Côte d'Ivoire, Liberia and Sierra Leone (Figure 71). The country is divided into four geographic regions with a total land area of 245,857 km²: A narrow coastal belt (Lower Guinea); the pastoral Fouta Djallon highlands (Middle Guinea); the northern savanna (Upper Guinea); and a southeastern rain-forest region (Forest Guinea). The Niger, Gambia, and Senegal Rivers are among the 22 West African rivers that have their origins in Guinea. The coastal region of Guinea and most of the inland have a tropical climate, generally hot and humid, monsoonal-

type rainy season (June to November) with southwesterly winds; dry season (December to May) with northeasterly harmattan winds. Conakry's year-round average high is 29°C (85°F), and the low is 23°C (74°F); its average annual rainfall is 4,300 mm. Sahelian Upper Guinea has a shorter rainy season and greater daily temperature variations (en.wikipedia.org/wiki/Geography_of_Guinea).

Agriculture

In Guinea, only 2.6% of the country's arable land area is cultivated, yet agriculture accounts for 24% of the total GDP and employs 84% of the economically active population. The main subsistence crops are manioc, rice, sweet potatoes, yams and corn. The economy of Guinea also depends on cash crops such as sugarcane, citrus, bananas, pineapples, peanuts, palm kernel, coffee and coconuts (en.wikipedia.org/wiki/Agriculture_in_Guinea). Guinea also has considerable potential for growth in the agricultural and fishing sectors. Land, water and climatic conditions provide opportunities for large-scale irrigated farming and agro-industry. Possibilities for investment and commercial activities exist in all these areas, but Guinea's poorly developed infrastructure continues to present obstacles to investment projects (en.wikipedia.org/wiki/Economy_of_Guinea).

About pigeonpea

Nene et al. (1989), Nyabyenda (1987) and van der Maesen (1983, 1986) stated that pigeonpea is considered as a minor subsistence crop grown by small-scale farmers of Guniea. Pigeonpea, locally known as red gram congo pea and congo bean, is considered a native to tropical Africa where the crop travelled from Zanzibar to Guinea (www.soupsong.com/fpigeonp).

Guinea-Bissau

Geography

Almost wedged between Senegal in the North and Guinea in the South and East, Guinea-Bissau is a small sub-Saharan African country on the West African coast (Figure 71). The country is geographically located 10°55' N to 12°38' N latitude and 13°42' W to 16°41' W longitude measuring 36,125 km². The tropical climate varies between Guinean on the coastal areas to

Sudanese in the interior. This means it is generally hot and humid. It has a monsoonal-type rainy season (June to November) with southwesterly winds and a dry season (December to May) with northeasterly harmattan winds. Rainfall ranges from 1,200 to 2,600 mm with a concentration in July-September. Soil fertility is generally low, compounded by susceptibility to erosion. The average temperature is 20°C (De Amarante 2002, CIA 2002, en.wikipedia.org/wiki/Geography_of_Guinea_Bissau).

Agriculture

One of the 10 poorest countries in the world, Guinea-Bissau depends mainly on farming and fishing. Guinea-Bissau, a former Portuguese colony, is a small country to the west of Guinea. Its population is only 1.2 M people. Most of these people are subsistence farmers. It is estimated that 1.1 M ha are cultivable and another 180,000 ha are suitable for mangrove rice cultivation. Cashew crops have increased remarkably in recent years, and the country now ranks sixth in cashew production. Guinea-Bissau exports fish and seafood along with small amounts of peanuts, palm kernels and timber. Rice is the major crop and staple food (CIA 2002, en.wikipedia.org/wiki/Geography_of_Guinea_Bissau).

Rice, cassava, beans, sweet potato, yam, sugarcane and tropical fruits are the principal crops in the country. Of these crops, rice — grown in the south and west — is the most important one covering a third of the arable land. The most important export crops are cashews, groundnuts, palm kernels and cotton. Cattle ranching is very common in the interior of Guinea-Bissau. Manufacturing is limited to the processing of raw materials and production of basic goods (De Amarante 2002, Bradshaw 1997).

Land degradation and deforestation are the primary economic and environmental problems in Guinea-Bissau. Food security is in a precarious state because it imports or receives in aid significant proportions of the food domestically consumed. The subsistence agricultural production is constrained by the rudimentary technology utilized by smallholders. Small-scale village-based traditional agricultural farm plots make up the so-called *tabancas* while *pontas* constitute the commercial private land concessions that are much larger in size. There are an estimated 85,000 to 90,000 families and around 2,200 *pontas* with an average size of 113 ha as opposed to much smaller average size of the traditional holdings. Most farmers of all ethnic

groups keep some livestock but it is the Fula and Mandinga, concentrated in the eastern and northeastern regions, which depend more on livestock and have the bulk of the country's herd. The main constraints to the expansion of present livestock systems are the poor health of animals and the shortage of pastures and water during the long dry season. The absence of a meat-marketing network is another constraint to increasing productivity (De Amarante, 2002).

About pigeonpea

In this part of West Africa, pigeonpea, locally known as crioulo, feijão and congo pea, has not been documented as to its utilization and importance but local people grow the crop in minor quantities either as homegarden or at the boundaries of their homestead and farms (Nene et al. 1989; Nyabyenda, 1987; and van der Maesen, 1983, 1986).

Liberia

Geography

Liberia, located west of the Ivory Coast, is rectangle in shape, similar to El Salvador. Liberia is a large sub-Saharan nation in West Africa located at 4°18' N to 8°29' N latitude, 7°33' W to 11°36' W longitude with a total area of 111,370 km² bordering the North Atlantic Ocean, between Cote d'Ivoire, Guinea and Sierra Leone (Figure 71). Liberia has a mostly hilly terrain, from rolling plains along the coast to a rolling plateau and low mountains in the northeast. Liberia has a tropical climate. This means it is hot and humid throughout much of the year. The seasons are split into dry winters with hot days and cool to cold nights and wet, cloudy summers with frequent and heavy showers (Bradshaw 1997, CIA 2008c, en.wikipedia.org/wiki/Geography_of_Liberia).

Agriculture

In 2005, the estimated arable land of Liberia was pegged at 3.43%, 3% permanent crops and 1.98% permanent pastures (en.wikipedia.org/wiki/Geography_of_Liberia, CIA 2008c). Liberia's agricultural production is primarily aimed toward subsistence, providing enough food for individual farmers to survive. Liberia's main staple food is rice, but the country has low

yields despite improvements arising from new varieties. Rubber is the most important cash crop, though cocoa, coffee, sugarcane, cassava, bananas, plantains, citrus, pineapple, sweet potato, rice, corn, vegetables and palm oil are also produced. Liberia's GDP under agriculture in 2002 is about 76.9%. Coffee and cocoa are the export commodities (Encyclopedia of the Nations 2008).

About pigeonpea

Even with no accession identified in Liberia, Nene et al. (1989), Nyabyenda (1987) and van der Maesen (1983, 1986) considered this country as a minor producer of pigeonpea for subsistence farming. Interestingly, Liberia imports pigeonpea from neighboring countries like the Sierra Leone. However, in some cases, such as in the case of Mr Fasineh Kaba (a businessman from Kabala), he exported 10 bags (approximately 500 kg) of pigeonpea in Sierra Leone in mid 2008 (www.kiva.org).

Madagascar

Geography

Madagascar is an island in the Indian Ocean, off the eastern coast of southern Africa, east of Mozambique (Figure 71). The country with geographical coordinates of 12°7' S to 25°38' S latitude, 43°3' E to 50°37' W longitude, is the fourth largest island in the world. It has a total area of 587,040 km², with 581,540 km² of land, and 5,500 km² of water. The climate is tropical along the coast, temperate inland, and arid in the south. Madagascar has two seasons: a hot, rainy season from November to April; and a cooler, dry season from May to October (en.wikipedia.org/wiki/Geography_of_Madagascar).

Agriculture

Madagascar is classified among the world's poorest countries. The main activity is agriculture but it is constituted by a multitude of small exploitations mainly aimed at subsistence. Madagascar agriculture is typified by a multitude of small units (average cultivated area 1.2 ha), which involves several activities (crops and livestock) the products of which are mainly aimed at domestic subsistence (EPM 1999). Nevertheless, during recent years, the macro-economic situation has improved, the growth rate being 6.7%. The

economy is based on a number of classic export products (coffee, vanilla, cloves, seafood, etc) and the income from tourism, mines, manufacturing industries oriented to export). Several factors limit the rapid expansion of the economy, particularly the poor performance of agriculture, difficult access for producers to various markets: the state of the roads is such that farmers prefer to consume their production.

Agriculture is the main income source of the population and that population expends 70% of its income on food. Studies carried out in 1999 show that 91.6% of the stock-owning families practiced agriculture (EPM 1999). Rice is the staple food of the Malagasy population, but yields are stationary at about 2 t/ha (consumption estimated at 113.5 kg annually/inhabitant, one of the highest in the world). Foodstuff also absorbs 40% of all food expenditure. Protein of animal origin is consumed at the level of 22.4 kg annually/inhabitant. In 2000, agriculture represented about 35% of the GDP (Ministère des Finances 1999).

Traditional farming methods vary from one ethnic group or location to another, according to population density, climate, water supply and soil. The most intensive form of cultivation is practiced among the Betsileo and Merina groups of the central highlands, where population densities are the highest. At the other extreme are the extensive slash-and-burn methods of brush clearing and shifting cultivation in the south and the east. A similar system of shifting cultivation is practiced in the arid, sparsely populated regions of the extreme south and southwest. The dry brush or grassland is burned off, and drought resistant sorghum or corn is sown in the ashes. In the Antandroy and some Mahafaly areas, however, the main staples of subsistence—cassava, corn, beans and sorghum—are also grown around the villages in permanent fields enclosed by hedges.

In 1984-85, only 5.2% (3 M ha) of the country's total land area of 58.2 M ha is under cultivation; of this hectarage, less than 2 M ha are permanently cultivated. Agriculture is critical to Madagascar's economy in that it provides nearly 80% of exports, constituting 33% of GDP in 1993, and in 1992 employed almost 80% of the labor force (en.wikipedia.org/wiki/Economy_of_Madagascar).

About pigeonpea

Nene et al. (1989), Nyabyenda (1987) and van der Maesen (1983, 1986) have recognized Madagascar as one of the minor producing countries of pigeonpea in Africa. From very early times, pigeonpea was cultivated along with other crops and is also used as anti-erosion strips by smallholder farmers. The crop also serves as a host for silkworm and the *lac* insect, and the leaves are used to clean teeth ([best-home-remedies.com/herbal_medicine/grains&pulses/pigeon_pea](http://best-home-remedies.com/herbal-medicine/grains&pulses/pigeon_pea), van der Maesen 2006). According to Upadhyaya (2007), only one accession has been recorded growing in the country.

Madeira

Geography

Madeira is a Portuguese archipelago in the North Atlantic Ocean with geographic coordinates of 39°30' N latitude and 8°00' W longitude. It is one of the autonomous regions of Portugal, with Madeira Island and Porto Santo Island being the only inhabited islands (Figure 71). Although located in the African Plate, about 650 km off the North African coast, Madeira belongs and has always belonged ethnically, culturally, economically and politically to Europe, about 955 km from the European mainland. Madeira Island's geographical position and mountainous landscape result in a very pleasant climate, which varies between the north side, south side and smaller island groups such as Porto Santo and Savages. The island of Madeira is wet in the northwest but dry in the southeast. The mean annual temperature in the south coastline can reach more than 20°C. Air temperatures fluctuate between 16°–19°C in winter and 21–25°C in summer. Madeira has a fairly dry climate with around 80 days of rain each year, most of which occurs during the winter months and usually altitudes of between 700 m and 1,350 m (en.wikipedia.org/wiki/Geography_of_Madeira).

Agriculture

Agriculture in Madeira is fundamentally based on three platforms. Cattle raising, which provides abundant fertilizer for the land; terrace planting, which produces the amazing staggered terraces visible on so many steep mountainsides; the excellent irrigation systems provided by the extensive

'levada' systems, which allow for more productive crops. Even the driest areas of the island are provided with adequate water through these 'channels' to ensure abundant crops. The climatic conditions on Madeira, coupled with the mountain relief, allow for an enormous assortment of crops to be cultivated. The varieties are staggered in direct relationship to the altitude. At the lowest level we find the Mediterranean crops (figs, oranges, lemons and grapes, plus cereals such as maize, wheat, rye and barley). The European fruit trees flourish in the depths of the valleys producing cherries, apples and plums. A little further up from sea level the tropical species are cultivated (bananas, sugarcane, custard fruit, mango, pineapple and passion fruit) (en.wikipedia.org/wiki/Geography_of_Madeira).

About pigeonpea

Pigeonpea has been cultivated in Madeira from very early times but it is considered a minor crop (Nene et al. 1989; Nyabyenda 1987; and van der Maesen 1983, 1986) cultivated along with other crops and is likewise used as anti-erosion strips by smallholder farmers (best-home-remedies.com/herbal_medicine/grains&pulses/pigeon_pea).

Mali

Geography

Mali, a continental country lying between 10°18' N to 25°9' N latitude and 4°18' E to 12°18' W longitude, is a landlocked nation in West Africa, located southwest of Algeria, extending southwest from the southern Sahara through the Sahel to the Sudanian savanna zone (Figure 71). At about 1.2 million km², Mali is comparable in size to South Africa (en.wikipedia.org/wiki/Geography_of_Mali). Sixty-five percent of Mali's land area is desert or semi-desert. The Sahel is nearly 1,154 km long and from 77 to 269 km wide in a span across the continent of Africa. It is an area that is gradually being taken over by the southward creep of the Sahara Desert. In the southwestern region of Mali, rainfall and rivers are more plentiful and the climate is slightly more hospitable (www.vmfa.state.va.us/mali_geo_hist).

Mali's territory encompasses three natural zones: the southern cultivated Sudanese zone, central semi-arid Sahelian zone, and northern arid Saharan zone. The terrain is primarily savanna in the south and flat to rolling plains

or high plateau (200–500 m in elevation) in the north. There are rugged hills in the northeast, with elevations of up to 1,000 m. Mali's climate ranges from subtropical in the south to arid in the north. The country is mostly dry, with 4–5 months of rainy season. January is the coldest month, with temperatures ranging from 16°C to 33°C, and April is the hottest month, with temperatures averaging 34°C–39°C. The driest months are December and January with zero rainfall. The wettest month is August, which averages 220 mm of rainfall. Most of the country receives negligible rainfall, and droughts are a recurring problem. During dry seasons, a hot, dust-laden harmattan haze is also common. Flooding of the Niger River occurs regularly in the rainy season approximately June/July–November/December (en.wikipedia.org/wiki/Geography_of_Mali).

Agriculture

The Malian economy is basically agricultural. According to estimates in 1998, only 3.8% of Mali's area can be classified as arable land, and less than 0.1% was planted to permanent crops. Mali is an agropastoral country, the rural lands, that is to say the crop and pastures land; cover 64% of the territory. Potential agricultural land covers 12 M ha of which 2.8–3.5 M ha are regularly cultivated. Each farmer gains his subsistence from the land and, secondarily, that of his livestock. The farm corresponds, consequently, to an area of land used for essentially agricultural ends. The average area of holdings varies from place to place. In south Mali with strong technical support the areas vary from 4–5 ha for unequipped farms to 27 ha for a farm with 4 or 5 or more pairs of oxen. In the west of the country (Kaarta) holdings are 2 ha for unequipped and 3–7 ha for equipped farms. In the rice-growing areas holdings are between 2 and 5 ha (en.wikipedia.org/wiki/Geography_of_Mali).

Harvest levels depend almost entirely on changes in climate and on floods of the Niger and its tributaries. Most of the production is by small farmers engaged in subsistence farming. The main food crops are millet, rice, sorghum and corn. Peanuts, cotton and sugar cane are produced for export. Livestock rearing is also very important. Most of the cereals grown are consumed locally. They suffice (except in disasters) to meet the populations needs (Mali country profile 2005).

While the majority of Malians still rely on farming as a means of food and livelihood, agriculture is becoming more difficult to sustain. In the last 30

years there have been two major droughts adding to the continual spread of the desert and the loss of more farmable land. Moreover, over the past 50 years the desert/has overrun an area roughly the size of France and Austria combined. In 2005, about 80% of the people of Mali farm (millet, sorghum, corn, rice, sugar, cotton, legumes) and fish, while 10% of the people are nomads (cattle herders) who still live on what the desert provides (www.vmfa.state.va.us/mali_geo_hist.html).

About pigeonpea

In Mali, pigeonpea is cultivated as a minor crop as reported by Nene et al. (1989,; Nyabyenda (1987) and van der Maesen (1983, 1986), and likewise stated by Versteeg and Koudokpon (1993), but growing this in a larger area is a new experience. Small-scale farmers grow local landraces in backyards as a kitchen garden. Grown as a subsistence crop, pigeonpea is often grown along with cereals and other cash crops. To this writing, there are 4 identified accessions being cultivated in Mali (Upadhyaya 2007).

In 2006, a set of 21 pigeonpea varieties were tested for seed multiplication and agronomic observations. The varieties evaluated were the early maturing ones that flower from August to September, and the late maturing ones that flower after October. Results showed that the early maturing varieties were severely affected by thrips and the late maturing varieties were severely drought stressed. However, UPAS 120, ICPL 151, ICPL 84031 and ICPL 86012 produced the highest grain weight (McKnight Foundation 2007).

Mauritius

Geography

Mauritius is situated in the southern part of Africa. It is nestled in the Indian Ocean to the east of Madagascar (Figure 71). It lies at 19°53' to 20°52' towards South and 57°7' to 57°44' towards East of the Equator. This island has a volcanic origin and is surrounded by coral reefs. Mauritius is eleven times bigger in size when compared to Washington (www.mauritiusislandhotels.com/Geography-Mauritius). Mauritius has a tropical maritime climate generally dominated by the southeast trade winds and enjoys a warm moist summer during the months of December to May and a cool dry winter from June to November.

Agriculture

Arable land and the population of fishes mainly constitute the natural vegetation of Mauritius. About 49.26% of land is used for arable purpose, 2.96% of land is used for growing permanent crops, 3% land is used by the pastures and 22% land consists of forest. The area under cultivation for food crops was only 5,494 ha in 1991 (countrystudies.us/Mauritius). Recent statistics (1993) show that sugarcane covered about 88% of the cultivable land, 7.5% was under vegetable, fruits and flowers, 3.6% under tea and 0.6% under tobacco (Port 1995). Sugar production was the backbone of the Mauritian economy until the government decided to embark on a diversification program. A variety of anthuriums, andeanums and other flowers grown on the island are exported to Europe, Asia, Australia and the United States. The European Union imports mangoes, pineapples, lychees and bananas grown in Mauritius. The high cost of freight/has driven entrepreneurs to process fruits and vegetables for the export market (www.mauritius-embassy.de/agriculture).

With the implementation of the agricultural diversification policy, sugarcane is intercropped with bean, potato, groundnut, tomato and maize. The result is encouraging; the country has produced 67% of its needs in potato, 40% in onion, 17% in garlic and 5% in maize. However, sugarcane remains the most important agricultural export followed by flowers and vegetables (Port 1995).

About pigeonpea

Wild species of pigeonpea are also known to exist in Mauritius. They are believed to have been cultivated in the past 150 years and to have been introduced by Indian immigrants (Port 1995, ILDIS 2005).

Mozambique

Geography

Mozambique is located in Southern Africa, bordering the Mozambique Channel, between South Africa and Tanzania. The country stretches for 2,470 km along Africa's southeast coast. It is bordered by Tanzania (756 km) to the north; Malawi (1,569 km), Zambia (419 km) and Zimbabwe

(1,231 km) to the west; and South Africa (491 km) and Swaziland (105 km) to the south with coordinates of 10°29' S to 26°16' S latitude and 30°14' E to 40°46' E longitude (Figure 71). The coastline extends from 26°52'S to 10°40'S, and from south to north makes a double curve with a general trend outward to the east. It has a length of 2,300 km. The country is generally a low-lying plateau with a total area of 801,590 km² broken up by 25 sizable rivers that flow into the Indian Ocean. The largest is the Zambezi, which provides access to central Africa. In 2005, the estimated total land area of 784,090 km² consists of the following: arable land, 5.43%; permanent crops, 0.29%; and others, 94.28%. Generally, the climate is tropical to subtropical with average rainfall at 600 mm/annum (en.wikipedia.org/wiki/Geography_of_Mozambique).

Agriculture

Unlike most African countries, Mozambique possesses a huge coastline, vast tracts of virgin arable land, and no landless peasants. But despite these advantages, it suffers extreme poverty. Agriculture is the backbone of the economy providing employment to over 81% of the workforce in 2007 and contributing an estimated 26.2% GDP in 2005. Mozambique has immense agricultural potential, with an estimated 36 M ha of arable land, of which only 10% is presently in productive use. The wide diversity of soil types and the diverse climatic conditions in the country are suitable for a large variety of crops (tobacco, cotton, cashew nuts, sugarcane, tea, cassava (tapioca), corn, coconuts, sisal, citrus and tropical fruits, potatoes, sunflowers). Most of the agricultural land in Mozambique is non-irrigated (www.sadcreview.com/country_profiles/mozambique/moz_agriculture).

Mozambique's agriculture is, however, strongly bipolar, split between the 3.2 M small farmers, producing 95% of agricultural GDP, and 400 (5%) commercial farms. Large commercial farms that concentrate on cash and export crops cultivate the remaining arable land. At present the agricultural sector is still dominated by the family sub-sector, which accounts for 90% of the cultivated areas and includes 2.5 M households. This sub-sector who typically farm 1-1.5 ha relies on rainfed farming and has very basic techniques resulting in low yields (www.sadcreview.com/country_profiles/mozambique/moz_agriculture).

Farming conditions are reasonable, but drought and floods often affect production particularly in the southern part of the country, which is severely semi-arid. Cashew, sugarcane, tea, cotton, coconut and tobacco are among the principal cash and export crops while maize, sorghum, cassava, groundnut, pigeonpea, various types of beans and rice are the main food and cash crops for small-scale farmers. However, among smallholders, the recent high rates of growth in production are deemed unsustainable. Till now, growth came mostly from additional hectares under cultivation since yield for basic food crops in the smallholder sector have been basically flat over the past decade due to the limited adoption and use of agricultural technologies (World Bank 2005).

Pigeonpea Cropping System, Production and Marketing

Pigeonpea in Mozambique is considered a minor crop (Nene et al. 1989; Nyabyenda 1987; and van der Maesen 1983, 1986) but almost always present in small patches often in the kitchen garden. Land area covered with pigeonpea totals to 30,000 ha or an average of 150 m² per farmer with total production of 9000 t or 300 kg/ha. The main production areas are in the sub-humid north and in the sandy coastal belt in the south. The most common type of pigeonpea found is the late-maturing and tall variety, with five large cream colored seeds per pod. The early-duration type generally brown seeded is harvested mid-May. The smallholder farmer's way of cultivating this crop is in association with other crops, which often resulted in low yields. Pigeonpea is commonly grown on the edge of fields of maize, cassava and cowpea. Pigeonpea is also intercropped with cassava, maize and other grain legumes. Very few farmers grow this crop as the sole crop. Pigeonpea is sown in December or at the onset of the rains and generally grown in 2 or more years. In the second year, pruning is done at the onset of the rainy season. Pigeonpea seeds are usually eaten green cooked as a vegetable (Heemskerk 1986). Statistics show that 17.4% of households cultivating pigeonpea are smallholder farmers with less than 10 ha, and 4.4% are those with under 50 ha (MADER 2003).

Crop diversification is very common in this country because the system is more market-oriented than the basic food crops, whose productions are complementary. Because of variations in demand and agroclimatic conditions, producers tend to grow a mixture of crops simultaneously to minimize losses in case of adverse market and growing conditions. Like basic

food crops, these crops are normally produced without inputs under rainfed conditions using farm-kept traditional seeds, unless improved varieties are provided through the extension services of NGOs. Crop yields are far lower than what can be achieved with or without inputs because of poor seed, incorrect farming practices, and post-harvest losses. Pigeonpea production from 1996 to 1998 has an average yield of 413 kg/ha for dry pods (www.tcb-project.com).

Market linkages for these smallholders are therefore stronger than for other crops and their supply elasticity is higher. Markets for diversification crops are not normally limited to local or provincial outlets. Pigeonpeas are normally exported to Malawi for processing and then exported to India. In some cases, pigeonpea could be processed in Mozambique, instead of Malawi, and directly exported to India when production has not commenced and prices are very attractive (FAO 2004).

Niger

Geography

Niger is a landlocked nation in West Africa located along the border between the Sahara and sub-Saharan regions. Its geographic coordinates are latitude 11°57' N to 23°33' N and longitude 0°10' E to 15°54' E. Its land area is 1.267 M km² and water 300 km², which is comparable to Angola. Niger borders seven countries and has a total of 5,697 km of borders. The longest border is with Nigeria to the south, at 1,497 km. This is followed by Chad to the east (1,175 km), Algeria to the north-northwest (956 km) and Mali at 821 km. Niger also has short borders in its far southwest frontier (Burkina Faso at 628 km and Benin at 266 km) and to the north-northeast (Libya at 354 km) (Figure 71). Niger's climate is mainly hot and dry, with much desert area. In the extreme south there is a tropical climate on the edges of the Niger River Basin. The terrain is predominantly desert plains and sand dunes, with flat to rolling plains in the south and hills in the north (en.wikipedia.org/wiki/Geography_of_Niger).

Agriculture

Although only 2.8% of Niger's area is cultivated, farmers increased their production following the 1968-75 droughts, and in 1980, the country became self-sufficient in food crops. Almost 95% of the active population is engaged in crop cultivation or animal husbandry. Agricultural techniques are still rudimentary; there are a few tractors in use (only 130 in 1998), and most farmers do not keep draft animals. Very little fertilizer is used. Irrigated land in 1998 totalled about 66,000 ha. Only 12% of Niger's total land area, located along the southern border, is potentially useful for rainfed cultivation. Over 95% of agriculture is on farms of less than 5 ha, with the average about 3 ha. Production of millet, the staple food of most of the people, depends heavily on rainfall. Other crops (with their estimated output) include cassava, sugarcane, onions and sweet potatoes. Cowpeas are an important crop, but are only competitive as an export commodity in neighboring Nigeria's market due to transportation costs. The government of Niger is encouraging crop diversification and the raising of export crops like onions, garlic, peppers and potatoes, in addition to cowpeas. Peanuts, formerly the main source of agricultural export revenue, are planted mainly in the Zinder area (www.nationsencyclopedia.com/Africa/Niger-AGRICULTURE).

About pigeonpea

The cultivation of pigeonpea in Niger is for subsistence purpose and is grown by smallholder farmers as reported by Versteeg and Koudokpon (1993).

Nigeria

Geography

Nigeria is the largest country in Western Africa with an area of 923,768 km² and has 59% of the entire population of sub-Saharan Africa. Located between 4°12' N to 13°45' N latitudes and 2°43' E to 14°24' E longitudes, the country borders the Republic of Benin in the west, Chad and Cameroon in the east, and Niger in the north. Its coast lies on the Gulf of Guinea in the south and it borders Lake Chad to the northeast (Figure 71). The country is tropical with variations governed by interaction of moist southwest monsoon and dry northeast winds. Mean maximum temperatures are 30-32°C (south) and 33-

35°C (north). There is high humidity in the south February-November, and in the north June-September; low humidity during the dry season. Annual rainfall decreases northward; about 2,000 mm in the coastal zone (Niger Delta averages over 3,550 mm); 500 to 750 mm in north (Bradshaw 1997, Nigeria-Planet.com 2008, en.wikipedia.org/wik/Geography_of_Nigeria).

Agriculture

In Nigeria, about 75% of the population is peasant farmers living in the rural areas, which are the mainstay of agricultural production. These farmers operate on a small-scale with farm holdings of 1-2 ha that are usually scattered over a wide area. The production practices of small-scale farmers are synonymous with their production characteristics such as subsistence level of production, low hectare due to tenurial rights (Fawole and Oladele 2007). Along with Olayide et al. (1981), about 75% of Nigeria's land is under arable cultivation with land-human ratio of 58 persons/km² in southwestern Nigeria. This shows that the average sizes of farmlands are very small. According to a 1993 estimate, 33% of the land is classified as arable land. Permanent crops are spread across 3% of the country, while permanent pastures account for 44% of the area. Forests and woodland are estimated to cover 12% of Nigeria. There are approximately 9,570 km² of irrigated land (Nigeria-Planet.com 2008).

In 1996, a total of 33 M ha were cultivated to crops, out of which 17.7 M ha were for staples and 4.9 M ha were for industrial crops (The major agricultural products in the country are cocoa, peanuts, palm oil, corn, rice, sorghum, millet, cassava (tapioca), yams, rubber; cattle, sheep, goats, pigs; timber; fish (Applied Language Solutions 2008).

About pigeonpea

Pigeonpea in Nigeria is an important legume with very low human food preference because of the availability of other beans that are easier to cook and it is equally of no industrial use as of now even though there are 182 identified accessions (Upadhyaya 2007). As stated by Nene et al. (1989), Nyabyenda (1987), van der Maesen (1983, 1986) and Aiyeloja and Bello (2006), the crop is produced in minor quantity in the country. Although grown as a minor crop, pigeonpea can be observed in all the different agricultural land use systems on small fields of less than 1 ha as a hedge, sole crop,

intercrop or mixed crop. Pigeonpea is commonly grown in combination with cassava, yams, cocoyams, maize, sorghum, rice, cowpea, bambara nuts, melons and castor. Pigeonpea is also seen in homegardens and as a border crop. The crop is a multipurpose woody short-lived (2-3 years) perennial, usually grown as an annual for grain but can produce both food and fuel wood within a period of three to nine months. Perennial types with white and brown seeds and 3-4 seeds per pod are most commonly grown, and remain in the field for two years. Plants mature in 7-8 months and grow to a height of 2-3 m. The crop can grow up to four meters. Sowing is mostly done in May to July. Row to row spacing varies from 1-1.5 m and within row spacings from 0.3-1 m having an average of 2-3 plants/stand. No fertilizer and pesticide is applied. Most farmers harvest pigeonpea by picking the pods while others practice stem harvesting. The stems are cut at 25-30 cm from the base and the pods are picked at home. Harvesting is done when the crop is 90% mature and harvested 2-3 times (Tabo et al. 1995).

In Edo State, there is variation of plant type due to adaptation to a wide range of latitude, altitude, soil and annual rainfall. The most frequent combinations were *Cajanus/Manihot*, *Zea maize/Cajanus* and *Dioscorea/Cajanus* (Table 32). Cultivation is now largely restricted to the northern half of the state while in the southern half of the state, the cultivation of pigeonpea has dramatically diminished (Ogbe and Bamidele 2007).

Table 32. Percent crop combination of pigeonpea in the different farming systems in Edo State.

Crop Combination	Home Garden (%)	Near Farm (%)	Distant Farm (%)
<i>Cajanus/Manihot</i>	4	23	35
<i>Zea maize/Cajanus</i>	10	3	37
<i>Dioscorea/Cajanus</i>	4	18	25

In the Northern Zone, farmers regarded pigeonpea as the most important non-staple crop and second most important vegetable protein after cowpea. There is a demand in the northern zone of Nigeria where the crop is valued for home consumption as food as well as a source of cash income. Other uses include green manuring (*Cajanus/Manibut* combination), temporary shade for young cocoa crops, anti-erosion in soil conservation and stakes for yam. Yield is characteristically poor in the traditional farming systems (Ogbe and Bamidele 2007).

In southwestern Nigeria, crop mixture is a common feature of crop production and the predominant arable cropping systems are cassava-based, yam-based, maize based, rice-based, food legume-based and vegetable-based systems. The rationale behind this system is to ensure food security for the farm families year round (off-season and during the season) (NARP 1997, Fawole and Oladele 2007). Pigeonpea varieties grown are the tall *aiyolo*, *igarra* and *samaru* (Rotimi and Iloba 2008).

In the sub-humid zone, a wide range of other crops, including sweet potato, cassava, sesame, pigeonpea, and several fruits and vegetables, are cultivated, usually in mixed cropping systems. There is evidence that mixed cropping can increase both the net value of the production and the net return to labor (IDRC 2008). Pigeonpea is usually intercropped with maize and cassava or relayed with cocoyam or the stems serve as stakes for yam. Intercropping pigeonpea with cocoyam may therefore be of value as a pest control strategy and can be combined with chemical control to achieve remarkable control of pigeonpea pests under the integrated management concept (Dialoke et al. 2003). On the harvest of companion crops, it becomes a sole pigeonpea crop. In most cases, the fruits and vegetables are planted as companion crops to pigeonpea (NARP 1997).

In the Orlu and Owerri agricultural zones in the rainforest belt of Nigeria, resource-poor farmers' way of farming is by mixed cropping, wherein pigeonpea hedgerows are intercropped with yam/maize/egusi/cassava and sometimes with sweet potato. This system proved to be of value because of its monetary benefits, reducing labor cost for weeding, thereby reducing production cost (Anuebunwa 2000).

Soil erosion is a major problem in the central parts of the state due to the topography of the land. Increased utilization of the diverse genetic resources of pigeonpea will enhance the adoption of the plant for planted fallow. Cocoa is one of the crops benefiting from the Federal Government Agriculture reforms. There is a great potential in the development of the pigeonpea plant as a shade crop for young cocoa seedlings and as cover crop (Ogbe and Bamidele 2007).

Marketing

The largest market oriented cultivation of pigeonpea is in the Esan West, Esan Central and Esan North East local government areas (LGAs), which

is demand driven due to cultural inclination and high protein content. About 75% of total production gets to the market because there is preference for pigeonpea over cowpea.

Pigeonpea research activity

Although research into sustainable low input traditional agriculture is not a government priority in Nigeria, numerous research activities have been conducted because pigeonpea plays an important role in the farming system of the state. The ash has been recognized as having soil improvement property, the foliage can be used as green manure, and as a suitable multipurpose shrub species for alley farming systems in lowland non-acid soils of the sub-humid tropics (Bansh and Psychas 1992).

The under-utilization of pigeonpea in southwest Nigeria (SW) could be linked to the long cooking period that is necessitated by the need to remove the deep brown color and bitter taste in the seed through several draining of the cooking water. It often takes approximately 6-8 hours of effective cooking for a satisfactory removal of the deep brown color and bitter taste. In this study, the effect of decortications on oligosaccharide and anti-nutrient content of the two legumes was investigated. Results showed that decortications resulted in about 3 hour's reduction in cooking time for both legumes. The analyses also showed that the bulk of the oligosaccharides: raffinose, stachyose and verbascose (90-95%) reside in the cotyledon and not in the seed coat because decortications resulted in negligible reduction in oligosaccharide content of the two legumes. Decorticated grains lost approximately 80-85% of the raffinose, stachyose and verbascose after cooking while the raw sample lost 24-59% of the oligosaccharides after cooking. This shows that the seed coat is probably a barrier to the removal of the oligosaccharides. Decortication resulted in significant reduction of the phenolics, tannins and oxalate compared to the whole grains. Upon cooking, less than 3% of the anti-nutrients were retained in the decorticated grains whereas more than 35% was retained in the cooked whole grains. It was established in this study that significant content of these anti-nutrients reside in the seed coat. The brown coloration of the cooking water was also eliminated by decortication. The significant reduction in cooking time as a result of decortication will lead to reduction in the cost of fuel required for cooking while the reduction in the levels of anti-nutrients implies better health for consumers (Adebooye 2008).

Likewise, pigeonpea was tested to supplement maize and soybeans as feed to rabbit. The research was to determine the performance, nutrient digestibility and carcass characteristics of rabbits fed graded dietary levels of boiled pigeonpea seed meal (PSM) diets. There were no significant differences among the treatment diets in all the performance parameters measured. There was no significant difference among the treatments in all carcass and organ characteristics measured. It was concluded that boiled PSM could replace 20 and 43.9% of maize and soybean meal, respectively, in rabbit diets constituting up to 20% of the whole ration (Amaefule et al. 2005).

In another development, boiled pigeonpea seed diets resulted in higher body weight gain on broilers and better feed conversion ratio than toasted pigeonpea seed diets. Boiling of legume seeds as a processing method has been reported to be better than toasting (Akanji et al. 2003). Boiling, boiling with potash and toasting resulted in 4.16%, 4.05% and 3.49% reduction in crude protein content, respectively. The decrease in crude protein may be probably because processing enhances degradation. Cooking, for example, has been associated with solubilization and leaching of some nitrogenous compounds into the processing water (Onu et al. 2001, Udedibie and Carlini 2000).

Feed conversion ratio and protein efficiency ratio were significantly better for those on processed diets than those on raw pigeonpea seed meal (PSM). The superior feed conversion ratio of birds on processed diets suggests the enhanced availability, digestion, absorption and utilization of the nutrients in the processed seeds by broilers. Processing of pigeonpea seed resulted in a significant improvement over the raw seeds in most of the measurements recorded. Birds fed processed PSM gained significantly higher weight than those fed raw PSM. The enhanced performance obtained when pigeonpea seeds were subjected to either moist or dry heat indicates the beneficial effect of heat treatment in improving the nutritional value of pigeon seeds (Onu and Okongwu 2006). The fact is that pigeonpea seeds protease inhibitors and other toxic substances, when heated, were responsible for their destruction and the enhancement of the nutritive value of the seed (Liener and Kakade 1980).

Uses of pigeonpea

The common food preparation of pigeonpea in Nigeria is by cooking whole dry seeds until tender and mixing with cooked yam together with palm oil and other ingredients (ie, pepper, onion, Maggi cubes, salt and crayfish). This yam porridge meal is served with vegetables and meat or fish. Maize/pigeonpea porridge or *ayalaya*, as it is known locally, is another popular preparation and is considered a special treat by Nsukka people. Pigeonpea is boiled to tenderness. Partially milled maize grain is put into a basket or perforated container lined with unshredded vegetable leaves. The basket is then put in the pot of boiling pigeonpea grain but without immersing the milled maize in the boiling water. The milled maize, heated by the steam, swells, and when tender, is added to pigeonpea for further boiling. Additional ingredients such as fried palm oil, onion, pepper, salt and shredded leafy vegetables are also added. Pigeonpea is also used as a soup thickener, substituted for cowpea in *akara* balls (grinding the cotyledons into paste and deep frying), cooked as *moi-moi* and fermented to produce *dawa dawa* for food seasoning (Tabo et al. 1995, Enwere 1998). Esan farmers claimed that pigeonpea does not cause ‘heart-burn’ like cowpea.

Rwanda

Geography

With geographic coordinates of 1°8' S to 2°43' S latitude and 28°28' E to 30°45' E longitude and located in Eastern Africa, Rwanda is a landlocked country that extends over an area of 26,338 km², bordering Burundi in the south and the Democratic Republic of the Congo in the west, Uganda in the north and the United Republic of Tanzania in the east (Figure 71) (IFAD 2007). Although located only two degrees south of the equator, Rwanda's high elevation makes the climate temperate. The average daily temperature near Lake Kivu, at an altitude of 1,463 masl is 73°F (23°C). During the two rainy seasons (February-May and September-December), heavy downpours occur almost daily, alternating with sunny weather. Annual rainfall averages 800 mm but is generally heavier in the western and northwestern mountains than in the eastern savannas. Its countryside consists of grasslands and rolling hills (en.wikipedia.org/wiki/Geography_of_Rwanda).

Agriculture

In Rwanda 95% of agriculture cultivation is conducted by smallholders who operate within a semi-monetaryized, semi-subsistence, economy. The choice of crop and profitability will be determined by the value of a particular crop to household food security or cash income, and not by the availability or ease with which intensification could occur (World Bank 1991a). More than 90% of Rwanda's population of 8 million makes their living from working the land, the vast majority as subsistence farmers. As of 2005 estimates, Rwandan arable land is figured at 44.56% and permanent crops at 10.25% of total land area. The Rwandan economy depends largely on agriculture, which accounts for 41% of gross national product (GNP). Agriculture accounts for about 70% of Rwanda's exports, but needs to be developed and diversified as there is huge potential for investment. When it comes to exports, tea and coffee are Rwanda's star performers, accounting for 60% of their total exports. Ideal climate and soil conditions enable Rwanda to produce some of the best quality tea and coffee in the world all year round. Apart from tea, coffee and its other principal cash crops, namely pyrethrum and flowers, Rwanda produces bananas, beans, potatoes and sorghum. Likewise, substantial potential exists in the livestock sector (IFAD 2007, Applied Language Solutions 2008a, en.wikipedia.org/wiki/Geography_of_Rwanda, The New York Times 2006).

In 2002, about 1.6 M ha of land was devoted to cultivation of food crops (FAO 2003). There are normally two (2) distinct cropping seasons in Rwanda - Season A that stretches from September to January/February; and Season B from March to August, including short production periods of seasons C and D (Rwanda Development Gateway 2005).

About pigeonpea

Little has been written about the crop's existence in the country. Although there are 5 accessions (Upadhyaya 2007), pigeonpea is still a minor crop in Rwanda (Nene et al. 1989; Nyabyenda 1987; and van der Maesen 1983, 1986). There were researches documented but not fully stated such as the research that has been carried out into the use of trees (black wattle) and pigeonpea, which would cover contour strips without reducing soil fertility (World Bank 1984). Also, the Lake Kivu Project was successful in convincing farmers of the benefits of pigeonpea planted as hedges and by the completion of the project, 82% of farmers had adopted extension recommendations (World Bank 1995).

The Birth of Pigeonpea Research

According to Onim (1981), the pigeonpea improvement program started in Rwanda in the 70s with germplasm introduction from ICRISAT and neighboring countries and pure lines such as NPP610, RK101, TRT201 were identified for cultivation. However, Price and Cishahayo (1986) states that pigeonpea research in Rwanda began in 1983 with the introduction of early-maturity seeds from the cross NPP 610, originally made at the University of Nairobi. About 75 seeds from this cross as well as seeds of other Kenyan landraces were supplied by the International Development Research Centre (IDRC), Nairobi. In the same year, several Tanzanian landraces were obtained from the Tanzania Agricultural Research Organization at Ilonga. Several distinct phenotypes were isolated from the cross NPP 610. Material with desirable characters – early maturity, large seeds, reduced plant height, drought tolerance, high yield potential, and adaptability to poor soils – were selected and tagged from segregating NPP 610 and Tanzania selections. Three individual plants selected from NPP 610 were crossed in all combinations (Price and Cishahayo 1986).

Intra-population recurrent selection aimed at improving grain yield and adaptability was employed for three cycles on the segregating populations. Variability after cycle 3 was maintained by the very high natural out-crossing. The population RK101 (short, early maturing) was derived by this method. Selections from medium-duration types from Tanzania were crossed to produce the population RT 201 which was medium in height, early to medium duration, large-seeded, and adapted to the region. RKT 120, a tall, large-seeded, long-duration perennial type, is derived from single plant selections within a population of landraces received from Kenya. The improved varieties have larger seeds and more seeds per pod than the local varieties (Price and Cishahayo 1986).

Saint Helena

Geography

St Helena is a small and remote Island in the South Atlantic Ocean at 15°50' to 16°7' South latitude, 5°42' to 5°48' West longitude (Figure 71), near the mainland of West Africa (en.wikipedia.org/wiki/Geography_of_Saint_Helena; www.hridir.org). Annual rainfall ranges between 175 and 1050 mm

depending on elevation. The wettest months are from March to July with the driest being from October to November. Annual temperature ranges from 20 to 29°C with an average of 24°C in Jamestown, with the temperature decreasing by approximately 1.3°C per 100 m rise. Relative humidity is fairly constant throughout the year with figures remaining at the 75-80% range; however relative humidity increases by about 5% in the higher inland areas. Day length can vary for up to two hours on St Helena with the maximum sunshine hours received being about 45%. As the country is situated in the heart of the South East Trade Wind Belt, the South East Trade Winds blow constantly throughout the year (www.hridir.org).

Agriculture

The aspects of horticulture that can be found on St Helena can be divided into five main categories, mainly fruit production, arboriculture, silviculture, vegetable and coffee production. The production of fruit trees, mainly citrus has recently become one of the main aspects of horticulture. Vegetable production is centred on the production of staple food crops and also fresh vegetables, which are used to sustain the island's population. Vegetable production is practised island wide on different soil types and climatic conditions. Coffee production (arabica) is a steadily growing business directed towards a niche market of high value coffee abroad. Coffee arabica is considered to be among the best coffee worldwide, being in the same class as the Jamaican Blue Mountain (<http://www.hridir.org>). The main agricultural products of the country are maize, potatoes, vegetables, fish and crawfish (en.wikipedia.org/wiki/Economy_of_Saint_Helena).

About pigeonpea

According to Nene et al. (1989), Nyabyenda (1987) and van der Maesen (1983, 1986), pigeonpea is grown in St Helena as a minor crop. The crop is found mixed with vegetables in the kitchen garden or intercropped with maize.

São Tome and Principe

Geography

São Tome and Principe is a small nation composed of an archipelago located in the Gulf of Guinea of equatorial Atlantic Ocean (Figure 71). The nation's main islands are São Tome and Principe, for which the country is named and constitute one of Africa's smallest countries. These are located about 300 and 250 km, respectively, off the northwest coast of Gabon in West Africa. The nation's geographic coordinates are latitude of 0°2' N to 0°21' N and longitude of 6°24' E to 6°46' E with a total land area of 1,001 km². Its peaks reach 2,024 masl. At sea level, the climate is tropical hot and humid with average yearly temperatures of about 27°C (80°F) and little daily variation. At the interior's higher altitudes, the average yearly temperature is 20°C (68°F), and nights are generally cool. Annual rainfall varies from 5,000 mm on the southwestern slopes to 1,000 mm in the northern lowlands. There is only one rainy season, which runs from October to May (CIA 2008d, en.wikipedia.org/wiki/Geography_of_S%C3%A3o_Tome_and_Pr%C3%ADncipe).

Agriculture

Agriculture in São Tome and Principe is basically subsistence. The estimated land use in 2005 is 8.33% for arable land and 48.96% for permanent crops, which grow export products such as cocoa, coffee, copra and palm oil. Cocoa is now the largest export commodity but production has substantially declined in recent years because of drought and mismanagement. Other agricultural products are cinnamon, pepper, bananas, papayas, beans, poultry and fish (Garrison 2008, CIA 2008d).

About pigeonpea

Pigeonpea in São Tome and Principe is considered a minor crop grown by subsistence farmers (Nene et al. 1989; Nyabyenda 1987; and Van der Maesen 1983, 1986).

Senegal

Geography

Senegal, a coastal western Africa nation, is geographically stationed at 12°22' N to 16°38' N latitude, 11°25' W to 17°29' W longitude. The country's total area of 196,190 km² is bordered on the West by the Atlantic Ocean, on the North by Mauritania, East by Mali, southeast by Guinea, and South/southwest by Guinea-Bissau, and the interior Gambia that penetrates into Senegal from the Atlantic coast along the Gambian River that bisects Senegal's territory (Figure 71). Senegal's climate is tropical (hot and humid). There are two seasons observed, the rainy season from May to November has strong southeast winds. The dry season from December to April is dominated by the hot, dry, harmattan wind (Applied Language Solutions, 2008c; CIA, 2008e; en.wikipedia.org/wiki/Senegal).

Agriculture

Most of Senegal lies within the drought-prone Sahel region, with irregular rainfall and generally poor soils. With only about 5% of the land irrigated, Senegal continues to rely on rain-fed agriculture, which occupies about 70-75% of the workforce. Land use estimate in 2005 shows that arable land is registered at 12.5%, permanent crops at only 0.24% and others at 87.25%. Despite a relatively wide variety of agricultural production, the majority of farmers produce for subsistence needs. Production of food crops, some of which are grown in rotation with peanuts, does not meet Senegal's needs. Production is subject to drought and threats of pests. Millet, rice, corn and sorghum are the primary food crops grown. Senegal is a net food importer, particularly for rice, which represents almost 75% of cereal imports. Green beans, industrial tomato, cherry, melon and mango are the country's main cash crops. Likewise, peanuts, sugarcane and cotton are also important cash crops grown for local and export markets (Ndiaye 2007, Applied Language Solution 2008b, CIA 2008e).

About pigeonpea

As mentioned by Upadhyaya (2007), 11 accessions are grown in Senegal and based on Nene et al. (1989), Nyabyenda (1987) and van der Maesen (1983), pigeonpea is cultivated as a minor crop by smallholder farmers as a subsistence crop.

Seychelles

Geography

Seychelles, approximately 444 km², is located in the Indian Ocean about 1,600 km east of Kenya with coordinates of 4°26' S to 4°35' S latitude and 55°30' E to 55°40' E longitude (Figure 71). The nation is an archipelago of 115 tropical islands with two distinct collections of islands, some comprised of granite and others of coral. The climate is equable and healthy, although quite humid, as the islands are small and subject to marine influences. The temperature varies little throughout the year. Temperatures on Mahe vary from 24°C to 29.9°C (75°F-85°F), and rainfall ranges from 2,880 mm annually at Victoria to 3,550 mm on the mountain slopes. Precipitation is somewhat less on the other islands. During the coolest months, July and August, the temperature drops to as low as 70°F. The southeast trade winds blow regularly from May to November, and this is the most pleasant time of the year. The hot months are from December to April, with higher humidity (80). March and April are the hottest months, but the temperature seldom exceeds 88°F (Bureau of African Affairs 2008).

Agriculture

Agriculture in Seychelles is purely for home consumption except for fishing. There are only 400 ha devoted to agriculture. Many households cultivate gardens and raise livestock for home consumption. Copra, cinnamon, vanilla, coconuts, sweet potatoes, tapioca, bananas, tuna, chicken, teas are the major products produced. Market for traditional crops, copra and cinnamon has decreased; tea is grown for local consumption. Basic foodstuffs such as rice and sugar are imported (Bureau of African Affairs 2008, lcweb2.loc.gov 1994).

About pigeonpea

Based on ILDIS report (2005), pigeonpea has been introduced in Seychelles. The crop has been grown as a minor crop as revealed by Nene et al. (1989), Nyabyenda (1987) and van der Maesen (1983, 1986).

Sierra Leone

Geography

Sierra Leone, an independent nation, is located on the west coast of Africa, between the 7th and 10th parallels north of the equator with geographic coordinates of 6°55' N to 9°52' N latitude and 10°32' W to 13°11' W longitude. Sierra Leone is bordered by Guinea to the north and northeast, Liberia to the south and southeast, and the Atlantic Ocean to the west (Figure 71) (LeVert 2007). The country has a total area of 71,740 km². The tropical climate has rainy and dry seasons, high temperatures, and almost constant humidity. The rainy season extends from May to November (summer rainy season) but is heaviest between July and September, when over half of the annual rainfall occurs. In Freetown, annual rainfall is 3,810 mm or more; inland areas receive less. The beginning and end of the rainy season are marked by frequent strong electrical storms. Coastal temperatures during the rainy season range from a daily high of about 80°F to a nightly low of about 76°F. Winter dry season occurs from December to April (www.Pickatrail.com 2003; en.wikipedia.org/wiki/Geography_of_Sierra_Leone).

Agriculture

Since the mid 90s, Sierra Leone has been steadily and quietly re-positioning itself as West Africa's agricultural hub. A bulk of the population is engaged in subsistence farming. The total area of Sierra Leone is 72,326 km², and this can be classified into agricultural land (60%), pastures (18%), mangroves and inland swamps (8%), forest (4.25%) and other (9.75%). Agriculture is the largest sector of the economy, but, in spite of the economic and social measures applied this sector has the lowest income level. The poor productivity of the agricultural sector indicates the need for more effective approaches and practices. The current farming systems need to be re-evaluated and upgraded. In the northern half of the country, the long dry season limits production to cattle and annual crops, whereas the south has rainfall and climate suitable for the production of cocoa, coffee and oil palm, which together form the backbone of agricultural exports. The important food crops grown in Sierra Leone are rice, sorghum, millet, maize, cassava, sweet potatoes, groundnuts and sesame, with rice being by far the most important (staple food). Rice accounts for more than 75% of the area under food (Koroma 1982, TET 2008). But importation of rice is still needed because they cannot grow a sufficient amount for themselves (Bradshaw 1997).

About pigeonpea

Pigeonpea in Sierra Leone is locally known as Bulom sitil (Afzelius) and Fula-Pulaar and is cultivated as a minor crop (Nene et al. 1989; Nyabyenda 1987; and van der Maesen 1983, 1986), though at times this crop is exported to neighboring countries like Guinea (www.kiva.org).

In 1985, the International Legume Database and Information Service (ILDIS) in Sierra Leone initiated Phase II of the Food Legumes project in which pigeonpea was a test crop that would adapt to various ecological conditions, and they carried out cooking and acceptability trials as part of the project. Researchers determined critical phosphate application levels for pigeonpeas grown during the wet season and assessed responses to other fertilizers. They also identified pigeonpea types compatible with early season maize for intercropping, improved pigeonpea varieties of shorter duration than local varieties as well as planting times for best yield (Fonseca 2005).

Pigeonpea Farming System

Traditionally, upland farming has consisted mainly of the bush fallow or grass fallow system in which a few years of cropping is followed by an interval of fallow after 8–12 years of continuous cultivation in the Eastern Province, and 4–6 years in the Northern Province. After the fallow period, the natural groundcover is cut and burned. Rice seed is mixed with other upland crops, amongst them pigeonpea, and is broadcast by the farmers over a series of separate strips. The rice is harvested first. Cassava, the major root crop in the country, is planted as the last crop before the land is fallowed. The principal agricultural crop used in *taungya* is rice, but farmers are allowed to sow maize, guinea corn, pigeonpeas, sorghum, cassava and okra (Koroma 1982).

Somalia

Geography

Somalia, with geographic coordinates of 11°52' N to 1°41' S latitude, 40°52' E to 51°14' E longitude, is a coastal nation located in Eastern Africa at the Horn of Africa with a total area of 637,657 km². Its northern and mid-west region is bordered by Djibouti and Ethiopia. Kenya is at its southwest border and the Gulf of Eden is located north of Somalia. The Indian Ocean makes

up its eastern border (Figure 71). The climate in Somalia is predominantly desert. It has a year-round hot climate, with seasonal monsoon winds, depending on the region. Somalia has irregular rainfall patterns with recurring droughts. The range of daily temperature is 85-105°F, except for areas of higher elevations and along the coastline. Here the range of daily minimum temperature is 60-85°F. The southwest monsoon seasons are in the months of May to October. The northeast monsoon season occurs during December to February. The periods between the two monsoon seasons are termed *tangambi*. *Tangambi* is October to November and March to May. During this time, the weather is very hot and humid. Most of the country receives less than 500 mm of rain annually. A large area in the north receives 50-150 mm/year, except for some higher areas. The southwest, on the other hand receives 330-550 mm annually (CIA 2005a, www.ag.ohio-state.edu).

Agriculture

Somalia is one of the world's poorest and least developed countries in Africa and agriculture is an important economic activity not only in terms of meeting the food needs of the population, but also in terms of generating income through crop sales and agricultural labor opportunities. Agriculture is a major component particularly for two of the main rural livelihood systems in Somalia, namely, Agro-pastoralist - mix of agriculture and livestock production based livelihood and the Agriculturalist - agriculture based livelihood (FSAU 2008).

Agriculture constitutes 40% of its GDP and 65% of its export earnings. Only 1.6% of Somalia's total land area is cultivated, and 69% is permanent pasture. The Somalis have traditionally engaged in rain-fed, dryland farming or in dryland farming complemented by irrigation from either the waters of the Shebelle and Juba rivers or collected rainwater. Corn, sorghum, beans, rice, vegetables, cotton and sesame are grown by both methods. Somalian and Italian farmers operating the banana farms practice the more modern farming techniques, as do some of the newly created Somali cooperatives. Bananas constitute the nation's major commercial crop. Livestock raised in this country are sheep, cattle, goats and camels (www.ag.ohio-state.edu).

About pigeonpea

Cultivation of pigeonpea in Somalia is as a minor crop (Nene et al. 1989; Nyabyenda 1987; and van der Maesen 1983, 1986). The pigeonpea improvement program started with germplasm introduction from ICRISAT and the neighboring countries. Pure lines such as NPP610, RK101, TRT201 were identified for cultivation (Ohim 1981). The Somali diet consists of cereals and tubers, which are rich in starch and low in protein. Although pulse crops have potential and production fails to meet demand, little research has been conducted on pulses. Recently, the Central Agricultural Research Station at Afgoi and Bonka developed a program for grain legume production including pigeonpea. The status of grain legume research was reviewed by Abikar (1990 unpublished). However, little progress has been made due to the political instability since 1991. The fate of improved lines sent to Somalia in 1988 is not known (Kimani 2001).

South Africa

Geography

South Africa occupies the southern tip of the African continent, with geographic coordinates of 22°11' S to 34°57' S latitude and 16°31' E to 32°4' E longitude covering an area of 1.2 M km² of land. The northeastern corner of the country lies within the tropics, astride the Tropic of Capricorn (Figure 71). Although the country is classified as semi-arid, it has considerable variation in climate as well as topography. Climatic conditions generally range from Mediterranean in the southwestern corner of the country to temperate in the interior plateau, and subtropical in the northeast. A small area in the northwest has a desert climate. Most of the country has warm, sunny days and cool nights. Rainfall generally occurs during summer (November through March), but in the southwest, around the Cape of Good Hope, rainfall often occurs in winter (June through August). Rainfall varies considerably from west to east. In the northwest, annual rainfall often remains below 200 mm. Much of the eastern Highveld, in contrast, receives 500 mm to 900 mm/year; occasionally, rainfall exceeds 2,000 mm. A large area of the center of the country receives about 400 mm, on average, and there are wide variations closer to the coast. The 400 mm "rainfall line" has been significant because land east of the rainfall line is generally suitable for growing crops, and land west of the rainfall line, only for livestock grazing or crop cultivation on

irrigated land. Temperatures are influenced by variations in elevation, terrain and ocean currents more than latitude. The average annual temperature is 17.5°C, and the maximum temperatures often exceed 32°C in the summer, and reach 38°C in some areas of the far north. The country's highest recorded temperatures, close to 48°C, have occurred in both the Northern Cape and Mpumalanga (formerly Eastern Transvaal), while the coldest temperatures have been recorded about 250 km northeast of Cape Town, where the average annual minimum temperature is -6.1°C. Frost occurs in high altitudes during the winter months (en.wikipedia.org/wiki/Geography_of_South_Africa; worldfacts.us/South-Africa-geography).

Agriculture

About 13% of South Africa's surface area can be used for crop production. High potential arable land comprises only 22% of the total arable land. Slightly more than 1.2 M ha is under irrigation. The most important factor limiting agricultural production is the availability of water. Rainfall is distributed unevenly across the country with humid subtropical conditions occurring in the east and dry, desert conditions in the west. Almost 50% of South Africa's water is used for agriculture (UNCSD 2000). More than 70% of the population in the Southern African Development Community (SADC) region depends on agriculture for household food security, livelihoods and incomes (Setimela et al. 2004).

South Africa has a dual agricultural economy, with both well-developed commercial farming and more subsistence-based production in the deep rural areas. This biodiversity, together with a coastline 3,000 km long and served by seven commercial ports, favors the cultivation of a highly diverse range of marine and agricultural products, from deciduous, citrus and subtropical fruit to grain, wool, cut flowers, livestock and game. Agricultural activities range from intensive crop production and mixed farming in winter rainfall and high summer rainfall areas to cattle ranching in the bushveld and sheep farming in the arid regions. Maize is most widely grown, followed by wheat, oats, sugarcane and sunflowers. Today, South Africa is not only self-sufficient in virtually all major agricultural products, but is also a net food exporter. Farming remains vitally important to the economy and development of the southern African region. Since 1994, the government has been working to develop small-scale farming to boost job creation (South African agriculture - SouthAfrica_info 2008).

About pigeonpea

Pigeonpea is grown in South Africa as a minor crop (Nene et al. 1989; Nyabyenda 1987; van der Maesen 1983, 1986; and Swart et al. 2000). However, pigeonpea is a very important crop in the rural areas where it can be grown for human consumption and supplement the range of food crops available. The introduction of this crop in the rural areas will help alleviate poverty by providing a source of food (ARC-IIC 2008). The Agricultural Research Council-Vegetable and Ornamental Plant Institute (ARC-VOPI) is responsible for instituting the research and extension of vegetable and ornamental plants. The institute concentrates on a wide range of horticultural crops. Research is conducted on commercial vegetables, amongst others pigeonpeas (NDA 2007).

Pigeonpea is not grown widely as a field crop in South Africa. Some Indian farmers grow this crop only to meet their domestic needs. The green peas are used as vegetable and the dry whole seeds for making soup mixed with or without meat. A few stands of long-duration, unimproved pigeonpeas are usually grown singly as a shade plant or as a hedge plant in home gardens or around sugarcane fields in several provinces such as Kwazulu-Natal, Mpumalanga and northern and eastern Cape Provinces in South Africa. Locally known as '*oil-dal*', South Africa imports about 120–150 t each month or about 2000–2500 t annually from Malawi to meet the ever-growing demand for *dal* by the large Asian migrant community (Mathews et al. 2001, ARC-IIC 2008).

Sudan

Geography

Sudan is the largest country in north Africa and lies in northeast Africa between latitudes 3°30' N to 21°56' N and longitudes 21°58' E to 38°29' E (Figure 71). Covering an area of 2.5 M km², the country borders the Red Sea and has a coastline of 853 km along the Red Sea. Sudan is the largest country in the continent and tenth largest in the world. It borders the countries of Central African Republic, Chad, Democratic Republic of the Congo, Egypt, Eritrea, Ethiopia, Kenya, Libya and Uganda. The terrain is generally flat plains broken by several mountain ranges. There is also a marked distinction between the north and south. Northern Sudan is very dry, consisting of large expanses of desert and arid planes. Southern

Sudan contains large areas of rain forests and swamps making it much more adaptable for farming (en.wikipedia.org/wiki/Geography_of_Sudan). Sudan is hot, very hot. There is a dry season and a rainy season. The rainy season lasts for about three months (July to September) in the north, and up to six months (June to November) in the south. The extreme south of Sudan normally has a nine-month rainy season while a city like Atbara in the north is lucky to get more than a week of showers. Khartoum usually has a two-month rainy season lasting throughout July and August. Temperatures in Sudan are highest in May and June, which is also the common season for sandstorms. Average daily highs range between 100°F and 110°F with an occasional day in the 120's °F. Because the country is mostly desert, there is usually a large difference between daytime and evening temperatures. In Khartoum, a January day might/have a high of 80°F and dip to 45°F at night (en.wikipedia.org/wiki/Geography_of_Sudan).

Agriculture

Sudan's economy is based primarily on agriculture, employing 80% of the work force, while the remaining 20% works in industry to support the agriculture sector (National Biodiversity Strategy and Action Plan Project 2000). Figures for potentially arable land ranged from an estimated 35.9 M ha made in the mid-1960s to a figure of 84 M ha published by the Ministry of Agriculture and Natural Resources in 1974. Estimates of the amount actually under cultivation varied in the late 1980s, ranging from 7.5 M ha, including roughly 10 or 11% in fallow to 12.6 M ha. In 2000, Zaroug reported that of about 84 M ha of arable land (with reasonably fertile soils), 1.63, 8.21 and 7.93 M ha were under irrigated agriculture, traditional rainfed cultivation, and mechanized farming, respectively, in the 1994/95 season (countrystudies.us/sudan 2008).

Agriculture's contribution in 2006 has increased by 39% of GDP as compared to 1988. In the early 1990s, 61% of the working population were involved in agriculture and livestock production. Agricultural products regularly accounted for about 95% of the country's exports. Crop cultivation was divided between a modern, market-oriented sector comprising mechanized, large-scale irrigated and rainfed farming (mainly in central Sudan) and small-scale farming following traditional practices that was carried on in the other parts of the country where rainfall or other water sources were sufficient for cultivation (countrystudies.us/sudan 2008).

Although cotton remained the most important crop, peanuts, wheat and sugarcane had become major crops, and considerable quantities of sesame also were grown. Rainfed mechanized farming continued to produce mostly sorghum, while short-fiber cotton was also grown. Production in both sub-sectors increased domestic supplies and exports potentials. The increase appeared, however, to have been achieved mainly by expanding the cultivated area rather than by increasing productivity. Subsistence cultivators produced sorghum as their staple crop, although in the northerly, rainfed, cultivated areas millet was the principal staple. Subsistence farmers also grew peanuts and sesame (countrystudies.us/sudan 2008).

About pigeonpea

Considered as a minor crop (Nene et al. 1989; Nyabyenda 1987; and van der Maesen 1983, 1986), pigeonpea in Sudan, locally known as *Labia addasy*, is an important summer grain legume traditionally grown in North and Central Sudan. The crop is cultivated in about 29,412 ha yielding about 1,666 kg/ha of green pods. The grains are particularly consumed by boiling during the month of Ramadan. The plant is also grown on small-scale areas in Darfur state. A few pigeonpea plants are also often grown near the house for ease of harvest. Households use 'indeterminate' varieties because they produce a few pods each day over a long season. The cultivars commonly grown are local landraces (National Biodiversity Strategy and Action Plan Project 2000).

Traditionally, pigeonpea is dehulled by hand; thereafter it is pounded in wooden mortars before being ground using two stones. The products of these processes are either partially dehulled splits or powders that are used for preparing traditional dishes. At Food Research Corporation (FRC), processing technologies have been developed to improve these traditional processes that are laborious, lengthy and often produce poor quality products. The new process involves grading, cleaning (washing, conditioning, drying), dehulling, splitting and packaging of pigeonpeas. The equipment ranges from manual to mechanical. The capacity of the machine ranges from small-scale (1-5 kg/hr) for household level, pilot-scale (10-50 kg/hr), and commercial-scale (greater than 50 kg/hr) (Bureng et al. 2001).

The birth of pigeonpea research

Pigeonpea research in Sudan started with studies on crop improvement and agronomy at the Hudeiba Research Station during 1975-80, which was supported by IDRC. The main objectives of the program were to select high-yielding, adapted pigeonpea varieties, and to obtain information on maturity, plant type, and seed size and color. Forty early, medium and late-maturing entries from ICRISAT and neighboring countries such as NPP610, RK101, TRT201 were identified for cultivation (Onim 1981) and compared to the standard local variety 'Baladi' for three seasons. Three introduced varieties out-yielded 'Baladi' by over 100% (Nourai 1987).

Swaziland

Geography

Swaziland is a landlocked country in southern Africa, lying between Mozambique and South Africa (Figure 71). The country is located at the geographic coordinates of 25°47' S to 27°12' S latitude and 30°45' E to 32°15' E longitude. The country has an area of 17,363 km², of which 160 are water. The major regions of the country are Lowveld, Midveld and Highveld. The climate of Swaziland varies from tropical to near temperate. The kingdom of Swaziland is prone to floods and drought. Soil erosion as a result of overgrazing is a growing problem (en.wikipedia.org/wiki/Geography_of_Swaziland).

Agriculture

Swaziland has an estimated arable land of about 15-20%. Agriculture and agro-industry is the backbone of the Swazi economy and is critical for achieving the overall development objectives of the country. The agriculture sector is acutely dualistic. A traditional sub-sector, based on communal tenure involves semi-subsistence smallholder agriculture with communal grazing. The majority of the population lives in farm households located on communal Swazi Nation Land (SNL) and most of them (70%) are engaged in low-productivity subsistence agriculture and animal husbandry. Crucially, agriculture plays a key role in the lives of the majority of the population, since most households rely on agricultural output as a major source of income and food security, either as small-scale producers or as recipients

of income from employment on medium and large-scale farms and estates (Nkambule 2005).

The agricultural sector in Swaziland contributes to the livelihoods of the majority of the population and provides raw materials for the largely agro-based industries. Maize remains the staple food and is grown by the vast majority of rural households, accounting for approximately 86% of the entire land cropped on communal Swazi National Land (SNL) (Agricultural Sector Policy Report 2004). The remaining SNL area is cropped to relatively small amounts of cotton, groundnuts, pumpkins and sweet potatoes. Much of the Title Deed Land (TDL) is planted to commercial forests in the Highveld and is used for grazing, but a small proportion is used for the production of citrus, pineapples, vegetables, maize and fodder (FAO 2004).

About pigeonpea

Pigeonpea, seen as an exotic crop in Swaziland, is considered a minor crop (Nene et al. 1989; Nyabyenda 1987; and van der Maesen 1983, 1986). In 2003, a scheme implemented by the FAO/WFP CFSAM was the Food-for-Training program as an entry point to the communities in which food was provided as an incentive for farmers to attend training programs that encourage a wide range of improved agricultural practices that included the cultivation of multi purpose legumes such as pigeonpea for drier areas (FAO/WFP-CFSAM 2004).

Togo (Togolese Republic)

Geography

Togo is a small sub-Saharan nation comprising a long strip of land in West Africa. Togo's geographic coordinates are latitudes 6°8' N to 10°55' N and longitudes 0°15' E to 1°40' E. It is bordered by three countries: Benin to the east, Burkina Faso to the north and Ghana to the west (Figure 71). Togo has an area of 56,785 km², of which 54,385 km² is land and 2,400 km² is water. Togo's climate varies from tropical to savanna. The rainy season occurs between April and June as well as between September and October in the southern regions. The coastal regions are the driest parts of the country, with an annual rainfall of only 890 mm. The northern half of Togo only has one rainy season lasting from June to September. The average rainfall in

these areas is about 1,200 mm. Most of this rain falls during the short rainy season. The rest of the year is mostly dry and warm. A warm and dust-laden wind called *harmattan* predominates during the dry times. The south is humid, with temperatures ranging from 23°C to 32°C (75°F to 90°F). In the north, temperature fluctuations are greater—from 18°C to more than 38°C (65°F to 100°F). In August, temperatures between 20°C and 38°C can be observed (en.wikipedia.org/wiki/Geography_of_Togo).

Agriculture

Togo is predominantly an agricultural country, with about four-fifths of the work force engaged in subsistence farming. Approximately 12% of the land area is arable. Most food crops are produced by subsistence farmers who operate on family farms of less than 3 ha. Peanuts and sorghum are grown in the extreme north; sorghum, yams, and cotton in the region around Niamtougou; sorghum, cotton and corn in the central region; coffee, cocoa and cotton in the southern plateau; and manioc, corn and copra near the coast. Main food crops in 1999 included manioc, yams, corn, sorghum and millet. Although Togo is basically self-sufficient in food, certain cereals, notably wheat, which cannot be grown, is imported. The leading cash crops are coffee and cocoa, followed by cotton, palm kernels, copra, peanuts and shea nuts (*karité*) (en.wikipedia.org/wiki/Economy_of_Togo, Bradshaw 1997, Bureau of African Affairs 2008a).

About pigeonpea

Nene et al. (1989), Nyabyenda (1987) and van der Maesen (1983, 1986) reported that pigeonpea in Togo is a minor crop grown by subsistence farmers. Likewise, pigeonpea was identified as an under-exploited and threatened food plant because of its intrinsic physicochemical characteristics. According to the importance of this food specie for human and plant diversity, a suitable track of improvement is required for better management of these characters (Akpavi et al. 2008).

Zaire (Democratic Republic of Congo)

Geography

Zaire, with coordinates of 11°57' S to 5°5' N latitude and 14°51' E to 31°17' E longitude, is located in central Africa, is the second largest country in sub-

Saharan Africa with about 2.3 M km². Zaire borders with Angola, Burundi, Central African Republic, Congo, Rwanda, Sudan, Tanzania, Uganda and Zambia (Figure 71). The climate is hot and humid all year round at the equatorial river basin, cooler and drier in southern highlands and cooler and wetter in eastern highlands. Dry season in the north is from December to March, in the south from May to October while the wet season in the north of the equator is from April to October and in the south is from November to March. The average annual rainfall in the interior is 1,700 mm with average maximum daily temperatures of 31°C (88°F) (WebWhacker 2008, en.wikipedia.org/wiki/Geography_of_Zaire).

Agriculture

The mining sector in Zaire is the major source of government revenues while most individuals and families hang on grimly through subsistence farming and petty trade. Subsistence farming involves 80% of the population and thus the country is not self-sufficient in food production because only 1% of total land area is under cultivation. Major food crops are cassava, corn, rice and plantains, followed by bananas, beans, peanuts, millet, sorghum, yams, potatoes and fruits. The main staple food is cassava. Principal cash crops are coffee, palm oil and palm kernel oil, sugar, cocoa, rubber and tea. Coffee is considered as the most important cash crop but an estimated 30 to 60% of coffee crop is smuggled out of the country (US Department of State 1993, WebWhacker 2008).

About pigeonpea

Pigeonpea is cultivated in Zaire as a minor crop (Nene et al. 1989; Nyabyenda 1987; and van der Maesen 1983, 1986) even though there are about 13 accessions identified in the country (Upadhyaya 2007).

In the Bas-Zaire region of southwestern Zaire, pigeonpea is the third most important grain legume after groundnut and *phaseolus* beans. Pigeonpea is grown most intensively along with cassava in the Songololo area. It fills a crucial protein gap in the local diet between September and December before the harvest that follows a long dry season. After the pods are harvested, farmers apply the leaves as green manure on intercropped cassava. This pigeonpea/cassava system of Bas-Zaire, which produces food and a little cash, may be a candidate for wider adoption. Experiments are in progress

at M'Vuazi and Kimpese to test different spatial arrangements and timing of operations that might improve the traditional system (Nair 1991).

Zambia

Geography

Zambia, with coordinates of 8°24' S to 18°3' S latitude, 21°53' E to 33°23' E longitude, is a landlocked country in southern Africa covering a total land area of 752,614 km². The country borders Angola, Democratic Republic of the Congo, Malawi, Mozambique, Namibia, Tanzania and Zimbabwe (Figure 71). The topography is mostly high plateau with some hills and mountains. Zambia has a favorable climate and diverse ecological landscapes. Zambia's climatic condition is tropical modified by altitude with rainy season from October to April giving it a moderately cool subtropical climate with three seasons (www.usais.org 1999). The cool-dry season is from April to August, the hot-dry season from August to November and the hot-wet season from November to April with mean annual rainfall varying from 700 mm in the south to 1,500 mm in the north, and mean annual temperature range of 20°C-30°C (FAO - UNESCO 1975).

Agriculture

Farming in Zambia is mainly in the hands of small-scale farmers and still largely based on traditional practices. These farmers and the local communities in which they live have contributed to the development and maintenance of a rich crop genetic diversity on which they have depended for their livelihoods in general and food security in particular. Traditionally, the local communities derive their livelihoods from a wide range of plants for food and other uses. Although there is a wide diversity in terms of crop species available in most communities, not all are utilized at optimum levels (Biodiversity Community Network 2006).

In Zambia, more than 60% of the population derives their livelihood from agriculture and approximately 51% of those are rural, small-scale farmers cultivating, on average, five hectares or less (Saasa et al. 1999). In 2005, the estimated arable land is 6.99% of the total area and only 0.04% with permanent crops (CIA 2008f). The main food crop is rainfed maize. It accounts for 80% of the area cultivated (Franzel 1999). Livelihood systems are generally based

upon rainfed agriculture. Total arable land in the Eastern Province of Zambia is about 3.8 M ha with approximately 35% of this being utilized for agriculture (Jha & Hojjati 1993, Peterson 1999). Soil degradation is the fundamental biophysical root cause of food insecurity among the farmers (CIA 2008f).

About pigeonpea

Pigeonpea is an important crop in Zambia with potential for expansion. It is grown in most provinces by smallholder farmers in their backyards and around the fields of annual crops. There are no official estimates of the extent of area and production for pigeonpea in the country. However, the amount of pigeonpea produced does not meet the domestic demand and considerable quantities of *dal* are imported (Mulila-Miui 1992). In Zambia, the ease of establishment and the simultaneous production of food make perennial pigeonpea a special agro-forestry option (Kwesiga et al. 2003, Boehringer and Caldwell 1989). The cultivation of pigeonpea has been reported by Boehringer and Caldwell (1989) and has been earlier revealed by Nene et al. (1989), Nyabyenda (1987) and van der Maesen (1983, 1986) as a minor crop. In the eastern region of Zambia, the maize-pigeonpea intercropping is widely practiced by subsistence farmers (MacRobert et al. 2007). In urban areas, pigeonpea is grown commercially as a sole crop for vegetable and dry seeds. Research on the genotype compatibility of pigeonpea in pigeonpea+maize intercropping revealed that LRG 30, C 11 and ICP 7035 were ideal genotypes and the yield of intercropped maize was the same as that of monocropped maize (Kannaiyan et al. 1988).

The local landraces presently cultivated are very tall shrubs that mature in 8–12 months with very low yield (200–300 kg/ha). Small farmers normally keep the crops for 2–3 years. Commercial farmers usually grow white seeded medium- to long-duration types as annual pure crops with yield of up to 500 kg/ha. The crop normally has a slow growth rate in the first two months. Diseases are less important in comparison with insect pests (Mulila-Miui 1992).

Research activity

In Zambia, pigeonpea research is restricted to varietal screening, disease and insect pest studies, and intercropping. Varietal evaluation started in mid-1970 at Copperbelt Regional Research Station at Mufulira in collaboration

with IITA-Nigeria and ICRISAT-India. The research activity was short-lived. In 1982-1987, the research was continued by introducing 29 promising cultivars from ICRISAT and the National Dryland Farming Research Centre, Kenya through intercropping with maize and sorghum. ICP 7035, 423/50/3 and HY 3C were suitable for both sole cropping and intercropping and ICP 7035 and HY 3C (both ICRISAT varieties) were promising with yield of 1 t/ha. However, research activity was limited in 1988 due to human resource shortage (Mulila-Miui 1992).

Another research initiative is the improved fallows build upon traditional fallow practices by incorporating fast-growing, nitrogen-fixing vines, shrubs and trees into traditional fallows in order to accelerate the natural soil regeneration process. Whereas traditional fallows require up to 20 years to improve the soil, improved fallows can significantly improve soil fertility in only 2 years, depending on rainfall and the growth of the selected tree species. There are also secondary benefits of improved fallows, such as the provision of fuel wood, medicine, fodder, erosion control, weed suppression and shade. The improved fallow species being promoted include, amongst others, pigeonpea (Phiri 2002). Short duration rotations of managed fallows make use of fast growing, nitrogen fixing trees such as pigeonpea. This crop has the biological potential to replenish soil fertility and thereby increase crop yields of subsequent crops. The improved fallow technology by using pigeonpea has been recently introduced to smallholder farmers in Zambia as a viable alternative to chemical fertilizer use (Thangata et al. 2007).

Uses

Immature green peas of pigeonpea are used in soup or eaten with rice, and dried seeds are boiled and eaten as stew along with *nshima*. Pigeonpea is used as a perennial forage crop for livestock, and dried branches are used for fuel, thatching, and for making baskets and storage bins (Mulila-Miui 1992).

Zimbabwe

Geography

Zimbabwe is located in southern Africa, lies entirely within the tropics and has an area of 390,757 km² that lies over 300 masl. The country has

geographical coordinates of 15°47' S to 22°21' S latitude, 25°18' E to 33°2' E longitude (Figure 71). About 80% of the land is higher than 600 m and less than 5% is above 1,500 m, with the highest part in the Eastern Highlands (Gambiza and Nyama 2000).

There are three seasons in Zimbabwe: (1) a hot wet season from mid-November to March (summer); (2) a cold dry season from April to July (winter), and a hot dry season from August to mid-November (spring). The country has a short rainy season, which lasts about four months between November and March. The mean annual temperature ranges from 25°C in parts of the Zambezi Valley to less than 15°C above 1,800 m in the Eastern Highlands. Maximum temperatures are lowest in June or July and highest in October. During winter, mean daily temperature ranges between 11 and 20°C. Mean maximum daily temperatures can exceed 32°C during spring (Gambiza and Nyama 2000).

Agriculture

Prior to the collapse of Zimbabwe's economy in 2000, agriculture was the most important economic activity with about 60% of industry being agro-based. Furthermore, the agricultural sector consumed about 20% of total output of industry (CFU 2000). The agricultural sector employed a large proportion of the country's labor force and also contributed about 18% of GDP and 40% of export earnings annually in a normal year (Rukuni 1994). The major exports in the 1990s were tobacco, cotton, sugar, maize, tea, coffee, horticultural crops, fruits, vegetables and beef. The beef exports go mainly to the European Union and South Africa. Small-scale farmers, who comprise the majority of the population, only contributed 14% of the value of sales of principal crops in 1999. The majority of the smallholder farmers struggle to meet subsistence food requirements. High levels of poverty on these farms exacerbate the food problem, as they are unable to purchase food from the retail markets making food security fragile (Mudhara and Hildebrand 2001).

The sector is grouped into four major production sectors: (1) the large scale commercial farming sector (LSCF), (2) small-scale commercial sector (SSCF), (3) communal areas (CAs) and (4) resettlement areas (RAs). Before the land reform that began in 2000, most of the farmers in CAs had small landholdings and were located mainly in agro-ecological regions III

to V, where annual rainfall ranges from 450 mm to 800 mm. Production in these areas is mostly for subsistence (Vincent & Thomas 1965). About 70% of the population is dependent on farming for a livelihood. However, more than 80% of Zimbabwe is subject to conditions that make dryland cropping a risky undertaking because of low and erratic rainfall. Livestock and crop production are therefore important enterprises in most areas. The major ruminant species kept are cattle, goats and sheep. Cattle are the most important; donkeys, pigs and poultry are also kept. Natural grazing is the most important source of livestock feed. The number of domestic livestock fluctuates widely because of variations in annual rainfall (Gambiza and Nyama 2000).

About pigeonpea

Pigeonpea, a relatively minor crop (Nene et al. 1989; Nyabyenda 1987; van der Maesen 1983, 1986; Kamanga and Shamudzarira 2001), is considered by many as a new crop in Zimbabwe. Pigeonpea was chosen for its ability to grow on relatively infertile soils, and tolerance to drought and other environmental stress (Whiteman et al. 1985, van der Maesen 1991). There are 10 accessions identified (Upadhyaya 2007).

According to Mudhara and Hildebrand (2001), no market outlets for pigeonpea seed existed in the communal areas of Zimbabwe and those early adopters of pigeonpea-improved fallows were not likely to find a market for the pigeonpea seeds. However, it is anticipated that, over time, the market outlets might develop as entrepreneurs realize that there are viable quantities for setting up a market. Initially, the government might/have to purchase the seed as a way of promoting the use of pigeonpea improved fallows. In a study of the potential adoption of improved fallows by smallholder farmers, it was revealed that farms without draft power could rely on a one-year fallow planted in the first year, followed by maize in the second and third year then followed by another one year of planted fallow. The increased utilization of pigeonpea will enhance the adoption of the plant for planted fallow.

Zimbabwe's staple food is maize. Crop yields in the smallholder farms are low. Average maize yields of 1,300 kg/ha, ranging from 350 to 2,200 kg/ha are realized (Farm Management Research Section 1990). In this juncture, continuous research was conducted such as the study conducted by Mapfumo and Mtambanengwe (1999) on the growth and yield of maize after

pigeonpea cultivation. It was found that significant maize yield responses were obtained after pigeonpea despite low productivity of these legumes at all sites. Relative to the control, medium and long duration pigeonpea treatments resulted in increase in maize biomass (37% to 46%) and grain (20% to 28%). Yields across all treatments increased with increasing N application. Maize tissue analyses at 6 and 15 weeks after emergence showed significant increases in P, K, Ca and Mg uptake. It was further concluded that the residual benefits of pigeonpea in these cropping systems are largely due to their capacity to remobilize and recycle base nutrients, and that the productivity potential of granitic sandy soils is undermined by continued depletion of these cations under current management practices.

In another development, the objective of the study conducted by Mudhara and Hildebrand (2001) entitled the 'potential adoption of improved fallows to improve income and food security of diverse smallholder farmers' in Mangwende CA, Zimbabwe is to raise maize yield by improving fallow period through the adoption of pigeonpea. Awareness about the potential adoption of such technologies will help design appropriate extension approaches and policy interventions to support the small-scale farmers. Results indicate that there is potential of adopting pigeonpea fallows when a price incentive was offered on their seed or when *Sesbania sesban* was not an option. *Sesbania sesban* is the main legume planted by farmers during the fallow period. The adoption of pigeonpea as a fallow crop is bright. But findings showed that farmers are not cultivating pigeonpea when its seeds are not marketed. *Sesbania sesban* replaces pigeonpeas when pigeonpea seeds are not marketed. The adoption of pigeonpeas would increase if the price of the seed increases. To get an initial adoption of pigeonpea, improved fallows would require a price support and market for pigeonpea seed. Such a support could initially be provided through public funding. Therefore, policies to support pigeonpea-improved fallows are suggested.

Pigeonpea as an intercrop was also studied by Waddington et al. (2007). In their findings, the pigeonpea-maize intercrop grown without fertilizer produced 0.11 t/ha (6.25%) more maize grain yield per year than sole crop maize, in addition to pigeonpea grain and haulms. Pigeonpea or cowpea-unfertilized maize generated more financial returns than the other intercrops, but the low yields and high labor costs for the legumes made the intercrops financially unattractive. They also concluded that regularly intercropping pigeonpea or cowpea can to a small extent help to maintain maize yield

when maize is grown without mineral fertilizer on sandy soils in sub humid zones of Zimbabwe, and simultaneously provide some nutritious food, but that financial considerations will encourage smallholder farmers to persist with growing low input sole crop maize.

The potential adoption of pigeonpea in Zimbabwe improved fallows depend on the composition of the household, farm size, and draft power (farmers with draft power also had access to cattle manure). Adoption of improved fallows increased household income for discretionary spending. The percentage increase in the incomes of households with more limited resources was greater than the better-endowed households. When pigeonpea and *Sesbania* fallows were modelled together, pigeonpeas were adopted only when there was potential to sell the pigeonpea seed. However, when modelled alone, without other fallows species, pigeonpeas were adopted even without a market for the seed. Households relied on one-year fallow and on average, planted 0.53 ha in the first year and 0.46 ha in the third year. Fallows of other durations were planted on 0.1 ha or less and the three-year fallow was not adopted (Thangata et al. 2007).

The Americas and the Caribbean

The role that agriculture has played in reducing poverty is important not only because it is a way of life for millions of people in the Americas and the Caribbean, but also because it is a strategic sector that contributes to economic, social, environmental and political development at the national level. Furthermore, agriculture's true contribution to economic development in the hemisphere is enhanced when the region's favorable agro-ecological conditions are underpinned by trade policies that ensure better prices for its products, promote trade negotiations that make it possible to take advantage of new market niches, implement more effective public policies that guarantee product quality and safety, and allocate more resources to investment in science and technology. Actions of this kind are the only way to make agriculture a catalyst in translating the current sustained economic growth in the developing countries into significant reductions in poverty and hunger (Brathwaite 2007).

The Americas continues to be the world's leading net exporter of agricultural products, followed by Oceania. Soybean is the leading export commodity with 8.5% of all agricultural exports. The region mainly imports processed agricultural products and this trend has been accentuated in recent years (Arias et al. 2006), while in the Caribbean region, both agricultural exports and imports have declined. The trend was even more marked in 2005 because it/had a negative agricultural balance of trade.

According to Sinha (1977), pigeonpea landraces are grown mostly in the Dominican Republic, Puerto Rico, West Indies in the Caribbean region (Figure 72) and Latin America (Figure 73). The range of suitable elevations depends on latitude. In Venezuela they are grown up to 3,000 m while in Jamaica it is up to 1,100 m, but in Hawaii, they failed to set seed at 1,000 m. Eighty percent of pigeonpea are cultivated for its green seeds or pods and 20% for dried grains.

Pigeonpea is cultivated commercially for canning in the Dominican Republic, Trinidad and Tobago, Puerto Rico and Hawaii. Yield of green-pods in the region vary from 1,000 to 9,000 kg/ha. In 1975, North America produced 41,000 MT, averaging 1,415 kg/ha while in South America, it produced only 4,000 MT averaging 449 kg/ha. In the Dominican Republic, the yield of fresh seeds or pods was 2,194 kg/ha (FAO 1975, Duke 1981), although according

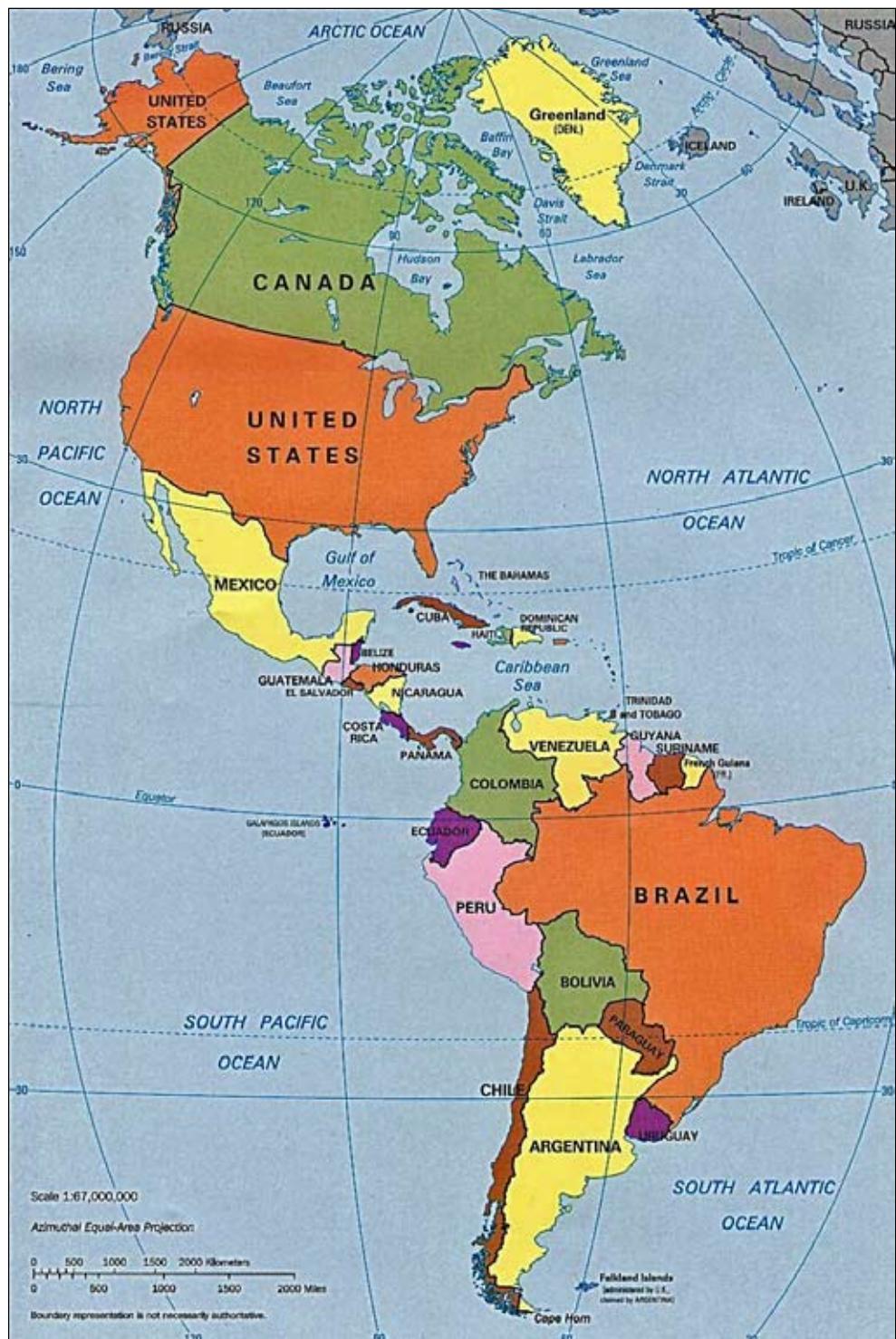


Figure 72. Map of Americas.

to Price (1990), the country actually reached a yield of 11 t/ha of green-pods in five pickings on one plot.

Area

Table 33 shows the area planted to pigeonpea in the Americas and Caribbean for more than four decades (1961-2005). The highest was in 1990 and the lowest in 2000. The data shows that two countries largely account for the sharp fluctuations in the total area cultivated namely the Dominican Republic and Venezuela. A sharp decline was also experienced by countries like Puerto Rico and Trinidad and Tobago in 2000. The year 2005 had the second lowest decrease in the total area. The differences in earlier decades are not as pronounced as in the later decades.

Production

Table 34 shows the total production of pigeonpea in nine countries that comprise the Americas and the Caribbean and the combined totals from 1961 to 2005. The highest production was in 1990 while the lowest was in 2000. The FAO data indicating a significant fluctuation in the area planted (Table 33) showed a corresponding fluctuation in the production for the same period or year covered. The reduction in area in 2000 showed a parallel reduction in production.

Productivity

Table 35 contains the data on productivity of pigeonpea in the Americas and the Caribbean from 1961 to 2005. Of the nine countries in the region, Trinidad and Tobago has the highest level of productivity and with the least fluctuations. Haiti remained consistently low and further declined in the latest year on record (2005).

Table 36 presents a summary of percent distribution of area cultivated and production of pigeonpea for a period of seven years (2000-2006). The Dominican Republic consistently showed the highest percentage area and production for seven years while the least was the Bahamas.

Table 33. Area (ha) cultivated with pigeonpea in the Americas and Caribbean (1961-2005).

EAOStat 2008

Table 34. Pigeonpea production (t) in the Americas and Caribbean (1961-2005).

Country	Production (t)					
	1961	1965	1970	1975	1980	1985
Bahamas	320	430	540	625	520	650
Dom. Republic	20,700	21,000	25,000	29,454	16,598	13,424
Grenada	750	770	650	700	901	630
Haiti	2,800	3,000	3,250	3,700	4,000	4,300
Jamaica	998	870	1,996	2,143	2,351	2,139
Panama	1,400	1,300	1,400	1,497	2,004	2,346
Puerto Rico	4,989	4,209	3,175	4,309	5,216	3,311
Trinidad & Tobago	1,500	2,404	1,814	2,540	3,532	2,216
Venezuela	1,989	5,400	7,619	3,422	3,447	4,740
Total	35,446	39,383	45,444	48,390	38,569	33,756

FAOStat 2008.

Table 35. Productivity (kg/ha) of pigeonpea in the Americas and Caribbean (1961-2005).

Country	Productivity (kg/ha)					
	1961	1965	1970	1975	1980	1985
Bahamas	700	700	700	700	700	710
Dom. Republic	1110	1110	1110	2194	854	1110
Grenada	1177	1177	1177	1177	1177	1197
Haiti	480	480	480	480	482	480
Jamaica	1190	1190	1190	1190	960	1190
Panama	480	480	480	480	875	480
Puerto Rico	1490	1490	1490	1490	857	1490
Trinidad & Tobago	2000	2000	2000	2000	1889	2000
Venezuela	800	800	1603	800	515	800
Total	1047.44	1047.44	1136.67	1167.89	923.22	1047.44
					838.78	1050.78
						1020.55
						1077.67

FAOStat 2008.

Table 36. Percent area cultivated and production of pigeonpea in the Americas and Caribbean (2000-2006).

Americas & Caribbean	Area Cultivated and Production (%)												2006	
	2000		2001		2002		2003		2004		2005		2006	
	Area	Prod	Area	Prod	Area	Prod	Area	Prod	Area	Prod	Area	Prod	Area	Prod
Bahamas	00.64	00.50	00.58	00.48	00.59	00.47	00.53	00.48	00.62	00.50	00.61	00.50	00.61	00.50
Dom. Republic	46.37	57.47	47.44	57.18	46.63	52.86	48.23	52.11	45.10	52.58	44.21	51.84	44.27	51.84
Grenada	01.99	02.18	01.91	02.20	01.52	02.03	01.81	02.00	01.81	02.02	01.77	02.00	01.77	02.00
Haiti	25.41	13.05	20.05	11.44	19.40	10.77	20.01	10.42	19.35	09.71	20.42	10.37	20.43	10.37
Jamaica	04.97	05.33	05.04	05.93	03.95	05.30	03.36	05.21	03.80	05.26	03.74	05.18	03.75	05.18
Panama	09.19	08.97	15.18	08.39	14.08	07.89	12.46	07.80	16.25	09.10	16.32	09.17	16.35	09.17
Puerto Rico	00.56	00.43	00.37	00.66	00.87	01.42	00.62	01.00	00.58	01.01	00.56	01.00	00.56	01.00
Trinidad & Tobago	01.18	03.41	02.44	07.22	03.60	11.30	02.98	11.22	03.82	11.73	03.87	11.96	03.75	11.96
Venezuela	09.69	08.66	06.99	06.50	09.36	07.96	10.00	09.76	08.67	08.09	08.50	07.98	08.51	07.98

FAOStat 2008.

Latin America and the Caribbean

In Latin America and the Caribbean (LAC), about 77% (1,683 M ha) of the land is tropical. In 2005, the countries in this region achieved their best economic and social indicators of the last 25 years, with major progress made in reducing poverty and unemployment, an improvement in income distribution in some countries and the creation of new jobs. The region's agricultural sector played a key role in this solid performance, lending further weight to the idea that it is extremely important for the development of the countries of the Americas and Caribbean. Agricultural production continued to rise throughout the region, although the rate of growth was slower in 2004 and 2005 than in 2003, which was a particularly good year for agriculture in Latin America except the Caribbean. In 2005, the agricultural GDP of LAC rose by 2.2%. However, the share of agricultural commodities in world trade has been declining since 2000. This is because its agricultural exports have grown more slowly than those of the rest of the world. While global agricultural exports grew at an annual rate of 10.5% during the period 2000–2005, the annual growth of the LAC's agricultural exports was only 7.2% in 2005 down from 13% in 1995 (Arias et al. 2006).

Latin America is a cultural entity consisting of 19 Spanish-speaking countries and Portuguese speaking Brazil, as a result of colonization by Europeans from the Iberian Peninsula (Figure 72). It is estimated that in Latin America there are about 16 million peasant units occupying close to 160 M ha and involving 75 M people, representing two-thirds of the region's total rural population. According to Altieri (2000), in this region, traditional farming systems still evolve where traditional farmers cultivate a diversity of crops and varieties for food security within the boundary of their landscape with limited environmental impact. He further suggests that Latin America's systems range from 'low intensity' long-fallow swidden to 'high intensity' permanent cultivation wherein large areas have been greatly modified from their natural state and are dominated by monocultures. In commercial agricultural areas, natural habitats are lost through expansion of agricultural production, especially of cattle, sugarcane, cotton, soybean, coffee, and (recently) non-traditional export crops. Highly capitalized farms tend to be on high-quality lands where profitability is contingent on low wages and large land holdings. By contrast, farms of resource-poor peasants tend to be on ecologically marginal lands or on lands recently opened to agriculture. Thus, impoverished farmers lack access to good farmland and capital and are

forced by necessity onto remnants of natural areas, which generally occur on steep slopes, along rivers, and in other fragile environments such as forest margins.

The Caribbean region consists of 25 island-states and four associated continental countries (Figure 73) with a total land area of 61 M ha, of which 25% is under agriculture and only 11% is arable. The Caribbean island-states consisting of 22.9 M ha (37% of the land area) has 94% of the total Caribbean population of 37 million. Hence, the per capita arable land area in most of the Caribbean island-states with the exception of the larger Caribbean island-states of Cuba, Dominican Republic and Haiti is below the minimum of 0.07 ha required to achieve food security. Traditional plantation crops grown in this region are sugarcane, banana, rice, cocoa, coffee and coconut (FAO 2000).

While agriculture is the major economic land-use activity in most Caribbean countries, it accounts for less and less of most islands' GDP. The islands of the West Indies have long been noted for their small farm subsistence agriculture. However, one important aspect of this production system, the kitchen garden, has received little attention in terms of both basic research and programs aimed at its improvement. Caribbean kitchen gardens date back to slave plantation days. They have challenged the descriptive talents of early travellers like Beckford (1790), Edwards (1793), Trollope (1860) and Kingsley (1872). Kitchen gardens sustained slave workers on sugar plantations and provided the basis for future farming enterprises for slave families upon liberation. Today these gardens continue to be a ubiquitous feature of the agricultural landscape in the Caribbean. These small units of production surrounding the Caribbean homestead are an important component of the farming system: the crop production knowledge and the skills of successive generations are acquired and passed on via the kitchen garden, which can be either a principal component of subsistence farming or the embryo from which a commercial agricultural or horticultural enterprise may develop. Its roles range from that of a farm family's major source of subsistence to that of a minor source of income (www.unu.edu).

Pigeonpea, likewise considered a staple food in the Caribbean, is found all over the region where they are mostly harvested in mid-March to April, and from November to January. At these times the peas are available in their fresh form and find themselves in a host of dishes especially during

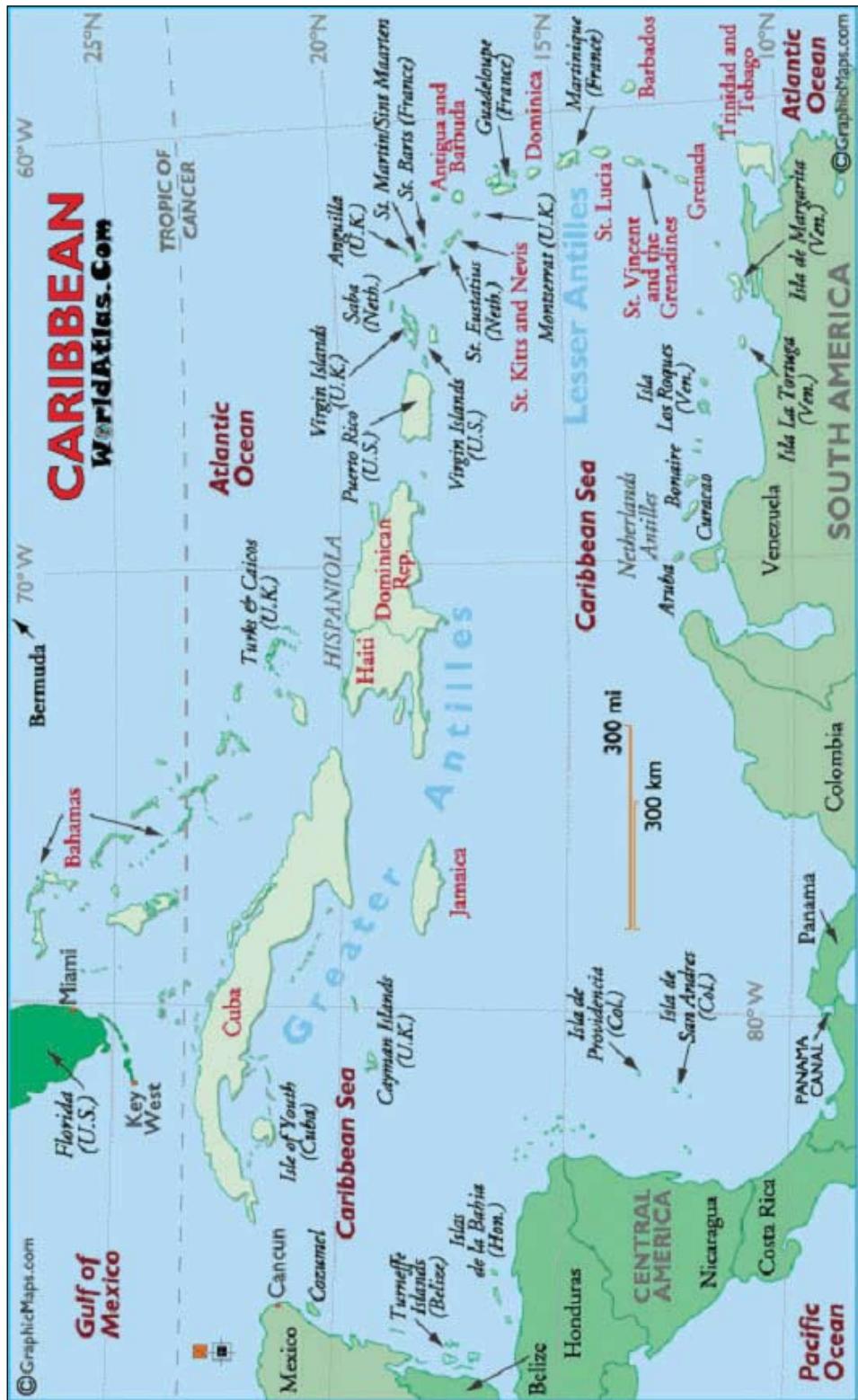


Figure 73. Map of the Caribbean Islands.

Christmas. There are three pigeonpea production systems that exist in the Caribbean regions; the full-season crop production followed by small farmers, mechanized large-scale production, and the dry grain production. In the first system, tall, indeterminate, long-duration cultivars are grown at low density while in the dry grain production, early-maturing types are grown at high plant population (Arinayagam 1981).

In terms of production, the Dominican Republic, Haiti, Panama and Jamaica are the major producers in the region. About 20 other smaller countries produce substantial amounts of the crop and are the best adapted grain legumes. Significant potential exists for expanding pigeonpea cultivation in some of these countries such as Guyana and Belize (Ariyanayagam 1981). The crop is popular because of its palatability and its hardiness. The crop is grown mainly in small farms, requires low-input and is often planted as an intercrop or around boundaries of plots and homesteads. It is estimated that at least 5,500 ha are sown annually throughout the region with farm yields of green-pods varying from as low as 400 kg/ha to as high as 1,500 kg/ha. However, despite having been introduced over 30 years throughout the region, it remains resistant to commercialization. The main cultivars planted are still the unimproved, tall, indeterminate types such as 'Tobago Pea', 'La Seiva', 'Pedro Giant' and 'Khaki'. These varieties are photosensitive, bearing pods between December and March (www.new-agri.co.uk).

In Latin America and the Caribbean areas, green-pods are harvested for home consumption or canning. The Caribbean has developed dwarf cultivars with more uniform pod maturity, which are mowed and threshed with a combine harvester. Depending on the cultivars, the location and time of sowing and flowering can occur from as early as 100 days to as late as 430 days. The best vegetable pigeonpea cultivars have long pods, with as many as 9 large sweet seeds that are easily removed from the shell. Sweetness is also desirable. In contrast, what are usually sold in Indian markets for use as a vegetable are small pods with small seeds. Consumers prefer vegetable pigeonpea with green-pods, but tests have shown that differences in pod color are not related to cooking time, taste or quality. The large pods are especially attractive to insects. Insect damage can also be greater in cultivars that have the pods clustered in bunches at the top of the plants, but these varieties are also shorter and are easier to spray with insecticides and easier to harvest. If the rainy season is long, or the field is irrigated, pods may be produced as long as the plant remains free of disease and the

mean temperature remains about 15-30°C. The pods should be harvested just before the seeds start to lose their bright green color. Meanwhile in the Caribbean, harvesting has been mechanized by adapting green bean pickers. Harvesting is done mostly in mid-March to April and from November to January (Price 1990).

Promising cultivars

An early maturing, dwarf, determinate variety, UWI 10, is planted by growers in Trinidad and elsewhere in the Caribbean in August or September. This can then be harvested for the Christmas market when demand and prices are high, unlike traditional cultivars, which bear more heavily after Christmas. Another determinate variety, ICPL 289, was selected particularly in Barbados, for its ease of harvesting. It is short, growing to a height of 0.6 to 1.2 m and the pods, which generally mature evenly, are borne in clusters at the end of branches making manual harvesting relatively easy. Seeding of the crop has been successfully mechanized but, despite the introduction of dwarf or evenly maturing varieties, attempts at mechanical harvesting and threshing have been only partially successful. This is because it has proved difficult to reduce losses caused by falling and shattering of pods during the process of cutting of plants, windrowing and transporting to the thresher. A dehuller, designed by the Caribbean Industrial Research Institute (CARIRI) in the 1980s, continues to be used in the region.

Uses

Pigeonpeas grow well in hot climates, making them especially popular in the Caribbean. They have been cultivated throughout the tropics for centuries. The pigeonpea is a small, round, tan-colored seed with a pungent flavor and a mealy texture. It is sometimes mistaken for the black gram or mungbean. The ripe seeds are often ground into a meal, and then mixed with palm oil, salt and condiments, but Europeans use the young seeds like peas and the pods as a vegetable. Pigeonpeas have a slightly acrid taste due mainly to the seed coat, but when this is taken out the flavor improves (www.innvista.com/health/foods/vegetables/pigeonp.ht).

The Christmas dinner would not be considered complete by most Caribbean folks without the presence of *gungo* peas (as the pigeonpea is commonly known here) and rice or pigeonpea served in a soup. It includes the traditional

jerked or curried chicken and goat, and rice with *gungo* peas. The fresh peas tend to be sweet and cook more quickly, but the dried form may be stored for extended periods. And with good reason — the *gungo* pea, like most other legumes, is a good source of protein, minerals and fiber (www.gracefoods.com/site/gungopeas).

Consumer demand for commercialization

Fresh pigeonpeas are sold at local markets but it has been estimated that production only satisfies about 20% of the demand. CARICOM data indicate that more than 800,000 kg of dried peas are imported annually into the region. In 1997, 70% of these were imported into Trinidad with the majority being used for canning. In addition, a further 800,000 kg of processed (mainly canned) peas were imported into the region with about 50% going to Jamaica. Minimal amounts of fresh and frozen peas are exported from the islands but the export of canned peas is increasing from both Trinidad and, more recently, from Jamaica (www.new-agri.co.uk).

Marketing limitations

Pigeonpea, generally a staple food in the Caribbean and Latin America, is popular for both its palatability and its hardiness. And yet, despite over thirty years of research efforts throughout the region, it remains resistant to commercialization. For commercial year-round production, there is a need for photo-insensitive or day-neutral cultivars. Also, to facilitate harvesting and to satisfy consumer demand, short cultivars with an attractive appearance – large pods and seeds – are required. However, despite selections for these characteristics in breeding programs at various institutions, no variety has proved popular throughout the region. Caribbean and Latin American consumers consider many of the ICRISAT varieties too small, and many of the new introductions appear to be more susceptible to pod borers than the indigenous types. The out of season yield of the day-neutral varieties currently being grown is not very high and their use has not significantly increased year-round production. Plant breeders at the University of Puerto Rico have selected large seeded, day-neutral varieties but these tend to carry few seeds per pod.

Commercialization of pigeonpea is also inhibited by its susceptibility to a wide range of pests and diseases. Control for these is rarely practiced and

there is often a high incidence of Tobacco budworm, *Heliothis virescens*, and the pod borers *Fundella pellucens* and *Ancyclostomia stercorea*. A seed weevil (*Callosobruchus chinensis*) also attacks dried pods in the field and in storage. Indigenous natural enemies of the budworm and pod borers include the parasites *Bracon*, *Apanteles* and *Trichogramma* species, but these do not appear to give adequate control. The Caribbean Agricultural Research Institute (CARDI) attempted to enhance biological control through the selection and introduction of natural enemies originating in Asia, USA and the Caribbean. The trials achieved some success with the selection of a *Brachon* species that killed over 40% of Tobacco budworm caterpillars in several locations.

Future development work will undoubtedly need to focus on both domestic and commercial production systems. The appropriateness of the indeterminate varieties for domestic use should be recognized and these indigenous types, which are very vulnerable to crossing with the introduced varieties, must be preserved. At the same time, exploiting the commercial potential of this crop, as indicated by trade data, remains an exciting challenge (www.new-agri.co.uk).

Caribbean Pigeonpea Project Initiative

In 1982, an Italian Trust Fund executed by FAO mobilized the implementation of a three-year project, namely the FAO/Government Cooperative Programme for the members of the Caribbean community (CARICOM). During the three-year period of the project from 1992-1994, a regional information network called the Caribbean Seed and Germplasm Resources Information Network (CSEGRIN) was established for germplasm information, collection and exchange. This program aims to improve the seed production of crops to include pigeonpea. In addition, regional technical standards for true seed were developed and basic seed testing and equipment/handling services were provided. Recognizing the importance of Phase I of the project, the CARICOM countries, Grenada, Jamaica, Trinidad and Tobago, Antigua and Barbuda, Barbados, Belize, Dominica, Guyana, Montserrat, St Kitts and Nevis, St Lucia, St Vincent and the Grenadine and Suriname, requested further assistance for Phase II to be developed. Phase II of the project started in January 1995 and was completed on 30 June 1997. During this period, the first region-wide survey to collect information on seed demand and supply for various crops such as pigeonpea was initiated. The project's

objective was to provide quality seed and planting materials of major crops in order to enhance both national food security and export diversification. Improved high-quality seed or planting material can only be the result of conscious varietal improvement to generate good genetic material, which can then be massively propagated by farmers. Some varietal improvement had taken place but no systematic regional evaluation trials or seed multiplication programs were in place. In order to protect the genetic integrity of available improved varieties, the concept of a limited generation system of seed production was strengthened by the proposal of a seed certification system. A seed technical standard was developed and a testing procedure using the rules of the International Seed Testing Association (ISTA) were adopted (FAO 1998).

Major Pigeonpea Producing Countries

Bahamas

Geography

Bahamas is geographically considered part of the Caribbean with geographic coordinates of 23°43'N to 25°5'N latitude and 77°36'W to 78°43'W longitude. It lies in the North Atlantic Ocean, southeast of Florida, north of Cuba and northwest of the Turks and Caicos Islands (Figure 73). Bahamas is an archipelago of small islands, most of them uninhabited. More than 80% of the land surface is only a meter or less above mean sea level. The natural resources of the country are very limited (en.wikipedia.org/wiki/Geography_of_Bahamas).

The climate of the archipelago is semitropical and has two seasons, summer and winter. The summer, which extends from May through November, is dominated by warm, moist tropical air masses moving north through the Caribbean. Midsummer temperatures range from 21°C to 34°C with a relative humidity of 60 to 100%. In winter months extending from December through April, the climate is affected by the movement of cold polar masses from North America. Temperatures during the winter months range from 15°C to 24°C. Yearly rainfall averages 1,320 mm and is usually concentrated in the May-June and September-October periods. Mean annual rainfall varies from about 1,470 mm to about 865 mm (Knowles 2001).

Agriculture

Agriculture has historically been a challenge for Bahamians since only 1.5% (approximately 20,344 ha) of the land is suitable for crop production (Agricultural Census 1994). As a result, the majority of food products are imported mostly from the United States. As a matter of fact, some 80-85% of the food consumed in the country is imported. There is no large-scale agriculture, and most agricultural products are consumed domestically (CIA 2005). Agricultural products grown locally include citrus fruits, winter vegetables and poultry. A large portion of the citrus crop is exported to USA, Canada and Europe. The sector also produces substantial quantities of broilers and eggs. Agriculture's contribution to the economy is relatively small, a measly 1-2% of GDP. The economy is dominated by the tourism sector, which is the principal contributor to gross domestic product (GDP). It actually accounts for 50% of GDP (Knowles 2001).

The Bahamas depends almost entirely on imports to feed Bahamians and tourists. Livestock numbers are small. There is also no cultivation of rice or prescribed burning of savannas or crop residues. There is some slash-and-burn farming but the acreage is very small. Insignificant amounts of fuel wood and charcoal are used for cooking. Enteric fermentation by livestock, manure management and agricultural soils all produce emissions on a very small-scale. Many of the short-term subsistence crops grown are seasonal, and any significant shifts in climatic conditions will affect crop production (Knowles 2001).

Pigeonpea area, production and yield

The FAO has included Bahamas in the list of major pigeonpea producing countries in the Caribbean region since 1961. However, according to Nene et al. (1989), Nyabyenda (1987), van der Maesen (1983, 1986), pigeonpea has been considered to be a minor crop. Based on statistics derived from the FAOStat (2008), the area cultivated to this crop has been on a downtrend (Appendix 2 and Table 33). A significant decline was recorded at 186 ha in 1999 from an area of 936 ha in 1977 (Appendix 2). The trend continued up to 2006, which is the latest available data (Table 33). Consequently, the production was affected. The crop's productivity stagnated at 700-710 kg/ha between 1961 and 1999 (Appendix 4).

Dominican Republic

Geography

The Dominican Republic is a country with many mountains, located in the West Indies and occupies the eastern two-thirds of the Hispaniola Island between the Caribbean Sea and the North Atlantic Ocean (Figure 73). It has an area of 48,442 km², including offshore islands with coordinates of 17°53'N to 19°48'N latitude and 68°12'W to 71°48'W longitude. The land borders with Haiti, which occupies the western one-third of the island (De la Fuente 1976).

The country is a tropical, maritime nation. The annual mean temperature is 25°C; regional mean temperatures range from 18°C in the heart of the Cordillera Central (Constanza) to as high as 27°C in arid regions. Temperatures rarely rise above 32°C, and freezing temperatures only occur in winter in the highest mountains. The average temperature in Santo Domingo in January is 24°C and in July 27°C. The rainy season for the northern coast is from November to January. For the rest of the country, the rainy season is from May to November. The average annual rainfall is 1,346 mm, with extremes of 2,500 mm or more in the mountainous northeast (the windward side of the island) and 500 mm in the southwestern valleys. The western valleys, along the Haitian border, remain relatively dry, with less than 760 mm of annual precipitation. The northwestern and southeastern extremes of the country are also arid (De la Fuente 1976).

Agriculture

The agriculture of the Dominican Republic was described in the 1970s as a mixture of the traditional and modern cropping systems. Traditional agriculture is equivalent to 'subsistence' agriculture that grows cassava, rice, sweet potato, taro and pigeonpea. Modern agriculture was equivalent to plantation agriculture, represented by the extensive cultivation of sugarcane (Morales et al. 2000). The country is an upper-middle income developing country primarily dependent on agriculture, trade, and services, especially tourism. Although the service sector has recently overtaken agriculture as the leading employer of Dominicans (due principally to growth in tourism and Free Trade Zones), agriculture remains the most important sector in terms of domestic consumption and is second to mining in terms of export earnings.

With almost 30% of the total land area suitable for crop production and about 17% of the labor force engaged in farming, agriculture remains the primary occupation, accounting for 11% of GDP in 2001. Value of agricultural output grew at an average annual rate of 7.1% during 1968–73, but since 1975 the sector has been hampered by droughts (1975, 1977 and 1979), hurricanes (1979 and 1980), and slumping world prices and quota allocations for sugar (since 1985). In 1999, agricultural production was 0.4% higher than during 1989-91. The fertile Cibao Valley is the main agricultural center. In 1998, arable land totaled 1.02 M ha; with land under permanent crops at 0.480 M ha. After Cuba, the Dominican Republic is the second-largest Caribbean producer of sugarcane, the nation's most important commercial crop. Other leading cash crops and export commodities are coffee, cocoa and tobacco. The Dominican Republic also produces other crops such as rice, coconuts, cassava, tomatoes, pulses, dry beans, eggplants and peanuts (en.wikipedia.org/wiki/Economy_of_the_Dominican_Republic).

Pigeonpea area, production and yield

The Dominican Republic leads the Americas and Caribbean as the major producer of pigeonpea in the region as shown on Tables 31 and 32 and Appendix 2 and 3 (FAOStat 2008). Upadhyaya (2007) identified 63 accessions in addition to the latest cultivar 'Navideño' released in 2005. The area cultivated and production of pigeonpea has dramatically decreased over time (Tables 33 and 34). Average productivity level is pegged above 1,000 kg/ha (Table 35).

There are 8 regions in the Dominican Republic where pigeonpeas are grown (Table 37). The main region for the production of pigeonpea is in the Southwest of the country with 161,864 ha. Next is the Central Region with 63,397 ha followed by the Southern Region with 49,573 ha. The total area cultivated in 1998 was around 307,018 ha (Núñez et al. 2001). These areas however had been decreasing over the years (Appendix 2).

Table 37. Area planted and percent distribution of pigeonpea by region in Dominican Republic in 1998.

Region	Area (hectare)	% Distribution
Southwestern Region	161,864	52.72
Southern Region	49,573	16.15
Central Region	63,397	20.65
North-Central	2,868	00.93
Northern Region	8,857	02.90
Northwestern Region	12,445	04.05
Eastern Region	5,857	01.90
Northeastern Region	2,157	00.70
Total	307,018	100.00

Source: Núñez et al. 2001, USDA Gain Report 2001.

The production of pigeonpeas, the second most important bean, has been erratic over the years. According to Smith et al. (2001), pigeonpea production in 1992 was 100 mt and in 1997 33.5 mt. However, Núñez et al. (2001) reported that in 1992, 56.9 mt was produced with the highest production of pigeonpea of over 104.6 mt in the year 1991 (Table 38). In 1998, pigeonpea production was recorded at 44.3 mt (Smith et al. 2001, Núñez et al. 2001). But according to FAOStat (2008), the highest production of pigeonpea is in year 1991 at 47.5 mt (Appendix 3) with the least production recorded in 1983 at 10.7 mt. These conflicting records require a closer or more thorough examination (not just for this country but for the whole region).

Table 38. Ten (10) year production of pigeonpea in Dominican Republic (1989-1998).

Year	Production (mt)
1989	68.4
1990	41.0
1991	104.6
1992	56.9
1993	54.0
1994	47.0
1995	67.0
1996	37.0
1997	33.5
1998	44.3

Source: Núñez et al. 2001, USDA Gain Report 2001.

Trading: Domestic and International

Pigeonpeas are exported in all forms—fresh, canned, refrigerated or frozen. The country exported around 741,103 kg of fresh green peas and 292,389 kg of frozen green peas (Wright 1986). They come by such brand names as ‘Casera’, ‘Diana’, ‘El Jibarito’, ‘Goya’ and ‘Iberia’. They are mostly found in supermarkets in the USA, more commonly in southern Florida. The country, however cannot sustain the supply of fresh pigeonpeas for canning purposes. Hence, it resorted to importing them from nearby Caribbean countries, and even as far as Africa and Asia. For the latter, it imported a total of 230 mt of pigeonpea (*toor whole*) from Myanmar. As to domestic trading, the producers sell them to middlemen, who in turn sell to wholesalers or to agro-industries that distribute the same to small and large grocery stores (Smith et al. 2001). The amount of exported pigeonpeas in the country from 1990-98 is shown in Table 39.

Table 39. Exported pigeonpeas in Dominican Republic (1990-1998).

Year	Dry		Canned		Fresh	
	Kg	Value (USD)	Kg	Value (USD)	Kg	Value (USD)
1990	124,650	14,985	11,013,625	5,151,426	894,929	772,886
1991	849	481	9,984,837	3,919,987	2,758,364	2,467,117
1992	-	-	10,381,242	4,652,103	1,649,098	1,709,577
1993	210	74	4,474,725	2,639,644	3,212,426	2,342,050
1994	-	-	7,597,372	4,709,814	1,843,605	1,849,124
1995	-	-	14,227,970	10,816,873	1,674,862	1,895,080
1996	25,751	29,727	4,588,775	3,374,588	883,737	927,002
1997	19,723	9,164	6,642,242	4,914,977	2,034,358	1,860,843
1998	156,556	109,841	9,488,272	7,646,152	1,365,651	1,416,275

Source: Núñez et al. 2001, USDA Gain Report 2001.

Uses

Beans are an important source of protein for the Dominican population especially for those in the lowest income strata. Beans are usually eaten with rice and this contributes to a greater assimilation of its proteins because rice has amino acids that complement the amino acids of the beans. The favorite is the red bean or its imported substitute, the pinto bean, followed by pigeonpea, then black and white beans. The advantage of pigeonpea is its

diverse ethno medical uses. Folk medicine claims that pigeonpea can treat chest problems, sores, sore throat and wounds (Taylor 2005).

Grenada

Geography

Grenada, dubbed “Spice Island” because of the impressive amounts of nutmeg, cloves, mace, cinnamon, ginger and cocoa, is one of the smallest independent countries in the western hemisphere. The country is situated 110 km southwest of St Vincent and 145 km north of Trinidad and Tobago with a total land area of 348.2 km² located at 12°4'N to 12°07'N latitude and 61°28'W to 61°40'W longitude (Figure 73) (AQUASTAT Country Profiles; GEF 2001). Grenada’s climate can be classified as semi-tropical with an average annual rainfall of 2,350 mm. The country enjoys warm sunny weather throughout the year, which at times, however, is tempered by sudden showers. Annual rainfall on the island-nation, triggered largely by the warm and moisture-laden north-easterly trade winds, varies from more than 3,500 mm on the windward mountainsides to less than 1500 mm in the lowlands. The highest monthly totals are recorded from June to November, the months when tropical storms and hurricanes are most likely to occur. The terrain is mountainous and rugged, ending in cliffs that jut into the sea.

Agriculture

Grenada’s economy is vulnerable to external shocks considering its high dependence on tourism, exports and imports of most of the goods that are consumed or invested domestically. Food imports account for more than one quarter of Grenada’s total imports. The country is also prone to other adverse shocks such as natural disasters (en.wikipedia.org/wiki/Economy_of_Grenada).

Grenada’s economy relies heavily on the traditional production of spices and other agricultural crops. However, tourism in the country is the leading foreign currency-earning sector. The importance of agriculture to Grenada’s GDP has fallen steeply, from more than 26% in 1979 to an estimated 9.7% in 1996 and the World Bank estimates its contribution at 8.1% in 1999. The 1995 agricultural census estimated that the area of cultivated land in Grenada had fallen from 24,686 ha in 1961 to 12,545 ha in 1995. Total arable

land comprises 5.88% of the total land area of 340 km² while permanent crops were tallied at 29.41%. Grenada's soils are mostly well drained and reasonably fertile. Together with high temperature and rainfall in most areas, the country's land base has considerable potential for productive crop growth. However, as a mountainous country there is also high erosion potential, a factor that places substantial constraints on the way the vast majority of the country's land base can be sustainably utilized (PROCICARIBE_org 2008).

According to the World Bank, agriculture's decline has been balanced by the rising importance of industry, which has grown from 14.2% of GDP in 1979 to 22.2% in 1999 (nationsencyclopedia.com/economies/.../Grenada-ECONOMIC-SECTORS). The Draft Land Development Policy of the Ministry of Agriculture (1995) classifies 74.9% of the total landmass as being suitable for agriculture. In 1996 agriculture's share was 10.4% GDP, showing a decline from 1981 (17.5%). At the end of 1995, 4.5% of the workforce was employed in agriculture (including the fishing sector), while in 1999 the workforce increased to 32.8%. Grenada's main agricultural products are bananas, cocoa and nutmeg (CIA 2000). Grenada's farming practice is unusual as 87% of farming is an individual rather than a household activity. Both men and women are involved in agriculture, but most cultivate the land on a part-time basis. Land holdings tend to be small, with half of the farmers estimated to have less than 0.4 ha and 90% less than 2.0 ha (IFAD 2007).

Over the past two decades, the economy of Grenada has shifted from one of agriculture-dominant into that of services-dominant (with tourism serving as the leading foreign currency earning sector). The country's principal export crops are spices and nutmeg. As a matter of fact, Grenada is the world's second largest producer of nutmeg after Indonesia. Other crops for export include cocoa, citrus fruits, bananas, cloves, cinnamon, fruits and vegetables, cut flowers, fish and fish products (www.montrosetravel.com/index.php?cs_grenada).

Pigeonpea area, production and yield

Grenada is also considered as one of the major producers of pigeonpea in the world (FAOStat 2008). According to Upadhyaya (2007), there are 15 accessions of pigeonpea thriving in the country. The average yield was above 1,000 kg/ha (Table 33). However, the productivity level decreased by 961 per unit area (Appendix 4). Appendixes 2 and 3 and Table 33 give the estimates on production and area cultivated from 1961 to 2006.

Grenada's cropping practices

High cropping intensity is a functional characteristic of Grenadian gardens. As a result of varied cropping practices, as many as 18 vegetable varieties and 13 distinct types of food trees co-existed in a kitchen garden of less than 2,000 m². Many variations existed in regard to the crop combinations used in both mixed cropping and intercropping. One common practice was to plant two or three different vegetables in the same plot. Traditional groupings of species were observed, one of which combined French beans, maize and cocoyam (local name tannias). All gardeners, however, periodically followed the practice of devoting about one-quarter of the land to vegetables for one year (Innis 1973).

An outstanding feature of Grenadian kitchen gardens is the size of the area given to root and tuber production for home consumption. Dasheen, cocoyam and yams often occupy over two-thirds of the kitchen garden. Second in importance is intercropping of maize and pigeonpeas. However, the humid tropical gardens in the western region show the lowest species diversity both in tree and vegetable crops, with indices of 0.24 and 0.20. This ecological selection affects particularly maize and pigeonpeas as both crops require dry conditions to mature. Besides their ecological benefits, irregular planting arrangements in the gardens establish visual barriers that conceal more valuable crops such as pumpkin and papaya, thus making theft less likely. Pigeonpea bushes often serve as a hedge or cover for root crops and bananas, followed by a network of tall stakes of maize to support yam vines. Behind these 'barricades,' are rows of the most valuable vegetables such as cabbage, tomatoes, papaya and eggplant. This pattern of planting had its origins in the days of slavery when plantation slaves had to protect their provision grounds against praedial larceny. Today some farmers believe that this cropping arrangement promotes better plant growth (Brierley 1985).

A very common kitchen garden practice is intercropping where pairs of such crops as cassava and sweet potato, maize and pigeonpea, maize and sweet potato, and yams and 'tannias' are planted together. These intercrops are actually more of a rule than the exception.

Uses

Grenadian cuisine has a very strong African influence, which is evident in its national dish (oil down) comprised of root vegetables, cod fish and salted

meat cooked in coconut milk. This is usually served with their rice and green pigeonpea seeds, the nation's staple food.

Haiti

Geography

Haiti, a tropical and a semi-arid country, with geographic coordinates of 17°56'N to 19°50'N latitude, 71°43'W to 72°45'W longitude, is located on the Caribbean island of Hispaniola, which shares with the Dominican Republic in the Greater Antilles archipelago. Haiti is the third largest country in the Caribbean behind Cuba and the Dominican Republic (Figure 73) (en.wikipedia.org/wiki/Haiti). The country's terrain consists mainly of rugged mountains interspersed with small coastal plains and river valleys. The total area of Haiti is 27,750 km². Haiti has sometimes been called 'a little slice of Africa in North America' due to its demographics, poverty, high incidence of HIV and chronic instability (americanliterature.dukejournals.org).

Agriculture

Haiti has long been identified as one of the poorest nations in the world and the only least developed country in the Caribbean and in the American continent. Haiti has experienced growing and deepening poverty around the country over the past two decades. Although poverty afflicts both urban and rural households, the level of poverty appears to be higher in rural areas where the livelihood is mainly agricultural based (IHSI 2003).

The agricultural sector has always been the largest contributor to the Haitian economy. Two thirds of the Haiti population lives in rural areas and depend directly or indirectly on agriculture for their livelihood. Hence, the majority of Haitians are affected by what happens in agriculture. It contributes up to 27% of the Gross Domestic Product (GDP). It also provides employment for more than 60% of the general population and more than 80% of rural dwellers. Thus, agriculture forms the backbone of the economy though its importance has dramatically declined over the last two decades. As a matter of fact, the role of agriculture in the economy started to weaken as early as the 1950s. Prior to this, the sector employed 80% of the population, and then it dropped to about 66%, most of which was in small-scale subsistence farming (CIA 2008). Also around the same time, it accounted for 50% of the GDP and contributed to 90% of exports.

Haiti has a limited amount of cultivable land. Roughly 28.3% of the land is arable. According to soil surveys by the United States Department of Agriculture in the early 1980s, 11.3% of the land was highly suitable for crops, while 31.7% was suitable with some restrictions related to erosion, topography or conservation. The surveys revealed that 2.3% was mediocre because of poor drainage, but acceptable for rice cultivation, while 54.7% was appropriate only for tree crops or pastures because of severe erosion or steep slopes. According to estimates of land use in 1978, 42.2% of land was under constant or shifting cultivation, 19.2% was pasture land, and 38.6% was not cultivated (Malik 1989). Most farm production takes place on small plots owned by peasant farmers, with an average size of 1.2 ha. A few large plantations (1% of farms) specializing in coffee and 'sisal' make up about 10% of the cultivated area. Haiti has nearly 560,000 ha of arable land and about 75,000 ha are covered by an irrigation system. Approximately 80% of the households have access to land and the majority of these own and cultivate their plots (Delahaye 2005).

The farming systems in Haiti are characterized by the production of various annual crops like corn, sorghum, beans and cassava for the domestic market. Some perennial ones such as coffee, cacao and mangoes are produced mainly for the export market. While most rural households have access to land, production is carried out primarily on small farms generally divided into several scattered plots. On average, households cultivate 1.8 ha of land. Agricultural exports contributed to about 10% of total export earnings in 1999. Coffee is the only significant export crop while sugarcane, the major contributor to erosion problems, declined by 44% since 1987. Another major crop is rice, which contributes significantly to the national diet. However, cheaper imports have discouraged local production, which has dropped by 17% since 1987.

Agricultural limitations

The increasingly heavy dependence on food imports is not seen as a sustainable path for Haiti. The potential to expand export earnings to finance these imports may be further developed particularly through niche markets for agricultural commodities. Because of constraints to enhancing agricultural productivity, developing competitiveness in traditional or new production lines is a costly undertaking. Even if these were successful, they would only bear fruit in the medium to long term. Along with this is the pressing demand for a

solution to the dismal nutritional status of the growing population. Given the crucial role of agriculture for the survival of large segments of the population, an obvious policy option is to place emphasis on staple food production, especially at the small farm level, as a means for reducing poverty and improving the nutritional status of the rural poor. This would also reduce the need for food imports.

Pigeonpea area, production and yield

Haiti is considered a major producer of pigeonpea since 1961 although no landraces have been found growing in the country (FAOStat 2008). The area cultivated was highest in 1985 with 8,667 ha and lowest in 1995 with 4,054 ha. The area fluctuated within this range over a period of 40 years beginning in 1961 (Table 33). The country's highest production of 4,300 t was also in 1985 when the area cultivated was at its peak, but the lowest production was at 2,600 t in 2005 (Table 34). But in spite of having the third largest area devoted to pigeonpea in the region, Haiti's productivity was the lowest among nine countries in the region (Table 35).

Ethno medical uses

Pigeonpea in Haiti has been used by older folks as an antidote (*manihot*), as gargle, and as vulnerary/healing agent for jaundice, urticaria and wounds (Taylor 2005).

Marketing limitation

Responding to a request from an exporter in late 1998 to early 1999, Mr Junior Paul organized a trial shipment of fresh pigeonpea (*pois congo*, in French) from Cap Rouge near Jacmel. Fresh pigeonpeas are very fragile and must be harvested in the cool hours of the morning and quickly placed under refrigeration to preserve quality. In order for the trial shipment to be economical, the exporter wanted at least 3,000 pounds of the product. Given the scattered nature of small-scale farms in Haiti, assembling this quantity of pigeonpeas within a single morning was a significant organizational challenge. Amazingly, some 4,400 pounds of pigeonpea were collected from approximately 120 small-scale farmers and delivered on time to the exporter at the designated collection point. Farmers were pleased with the trial because they earned 3 Gdes/lb for the pigeonpea versus the current local market price of 1.5 Gdes/lb.

Jamaica

Geography

Jamaica, the largest island of the Commonwealth Caribbean and the third largest of the Greater Antilles, after Cuba and Hispanola, is centrally situated in the Caribbean Zone (Figure 73). With geographic coordinates of 17°48'N to 18°28'N latitude and 76°12'W to 78°23'W longitude, Jamaica lies 145 km south of Cuba and 190 km west of Haiti. Its capital city is Kingston. Jamaica is 235 km long and is between 35 and 85 km wide. It is the largest of the English speaking West Indian islands. It has an area of 11,424 km², which is more than twice the area of Trinidad. It measures 243 km from east to west. The tropical climate of Jamaica averages around 80°F. The northeastern part is one of the wettest spots on Earth with more than 2,540 mm of annual rainfall (en.wikipedia.org/wiki/Geography_of_Jamaica; www.discoverjamaica.com/gleaner/discover/geography/geography).

Agriculture

Jamaica has an ideal climate conducive to agriculture. Its size and varied terrain allow for a diversity of growing conditions that produce a wide variety of crops. Jamaican agriculture, an important engine of growth increased 15.3% in the third quarter of 1998 compared to the corresponding period in 1997, signalling the first positive growth rate in the sector since January 1997. But due to a serious setback the country faced in the fourth quarter of 1998, agricultural production, along with forestry and fishing accounted for only 6.6% of GDP in 1999 (en.wikipedia.org/wiki/Economy_of_Jamaica).

Sugarcane, the leading export crop, is produced in nearly all the parishes in Jamaica. Likewise, bananas formed 2.4% of the exports in 1999 and 7.5% for the Caribbean. Its coffee is considered among the best in the world, and formed 1.9% of the exports in 1999. Cannabis has also been one of Jamaica's leading economic assets. Over 15% of gross domestic product is contributed by this plant alone. Other export crops are cocoa, citrus, copra, pimento, ginger, tobacco, sisal and other fruits. Rice, which is mainly for local consumption, is grown round swampy areas surrounding the Black River and around Long Bay in Hanover and Westmoreland parishes (en.wikipedia.org/wiki/Economy_of_Jamaica).

Pigeonpea area, production and yield

Pigeonpea can grow even at 1,000 masl in Jamaica. There are 64 accessions that have been found growing in the country (Nene et al. 1989; Nyabyenda 1987; van der Maesen 1983, 1986). Locally known as 'gungo pea' or 'googoo beans', the crop comes in shades of brown to black and red to white with mottled versions as well (www.gracefoods.com/site/gungopeas). Jamaica is considered as one of the major producing countries in the Caribbean region (FAOStat 2008). The area cultivated to pigeonpea (1961–2005) showed fluctuations though not as pronounced, except for the lowest cultivated areas recorded in 1961 with 838 ha and in 1965 with 731 ha. The highest cultivated area was 2,550 ha in 1975 (Table 33). As for production, the highest was in 1985 with 2,351 t while the lowest was 870 t in 1965 (Table 34). The crop's productivity level averaged a little above 1,000 per unit area (Table 35). In 2006, Jamaica's production was at 1,300 t covering an area of 1,100 ha with a mean average yield of 1,182 kg/ha of green-pods (Appendix 2, 3, 4).

In Jamaica, pigeonpea is mostly harvested in mid-March to April and from November to January. The fresh peas tend to be sweeter and cook more quickly. The dried form may be stored for extended periods.

Panama

Geography

Panama is a country located in Central America. It borders the Caribbean Sea and the Pacific Ocean to the west and the Atlantic Ocean on the east, between Colombia and Costa Rica, (Figure 73). It is located on the narrow and low Isthmus of Panama. This S-shaped isthmus is situated 7°6'N to 9°32'N latitude and 77°55'W to 82°58' W longitude. Panama encompasses approximately 77,082 km², it is 772 km long and between 60 and 177 km wide. The country is divided down the middle from Costa Rica to the canal by the Cordillera Central mountain range. The shadow effect of the mountains causes the Pacific side of the mountains to have a dry season as well as a rainy season, whereas the Atlantic side of the country is rainy for most of the year.

Panama has a tropical climate. Temperatures are uniformly high as is the relative humidity and there is little seasonal variation. Diurnal ranges are low. On a typical dry-season day in the capital city, the early morning minimum may be 24°C and the afternoon maximum may be 29°C. The temperature

seldom exceeds 32°C for more than a short time. Climatic regions are determined less on the basis of temperature than on rainfall, which varies regionally from less than 1300 to more than 3000 mm/yr. Almost all of the rain falls during the rainy season, which is usually from April to December, but varies in length from seven to nine months. The cycle of rainfall is determined primarily by two factors: moisture from the Caribbean, which is transported by north and northeast winds prevailing during most of the year, and the continental divide, which acts as a rain shield for the Pacific lowlands (en.wikipedia.org/wiki/Geography_of_Panama).

Agriculture

Agriculture is big business in Panama. Not only does it account for much of the country's exports (over 50%), but also subsistence farming still employs many Panamanians who grow only enough food to feed their families (www.nationencyclopedia.com/Americas/Panama-AGRICULTURE). The main crop in Panama is banana, which is also one of the country's largest exports. The other exports are sugar and coffee beans, while the largest domestic crops are corn, rice, coconuts, tobacco and the exotic root vegetable 'yucca' (Bennett 1926). In spite of the fact that agriculture employs a large portion of the population and uses approximately half of the land, agriculture in Panama is in trouble. Panama's tropical maritime climate poses some restrictions to the growth of crops, but the troubling issue at/hand is the erosion of soils (Woolmington 2007).

Subsistence farming, widely practiced from the northeastern jungles to the southwestern grasslands, consists largely of corn, bean and tuber plots. Mangrove swamps occur along parts of both coasts, with banana plantations occupying deltas near Costa Rica (www.nationencyclopedia.com/Americas/Panama-AGRICULTURE).

Pigeonpea area, production and yield

Panama, a major producing country (FAOStat 2008), has only two (2) accessions of pigeonpea (Upadhyaya 2007). Though considered a minor crop, pigeonpea is grown in nearly every backyard and has been dubbed 'pea tree' since it can grow up to 20 feet high in just five months during the rainy season (geocities.com). The crop is also locally known as "guandu". This is usually mixed with rice in a favorite dish called *arroz con guandu* (geocities.com).

The area planted to the crop was highest in 1985 with 4,887 ha and lowest in 1980 with 2,290 ha. The production area experienced fluctuations in between these two extremes from 1961-2005. The crop's production was quite low when compared to some other countries in the region (Table 34). But the data do not reflect the produce harvested in home or kitchen gardens. The FAOStat (2008) data confirmed the low productivity, which averaged 555 kg/ha, just a little above Haiti's average of 470 kg/ha (Table 35).

Pigeonpea research initiatives

In Panama, severe droughts that last for six months often lead to a reduction in pasture, decrease in animal production, and high animal mortality rate. From 1978 to 1981, researchers focused on identifying varieties for animal feed and developing conservation and processing techniques for use during the dry season. As a drought-resistant forage legume that can grow in marginal soils, it was also found that pigeonpea can produce as much as 71 t dry matter/ha. Moreover, the use of pigeonpea for silage has the ability to increase milk, meat and poultry production (www.idrc.ca/pt/ev-67584-201_780032-1-IDRC ADM_INFO.html, 2 July 2008).

Puerto Rico

Geography

Tropical Puerto Rico with geographic coordinates of 17°43' N to 18°28' N latitude and 63°32' W to 67°3' W longitude is located between the Caribbean Sea and the North Atlantic Ocean, east of the Dominican Republic and west of the Virgin Islands (Figure 73). The main island of Puerto Rico is the smallest and most eastern of the Greater Antilles. The Antilles is a chain of islands that stretch more than 932 km from Florida (USA) to Venezuela (South America). Puerto Rico is an unincorporated territory of the United States with a land area of 8,897 km². It is the third largest island in the United States and the 82nd largest island in the world (en.wikipedia.org/wiki/Geography_of_Puerto_Rico).

Puerto Rico enjoys an average temperature of 26°C (80°F) throughout the year. The seasons do not change very drastically. The temperature in the south is usually a few degrees higher than in the north while temperatures in the central interior mountains are always cooler than the rest of the island. The

dry season spans from November to May while the wet season coincides with the Atlantic hurricane season from June to November. The climate is tropical marine with a regular temperature of 80°F (26°C). Puerto Rico enjoys warm and sunny days most of the year. Lightweight clothing is appropriate year-round. In the interior, the temperature fluctuates between 73°F and 78°F (22°C and 25°C). Rainfall tends to be evenly distributed throughout the year, but doubles from the months of May to October coinciding with the hurricane season. Then it drops from November to April, with the driest period during the month of January up to April. The north coast gets twice as much rain as the south coast. Annual precipitation is highest in the mountains with 5,080 mm while in the coastal regions, it could range from 2,565 – 9,677 mm. The yearly precipitation in the north is 1,550 mm while in the south it is 910 mm (en.wikipedia.org/wiki/Geography_of_Puerto_Rico).

Agriculture

Puerto Rican agriculture is a small but significant part of the island's economy. It is specialized and commercial, devoted primarily to crops that can be sold in the United States. The development of high value horticultural crops for export, and for the island's growing middle class, should add value and diversity to the Puerto Rican economy now and in the future. In addition, the benefits of a strong agricultural industry as a buffer between urban development and the island's natural areas cannot be overstated (www.mccc.edu/tropicalhort/page6.htm).

Prior to 1940, agriculture was the basis of Puerto Rican economy. At the time, sugarcane production was the main agricultural activity and coffee production a near second. Puerto Rican coffee is rated among the best in the world. Production is still not sufficient to meet high local demand for any of the main agricultural products. Consequently, several products are imported from the neighboring Caribbean islands, Central America, the United States of America and the rest of the world (www.dollarman.com/puertorico/agriculture).

Important food plants, such as rice, mangos, avocados, maize, coffee and green cover crops have been introduced into the Island. Root crops such as sweet potatoes, cassava, yams, dasheen and taro are staples for the Puerto Rican peasant. Were it not for these foodstuffs his diet would be even more deficient. Other crops grown wholly for home consumption are corn, beans,

pigeonpeas, cowpeas, peanuts and sesame. Corn, beans and pigeonpeas are grown on a large scale in regions where crop diversification is practiced (Federal Writers Project 1940).

The birth of pigeonpea

Since 1914, the Department of Education in Puerto Rico has for many years striven to encourage the planting of garden vegetables, among them is pigeonpea. A campaign to raise vegetables and other garden produce was waged under the administration of Dr Paul Gerard Miller, former Commissioner of Education, and was followed by a similar campaign during the World War (newdeal.feri.org).

The pigeonpea breeding programs in Puerto Rico made good progress as a few vegetable type varieties such as 'Panameno', 'Amarillo', 'Kaki', 'Saragateado', 'Totiempo' and 2B Burky were released (Aponte 1963, Rivas and Rivas 1975). The program's objectives were to develop high yielding varieties for different maturities as well as to develop suitable dwarf lines for mechanical harvesting (Abrams et al. 1978). The recent release of pigeonpea cultivars were 'Guerrero' and 'Cortada' in 2000.

Pigeonpea area, production and yield

Pigeonpea in Puerto Rico has been growing naturally (Liogier 1988, Long and Lakela 1976). It has 78 recognized accessions (Upadhyaya 2007) and is cultivated throughout the south coast and the Lajas valley. The crop is cultivated mainly for canning and for the local fresh pod market. The annual farm value of the crop is over \$3 million. Pigeonpeas are the most important edible leguminous crop in Puerto Rico, and represents an important contribution to the total consumption of vegetables on the island. It ranks 4th in importance among edible legumes in worldwide production (Morton 1976). The crop is known to be particularly drought-resistant because of its deep-root system (Rivera et al. 1983). Puerto Ricans prefer to consume fresh pigeonpeas rather than canned or frozen peas. The per capita consumption of fresh and frozen pigeonpeas was 0.82 kg during 1999/2000 (Departamento de agricultura del estado libre asociado de Puerto Rico 2004).

The planting of indeterminate genotypes can be made until October, though it is preferably done from June to August. Harvesting is between December

and March and the produce is mainly for the fresh market (Hernandez 2002, Acosta et al. 1992, Morton 1976). Meanwhile, determinate genotypes are targeted for the canning industry. Planting is recommended from June to August if it is for manual harvest and between August and November for the mechanical harvest (Hernandez, 2002).

The highest production area recorded was 6,085 ha in 1980 while the lowest was 143 ha in 2000 and 165 ha in 2005. The sharp decline began in 1995 with 396 ha from a high of 3,225 ha in 1990 and this downward trend continued for the next ten years (Table 33). Based on the same source, the production of pigeonpea followed the same downward trend from 1995 up to 2005 with the lowest at 100 t in 2000. The highest produce was 5,216 t recorded in 1980 (Table 34). The country's productivity of 1490 kg/ha is the second highest in the region after Trinidad and Tobago except when it first plunged in 1980 to 857 kg/ha and further declined in 1990 to 562 kg/ha, which was the lowest (Table 35).

Marketing

The canning of green pigeonpeas is a major industry in the country. The fresh immature seeds are very popular even if the shelf-life is shorter than the processed pigeonpeas (Rakotonirainy et al. 2001). It sells at twice the price as compared with the mature dried seed because it is tastier, tender and cooks in less time (Morton 1976). However, they are currently distributed to traditional markets and supermarkets and sold without any special care in packaging, refrigeration and sanitation.

Fresh shelled pigeonpeas from Puerto Rico and the US Virgin Islands are among the products that are moved interstate without meeting the certification, marking and treatment as long as they are free from plant litter and soil. However, it is subject to inspection, either in the field or when presented for shipment. If injurious insects are detected in the course of an inspection, the movement of the product may be prohibited or certification and treatment measures may be required. There is a tendency among individuals leaving by plane from Puerto Rico and the US Virgin Islands to take pigeonpeas (fresh shelled or in the pod) to other parts of the United States.

During such inspections, *Melanagromyza obtusa*, a pigeonpea pod fly, has been detected in untreated pigeonpeas from Puerto Rico. In fact inspectors have been intercepting insect-laden pigeonpeas over 300 times since

February 2000. The pigeonpea pod fly, which is a serious pest to pigeonpea, is also found widely in Asia and Australia.

Uses

Rice together with green pigeonpeas makes up the main traditional food and is served as a part of Puerto Rican cuisine in many food festivals around the world.

Trinidad and Tobago

Geography

Trinidad and Tobago (T&T), an archipelagic republic consisting of 23 islands, are the southernmost islands of the Lesser Antilles located close to the South American continental shelf. The country is geographically located 9°42'N to 10°31'N latitude and 60°32'W to 61°52'W longitude covering an area of 5,128 km² (Figure 73). Geologically, the islands are not part of the Antillean arc. Rather, Trinidad was once part of the South American mainland while Tobago is part of a sunken mountain chain related to the continent. The islands are now separated from the continent of South America by the Gulf of Paria, a 19 km wide northern passage called the Dragon's Mouth and a 14 km wide southern passage called the Serpent's Mouth. Trinidad comprises an area of 4,828 km². Most of its soils are fertile with the exception of the sandy and unstable terrain found in the southern part of the island (country-studies.us/caribbean-islands).

Tobago is located 30 km northeast of Trinidad, from which a channel thirty-seven km wide separates it. The island is 42 km long and 13 km wide, with a total area of 300 km². Tobago is cigar-shaped in appearance and has a northeast-southwest alignment. The country is characterized by a generally rugged elevation with the only extensive lowland being a coral platform at the southwestern end. It is mountainous and is dominated by the Main Ridge, which is 29 km long with elevations up to 640 m. There are deep fertile valleys running north and south of the Main Ridge. The southwestern tip of the island has a coral platform. Forestation covers 43% of the island. There are numerous rivers and streams, but flooding and erosion are less severe than in Trinidad. The coastline is indented with numerous bays, beaches and narrow coastal plains. Tobago has several small satellite islands. The largest

of these is Little Tobago, which is a hilly starfish-shaped island consisting of 120 ha of impenetrable vegetation ([country studies.us/caribbean-islands](http://countrystudies.us/caribbean-islands)).

Trinidad and Tobago, well within the tropics, both enjoy a generally pleasant maritime tropical climate influenced by the northeast trade winds. The tropical humid climate is characterized by a rainy season that extends from June to December, and a dry season that extends from January to May. The annual average rainfall is 2,150 mm. The annual minimum temperature is 22°C while the maximum is 32°C. Flooding is common during the rainy season ([country studies.us/caribbean-islands](http://countrystudies.us/caribbean-islands)).

Agriculture

Trinidad and Tobago's total land area covers 513,000 ha, of which less than one-third is arable. Approximately 11,000 ha or only 2% of the total area is devoted to pasture, the lowest percentage in Latin America or the Caribbean. By contrast, approximately 45% of total land is forest or woodland, making timber abundant. Although Trinidad's three corridors of mountains place the greatest restriction on agricultural activity, the plains between the ranges are generally fertile. The total arable area in the country is estimated at 312,568 ha of which 44,239 ha are under permanent crops and 35,960 ha under annual crops. Only about 13% of the arable land is irrigated, although there are numerous streams and small rivers. Wetlands or mangrove forests in particular occupy 23,540 ha and natural forests cover 230,000 ha. The principal agricultural products are sugar, cocoa, coffee beans, citrus and copra (country studies.us/caribbean-islands).

Growth in agricultural output in the 1980s was led by the strong performance of domestic agriculture, especially small-scale family gardening. Sugar continued to be the most important cash crop despite some overwhelming structural problems or obstacles that the sugar industry faced. Mixed farming systems constitute the majority of both subsistence and commercial farmers. The fastest growing subsector in agriculture in the 1980s was domestic agriculture consisting mainly of vegetables, rice, tubers and livestock. The revival of domestic agriculture was the consequence of falling oil prices, balance of payments constraints, the return of labor to the land, and growing experimentation with larger scale farming for domestic agriculture. In the late 1980s, Trinidad and Tobago was nearly self-sufficient in green vegetables, which were typically grown on small garden plots. Rice, a staple food,

was an expanding domestic crop but was still imported in large quantities. Vegetables such as yams, sweet potatoes, dasheens and eddoes (all tubers) were also produced mostly for direct consumption. (countrystudies.us/caribbean-islands/52.htm).

The evolution of pigeonpea

In 1934, the Imperial College of Tropical Agriculture began a pigeonpea improvement activity. The program instigated eight pigeonpea introductions, six from Hawaii and two from India. Among the varieties, determinate type 'Prasando' was selected although it did not have commercial value. A few years later, landraces of indeterminate type called *Tobago*, *St Augustine* and *Lasiba* were released for commercial production because of their large pods and seeds. Some of these varieties are still common for backyard and mixed farming. From 1956 to 1960, another pigeonpea cultivar was released. It was a semi-dwarf and determinate cultivar called *St Vincent Hedge* that produced large seeds, acceptable after-cooking color, resistance to pod borer (*Ancylostoma stercorea* Zell) and to diseases such as rust and canker. It was also well-accepted by the farmers and consumers and remains the best commercial variety up to the present (Arinayagam and Spence 1978a).

In 1970, Spence and Williams (1972) also noted that late planting of dwarf determinate varieties was good. Planting them in December instead of the usual months of May and June promoted flowering and pod set since the plants were immediately subjected to the short day influence during that month. This indicated that it is possible to obtain more than one crop per year under appropriate management. Furthermore, the potential profits from late planting were shown to be substantially larger than the traditional system of cropping pigeonpea.

Another development that began in 1976 was the screening of segregating populations from ICRISAT. About 20 genotypes with desirable traits were isolated for production. The view of increasing production formed the basis for the current pigeonpea improvement program, which was multidisciplinary in outlook. Crop breeding, crop protection, agronomy, microbiology, microclimatology, physiology, mechanization and biochemistry were areas of collaboration to develop an efficient plant type (Arinayagam and Spence 1978).

Pigeonpea area, production and yield

According to Ariyanayagam (1981), the most important leguminous crop in the nation's agriculture is pigeonpea and its production is essentially a smallholder farmer's enterprise. In terms of production area, the plant surpasses cowpea. In fact, it has not departed from its age-old status as a backyard subsistence crop though a large number of accessions—it has reached 113—are available (Upadhyaya 2007).

Gooding (1962) reported that in Trinidad, there are two existing indeterminate cultivars: one that takes 60 to 106 days and the other 237 days from the time it is sown up to the time it develops pods. The pigeonpea flowered in two months as the days became shorter. The flowering continued even as the pods ripened.

A survey in 1964 also showed that the majority of the pigeonpea farms were less than 4.0 ha. Moreover, around 81% grew the crop as an intercrop to corn, root crops, vegetables and orchards. Yields ranged from 91 to 1,814 kg/ha of fresh peas or an average of 719 kg/ha. However, no further data on production and area were available since 1971. In addition, data collection was hampered by the fact that farmers do not produce pigeonpea as pure stands but mostly as an intercrop to either corn or root crops (eddoes, yam or cassava). As a result, estimations of area planted to pigeonpea are left to speculation and guesses. The status of pigeonpea production in the country is quite similar to those of other Caribbean countries. Despite these limitations, future production trends will focus on expansion due to increasing domestic demands. There will also be an emphasis on the setting up of numerous processing plants capable of canning both fresh and dry seeds (Cropper and Aryu 1974).

Based on statistics obtained from the FAO covering over four decades (1961-2005), the country's highest area planted to the crop was 1,870 ha in 1980 while the lowest was in 2000 with 302 ha. These were, however the two extremes as the areas within the time period covered did not show significant fluctuations (Table 33). The highest production was 3,532 t/harvested in 1980 and the lowest was 785 t in 2000 (Table 34). It is noteworthy that the country had the highest productivity in the region, which it maintained for a period of more than forty years (Table 35). From 2000-2006 cropping season, the average yield was 2,683 kg/ha of green-peas (Appendix 4).

Marketing consumer demand for commercialization

Canning of green pigeonpeas is a major industry in Trinidad. Small scale farmers prefer to sell a large proportion of their harvest to retailers since it yields a greater margin of profit than selling to the Central Marketing Agency and processing plants where a guaranteed price is paid. Consequently, farmers try to limit their production to quantities that can easily be disposed of in the retail market.

Fresh pigeonpeas sold at local markets satisfy about 20% of the demand. CARICOM data indicate that more than 800,000 kg of dried peas are imported annually into the region of which 70% is brought to Trinidad mostly for canning. Minimal amounts of fresh and frozen peas are being exported from the islands but the export of canned peas has been increasing.

Folk Medicine

Pigeonpea has been part of folk medicine in Trinidad and Tobago for the treatment of flu as well as for the prevention of strokes (Taylor 2005).

Venezuela

Geography

Venezuela is a country on the northern tip of South America between 0°52'N to 11°31'N latitude and 59°51'W to 73°12'W longitude. Its surface area is 916,445 km², of which 882,050 km² are continental. It borders on the Caribbean Sea and the Atlantic Ocean to the North, Colombia to the West, and Brazil and Guyana to the South (Figure 73). Although the country lies wholly within the tropics, its climate varies from tropical humid to alpine, depending on the elevation, topography and the direction and intensity of prevailing winds. Seasonal variations are marked less by temperature than by rainfall. Most of the country has a distinct rainy season. The rainy period (May through November) is commonly referred to as winter and the remainder of the year as summer. The country falls into two horizontal temperature zones based primarily on elevation. In the tropical zone – below 800 meters – temperatures are hot, with yearly averages ranging between 26°C and 28°C. The temperate zone ranges between 800 and 2,000 m with averages from 12°C to 25°C (en.wikipedia.org/wiki/Geography_of_Venezuela).

Agriculture

Agriculture, the backbone of the national economy for centuries has played a smaller role in the Venezuelan economy than in virtually any other Latin American country in the 1980s. Agriculture entered a period of steady decline in the early twentieth century as the oil industry eclipsed all other sectors of the economy. As late as the 1930s, agriculture still provided 22% of GDP and occupied 60% of the labor force. The industrial development of the nation by the 1940s, however, seemed to have relegated agriculture to permanent secondary status. In 1988 the sector contributed only 5.9% of GDP, employed 13% of the labor force, and furnished barely 1% of total exports. Agricultural output was focused almost entirely on the domestic market (countrystudies.us/venezuela/25.htm). However, in the late 90s, agriculture has declined in its contributions to the country's economy to only 5% of GDP (CATIE/FAO 2000, World Bank 2001).

Venezuela's abundant farmland and temperate climate provide ideal conditions for agriculture. However, as oil came to dominate the economy, agriculture languished and, during the oil-boom years of the 1970s, imports of agricultural products rose rapidly. The sector today only provides less than five percent of GDP, whereas four decades ago it was one of the main backbones of the economy. Even though today approximately only one-fifth of the land is used for agriculture, it remains an important source of employment (around 14% of the labor force). More than half of the agricultural income is from cattle ranching, while dairy products, fruit, grain, poultry farming and vegetables together generate approximately 40%, with the rest coming from forestry and fishing.

The agricultural area of Venezuela is variously reported as 21.6 M ha (FAO 2006) to 34.6 M ha (Venezuela 1995). The FAO databases report that permanent pastures, a fraction that remained stable over the last 20 years, cover 84%, while Venezuela (1995) estimated that 79% of the latter area was adequate for livestock production.

Corn was the country's major domestic food crop. Most of Venezuela's corn crop came from the central plains, particularly the states of Portuguesa, Barinas and Guárico. A traditional staple, corn surpassed coffee as the nation's leading crop in the 1960s; by 1988 farmers cultivated corn on about 642,000 ha. Farmers also cultivated a wide variety of tubers, legumes, vegetables, fruits and spices. Principal tuber crops consisted of yucca,

potatoes, sweet potatoes and yautia. In some areas, peasants milled cassava for use as a flour. Legumes included yellow, black and white beans, as well as a local pulse called *quinchoncho* (pigeonpea). Vegetables included tomatoes, lettuce, cabbage, carrots, cauliflower, eggplant, cucumber, beets and peas (countrystudies.us/venezuela/25.htm). Important crops, in decreasing order of sown area, include maize, coffee, sorghum, sugarcane, rice and cassava (CEPAL 2001). Several species and types of bean, although sown in smaller areas, are important components of the diet. Despite long periods when heavy subsidies were provided to the agricultural sector, Venezuela imports more than half of its needs for wheat, sugar, vegetable oil and yellow maize, with the United States supplying more than one-third of Venezuela's total food imports (LatinFocus 2002).

Pigeonpea area, production and yield

In Venezuela pigeonpeas, 'quinchoncho' in local dialect, are grown in an elevation of up to 3,000 m. A few pigeonpeas are also often grown near the house for ease of harvest. Households prefer the 'indeterminate' varieties because they produce a few pods each day over a long season (Price 1990). According to Upadhyaya (2007), there are 134 accessions of pigeonpea identified in the country. The pigeonpea breeding programs in Venezuela made fairly good progress and released a few vegetable type varieties such as 'Panameno' (released in 1972), 'Amarillo', 'Kaki', 'Saragateado' and 'Totiempo' (Rivas and Rivas 1975).

Likewise, the crop is also used as green manure for sorghum. In a report by FAO and International Atomic Energy Agency (IAEA) (2004), pigeonpea as green manure rotated after sorghum, has increased soil organic carbon on Acrisols and has also increased sorghum yields. In addition, zero tillage with inclusion of green manures in crop rotations has been practiced to enhance soil fertility to sustain agricultural production systems in the country.

According to FAOStat (2008), the area under pigeonpea cultivation in Venezuela has been changing over time. Appendix 2 shows how the crop has been grown for four decades; the area under pigeonpea cultivation reached a high of 10,653 ha in 1991 to a low of 2,424 ha in 1999. Moreover, the low hectare covered in 1999 was maintained during the period 2000-2006 cropping seasons. The production of this crop has been following the same trend with the area cultivated to pigeonpea. In 1970, a total of 7,619 t

was recorded as the highest between 1961-1999 seasons (Appendix 3). In 2006, the production was reported at 2,000 t.

Yield per hectare for pigeonpea was stagnant in 2000-2006 cropping season at 783 kg/ha. The highest recorded yield was in 1970 and 1974 where it registered 1,603 kg/ha and 1,411 kg/ha, respectively (Appendix 4). The lowest productivity level was during the early 80s and the 90s recording as low as 515 and 529 kg/ha, respectively (Table 35).

Uses

In Venezuela, pigeonpea as food has significantly influenced researchers and/or nutritionists to expand the use of this crop by improving nutritional value of basic foodstuff such as pasta and the local soft drink called 'Chicha'. Pasta has been incorporated into a number of local cuisines that may have significantly different ways of preparations from those of its country of origin. In a study by a joint team of Spanish-Venezuelan researchers, it was found that adding pigeonpea flour into semolina pasta has increased the nutritional value without affecting the sensory properties, has a quicker cooking time and it boosts the flavor as well. The researchers prepared pasta using traditional durum wheat with different concentrations of germinated pigeonpea flour as an ingredient ranging from 5 to 8%. It was found that the supplemented pasta products had significantly enhanced nutritional content, compared to control (100% durum wheat flour) pasta. Levels of vitamin B1, B2 and E were all increased in the pigeonpea flour pasta. Levels of protein, fat, dietary fiber and mineral contents were also reported to be improved by the inclusion of pigeonpea flour (Foodchem 2006).

Aside from pasta, a local soft drink known as 'Chicha' is likewise made from pigeonpea. Moreover, most recent evidence indicates the possibility of its use for paper pulp (www.ikisan.com/links/knt_redgramHistory).

Minor Growing Countries

Very few books or articles have been written or cited about pigeonpea in the minor growing countries of the Caribbean. Although pigeonpea has been grown in these countries as cited by Nene et al. (1989), Nyabyenda (1987) and van der Maesen (1983, 1986), the usefulness of this crop has not been given due importance. But interestingly, in some of these countries

pigeonpea landraces have been grown centuries ago as a subsistence and exotic crop (as food and as medicinal plant) by small-scale farmers or peasants. Some countries identified by the authors have either no accession or data regarding pigeonpea or no accessions but/have existing pigeonpea cultivars grown as a minor crop.

Anguilla

Geography

Anguilla is the most northerly of the Leeward Islands in the Lesser Antilles. With geographic coordinates of 17°53'N to 18°10'N latitude, 62°53'W to 63°5' W longitude, its territory in the Caribbean includes nearby Scrub, Seal, Dog and Sombrero islands and Prickly Pear Cays. The Islands is located between the Caribbean Sea and North Atlantic Ocean, east of Puerto Rico (Figure 73). The combined land area is about 102 km². Anguilla is a relatively flat, coral and limestone island covered with sparse, dry woodlands and fringed by white sand beaches. The highest elevation is about 65 m (www.answers.com/topic/anguilla; www.montrosetravel.com/cs_anguilla).

Anguilla has a tropical though rather dry climate, moderated by northeast trade winds. Temperatures vary little throughout the year. Average daily maxima range from about 27°C (80°F) in December to 30°C (86°F) in July. Rainfall is erratic, averaging about 900 mm/year, the wettest months being September and October, and the driest February and March. Anguilla is vulnerable to hurricanes from June to November, peak season August to mid-October (www.answers.com/topic/anguilla).

Agriculture

Most residents of Anguilla are involved in fishing and subsistence farming. Anguilla's thin arid soil is largely unsuitable for agriculture, and the island has few land-based natural resources. Only 13% of Anguilla's total area was cultivated. Crops grown are primarily for domestic use. Legumes such as pigeonpea, sweet potatoes, sorghum were the main crops, mostly grown as 'backyard garden'. However, when rainfall is good and produce surplus of vegetables and fruits, the country exports small amounts to neighboring islands. The country's major exports are fish, lobster and other seafood (www.answers.com/topic/anguilla; www.montrosetravel.com/cs_anguilla; www.defra.gov.uk/science/geneticresources/Access/Overseas.asp).

About pigeonpea

Most residents in Anguilla are involved in subsistence farming. The local community regards pigeonpea as an important crop due to its high protein content. Anguilla looks upon pigeonpea as a major crop because pigeonpeas are a local favorite and a staple in most Anguillian households. Aside from the rice and peas (served as a side dish with fish, pork, chicken or lamb), which takes the place of potatoes at lunch and dinner, Anguillans also prepare numerous dishes such as cream of pigeonpea soup, coconut and pigeonpeas, island pea soup made with pigeonpeas and local sweet potato (www.anguillaguide.com/article/articleview/74/1/99; www.yorku.ca/rjarrell/chap5).

Antigua and Barbuda

Geography

The State Antigua and Barbuda comprises three islands in the West Indies, in the Leeward Islands in the Caribbean region (Antigua, Barbuda and Redonda), with a total land area of 442 km² (Figure 73). With geographic coordinates of 17°03'N to 17°10'N latitude and 61°34'W to 61°55'W longitude, the island of Antigua is about 280 km²; the sister-island Barbuda is 165 km². The third island, which is uninhabited, is Redonda, a rocky volcanic island measuring about 1 km². Redonda is uninhabited. Antigua is the largest of the Leeward Islands, and the most developed and prosperous due to its upscale tourism industry, offshore banking, internet gambling services and education services, including two medical schools (en.wikipedia.org/wiki/Antigua).

Antigua and Barbuda is subject to frequent droughts, and although the average rainfall is 1158 mm, the variations from year to year is great. The problem is partly solved by desalination of sea water. The climate is tropical marine with little seasonal temperature variation (en.wikipedia.org/wiki/Antigua).

Agriculture

In 1960, Agriculture accounted for 40% of the Antiguan economy, primarily in the form of sugar production. Prior to 1975, the most prevalent use of land was in agriculture and livestock grazing. Between 1946 and 1983, the

percentage of the labor force employed in agriculture fell from 46% to 9%. This is clearly reflected in the decline of land in agriculture from 10,073 ha in 1964 to 2,226 ha in 1985. Furthermore, most of the employment in agriculture in 1985 was in small livestock holdings utilizing over 10,522 ha of pasturelands. Currently, most agricultural land is left idle or is under low intensity agricultural use. The failure to fully exploit areas with the potential for agriculture has left such lands vulnerable to encroachment by urban development and squatting. In 2001, agriculture only accounted for 4% of GDP and was focused only on the domestic market due to being severely constrained by a limited water supply (Williams 2003). Antigua's limited agricultural production forces it to import nearly all of its food needs from North America, Europe, and the Caribbean. Agricultural commodity imports are roughly 55 to 65% of total food purchases (USDA 2007).

About pigeonpea

There are six (6) accessions of pigeonpea identified in this country (Upadhyaya 2007), grown as a minor crop (Nene et al. 1989; Nyabyenda 1987; van der Maesen 1983, 1986). Pigeonpea grown are mostly landraces and they are mainly used as a vegetable. The plant is ideally suited to the Caribbean summer environment (hot and dry) where small-scale farmers plant this in the kitchen garden in full sun or with a little shade producing lots of pigeonpea pods. In 1978, the Caribbean Agricultural Research and Development reported that 5 ha of land were devoted to pigeonpea with a production of 2.5 t.

Argentina

Geography

Argentina is a country in southern South America, situated between the Andes in the west and the southern Atlantic Ocean in the east. It is the second largest country in South America after Brazil and the 8th largest country in the world. Its total area is approximately 2.7 M km². With geographic coordinates of 52°16'S to 22°6'S latitude and 56°41'W to 71°9'W longitude, the country is bordered by Paraguay and Bolivia in the north, Brazil and Uruguay in the northeast and Chile in the west (Figure 72). Argentina's climate is mostly temperate but arid in southeast and sub-Antarctic in the southwest (CIA 2008).

Agriculture

Argentina's total arable land is estimated at 9% of total land area on which only 1% is devoted to permanent crops (CIA 2008). The soils of the Pampas are among the richest of the world and consist of a deep accumulation of loose, wind-blown materials, resting upon granite and ancient crystalline rock, entirely free of stones. Numerous plants grow in the Pampas and livestock also flourish well. This soil is so rich that farmers never have to use artificial fertilizer. The soil accounts for $\frac{3}{4}$ of Argentina's wealth. But in other regions, the soil is not as fertile. The country's less productive soils range from laterite in the north to desert sands and sierozems in the west and south. The land is difficult to work in the mountains and in Patagonia region. Throughout Argentina only about 11% of the land can be cultivated though agriculture is one of the bases of Argentina's economy. Agricultural goods, however, whether raw or processed, still earn over half of Argentina's foreign exchange (Ministerio de Producción-Republlica Argentina, Modified August 2008) and, arguably, remain an indispensable pillar of the country's social progress and economic prosperity. The main production and exports of the country are cereals, centered on soybean, wheat and sorghum for export, as well as rice and barley mainly for national consumption. With a total area of around 210,000 km², the annual production of cereals is around 50 Mt.

In 2007, more than one fifth of Argentine exports of about US\$56 billion were composed of unprocessed agricultural primary goods, mainly soybeans, wheat and maize. A further one third was composed of processed agricultural products, such as animal feed, flour and vegetable oils (INDEC 2008). Argentina's wealth has traditionally come from ranching and grain growing, and agricultural commodities continue to be a mainstay of Argentine exports.

About pigeonpea

Although pigeonpea is not well recorded for its growing characteristics, area and productivity, there are 9 accessions recorded in Argentina (Upadhyaya 2007) where it is cultivated as a minor crop (Nene et al. 1989; Nyabyenda 1987; van der Maesen 1983, 1986). 'Guandul', 'poroto guandul', 'poroto paraguayo', 'sachacafé', 'falso café' and 'arveja' are the local names of pigeonpea in the country.

Ethno medical use

The notable report cited is the use of this crop as a folk medicine where the leaf decoction from pigeonpea is used for genital and other skin irritations, especially in females. Floral decoctions are used for bronchitis, coughs, and pneumonia (Morton 1976; Duke 1983, 1981; Taylor 2005).

Barbados

Geography

Barbados an island between the Caribbean Sea and the North Atlantic Ocean which lies within the tropics with coordinates of 13°1'N to 13°10' N latitude and 59°3'W to 59°32' W longitude covering a total land area of 430 km² (Figure 73). Barbados is fringed with coral reefs. The island itself is characterized by lowlands or gently sloping, terraced plains, separated by rolling hills that generally parallel the coasts. Elevations in the interior range from 180 to 240 masl. Mount Hillaby is the highest point at 340 masl (en.wikipedia.org/wiki/Geography_of_Barbados).

Barbados has a generally pleasant maritime climate that is influenced by northeast trade winds, which moderate the tropical temperature. Cool, northeasterly trade winds are prevalent during the December to June dry season. The overall annual temperature ranges from 24°C to 28°C; slightly lower temperatures prevail at higher elevations. Humidity levels are between 71% and 76% year round. Rainfall occurs primarily between July and December and varies considerably with elevation. Rainfall may average 1,875 mm/year in the higher central area as compared with 1,275 mm in the coastal zone.

Agriculture

Agricultural production has been the primary occupation of early settlers of Barbados, not just for local consumption, but also for export to England and for trade with other colonial territories. The first European settlers arrived in Barbados in 1627 and found much of the island covered with forests, however by 1700; most of this forest was cut down and replaced with agricultural crops (Watts 1966). Much of the landscape therefore was transformed from natural ecosystems into agricultural ecosystems comprised of large mono

specific plantations such as sugarcane, small-scale vegetable, root crop and pastures.

According to Homer (1998), the area under agriculture in Barbados has declined over the past two decades from about 28,328 ha in the 1960s to approximately 20,234 ha in 1996, primarily through the demand for land for settlements and tourism development, such as, hotels and golf courses. Sugarcane has long been considered the major agricultural crop, accounting for about 75% of the arable land, but has continued to decline because of reduced sugar prices, labor shortages, inefficient management of plantations, and old and inefficient processing machinery. There has been an increasing tendency towards agricultural crop diversification in order to reduce the dependency on sugar and to satisfy local demands for fresh vegetables and root crops.

About 16,000 ha or 37.2% of the total land area is classified as arable. At one time, nearly all arable land was devoted to sugarcane, but the percentage devoted to ground crops for local consumption has been increasing. Major food crops are yams, sweet potatoes, corn, eddoes, cassava and several varieties of beans. In a report by the Ministry of Agriculture and Rural Development (1995), production showed an increase in the area under vegetable by about 53% and a decrease in sugar production by about 30% between 1987 and 1996 (nationsencyclopedia.com/economies/Americas/Barbados-AGRICULTURE).

About pigeonpea

Although grown as a minor crop (Nene et al. 1989; Nyabyenda 1987; van der Maesen 1983, 1986), there are 25 accessions of pigeonpea recognized in Barbados (Upadhyaya 2007). According to Wickham (1995), there is no national program for conserving plant genetic resources in Barbados, however, through the initiative of the Ministry of Agriculture and Rural Development and the Caribbean Agricultural Research and Development Institute (CARDI) germplasm of various crops such as pigeonpea was conserved.

In the past, fresh pigeonpeas were generally available in Barbados only at Christmas – hence the traditional Christmas dish known as *jug jug*, which is made from pigeonpeas. The varieties commonly grown were quite large

shrubs or might even have been considered trees. Pigeonpeas were grown around the borders of cane fields and picking was made quite difficult by the scattered nature of the plantings and the height of the plants. Flowering and fruiting of these older local varieties were affected by day length, and most varieties were triggered into bearing only when the length of day became slightly shorter from October onwards, which meant that the pigeonpeas matured and were picked in time for Christmas. After Christmas, local pigeonpeas were rare but there were canned imports from other parts of the Caribbean and Central America. With the mechanization of sugarcane and also as a result of the increasing use of herbicides and the increase in cane fires, the pigeonpeas gradually disappeared from the borders of fields and were only found growing in backyard gardens and on small farms.

It was further reported that in 1990, a number of varieties were imported by CARDI, mainly from India, for testing under local conditions. The determinate variety, ICPL 289, was selected, particularly in Barbados as the best producer and for its ease of harvesting. The cultivar is short, matures evenly and grows to a height of 0.6 to 1.2 m. The pods are borne in clusters at the end of branches, making manual harvesting relatively easy. Seeding of the crop has been successfully mechanized but, despite the introduction of dwarf, evenly maturing varieties, attempts at mechanical harvesting and threshing have been only partially successful. This variety is not affected by day length and will produce fruit all year round as long as it is supplied with water. The pods and seeds are smaller than the older local varieties, but the advantage of plant size and year-round bearing outweighs this disadvantage.

The West Indies Central Sugarcane Breeding Station has used their knowledge and experience in seed production to set up a Pigeonpea Seed Production Program, which they have sustained for many years. They produce seed of the ICPL 289 for sale to the public. With the advent of the new variety and the ready availability of seed, pigeonpea has become a large-scale crop, which is planted in fields rather than on the borders of fields or as scattered plants. It has been demonstrated that plants can be cut back after they have finished bearing and will re-grow, but in most cases, new crops are planted. According to the Ministry of Agriculture and Rural Development, yield of green peas is estimated at 3,921 kg/ha and for dry peas 1,120 kg/ha.

Marketing

Harvesting of green peas usually begins about three months after sowing and will continue at weekly intervals. Several new flushes of flowers will be produced as long as moisture is available to the plant. Most of the harvesting is on a “pick your own” basis where traders pick their requirements.

Belize

Geography

Belize is a small Central American nation, located at 15°52'N to 18°30'N of the equator and 88°44'W to 89°9'W of the Prime Meridian on the Yucatan Peninsula. The country borders the Caribbean Sea to the east, with 386 km of coastline, Mexico to the north-northwest (250km) and Guatemala to the south-southwest (266 km) (Figure 73). Belize's total size is 22,960 km², of which 22,800 km² is land and 160 km² is water. (en.wikipedia.org/wiki/Geography_of_Belize; worldfacts.us/Belize-geography).

Belize has a tropical climate with pronounced wet and dry seasons. Temperatures vary according to elevation, proximity to the coast, and the moderating effects of the northeast trade winds off the Caribbean. Average temperatures in the coastal regions range from 24°C in January to 27°C in July. Temperatures are slightly higher inland, except for the southern highland plateaus, such as the Mountain Pine Ridge, where it is noticeably cooler year round. Overall, the seasons are marked more by differences in humidity and rainfall than in temperature. Average rainfall varies considerably, ranging from 1,350 mm in the north and west to over 4,500 mm in the extreme south. Seasonal differences in rainfall are greatest in the northern and central regions of the country where, between January and April or May, less than 100 mm of rainfall is received per month. The dry season is shorter in the south, normally only lasting from February to April. A shorter, less rainy period, known locally as the “little dry,” usually occurs in late July or August, after the initial onset of the rainy season (en.wikipedia.org/wiki/Geography_of_Belize).

Agriculture

The agriculture sector has been the bedrock of the Belizean economy and the main source of livelihood of many generations. In 2006, it employed

approximately 30% of the work force and contributed to 15% of GDP and 75% of foreign exchange (www.agriculture.gov.bz). However, in 2007, the sector plunged to 71% of the country's total foreign exchange earnings, and employs approximately 29% of the total labor force. Although around 808,684 ha or 38% of the total land area is considered potentially suitable for agricultural use, only 10 to 15% is in use in a year. About half of this is under pasture, with the remainder in a variety of permanent and annual crops. The traditional system of "milpa" (shifting cultivation) involves the annual clearing of new land for crop production; however, there are an increasing number of farmers making permanent use of cleared land by mechanical means (www.governmentofbelize.gov.bz/ab_agriculture). Citrus, banana, sugar, papaya and aquaculture are the main export products of the country. Aside from these major crops, the country imports other agricultural plant products such as vegetables, tubers and grains for human and animal consumption (Majil 2005).

About pigeonpea

Pigeonpea in Belize has two identified accessions (Upadhyaya 2007) and is considered an exotic crop. Grown as a minor crop (Nene et al. 1989; Nyabyenda 1987; van der Maesen 1983, 1986), the cultivars planted are the vegetable type, namely Goya and Red Flowering. According to Paul (2001), Belize has identified pigeonpea as one of the priorities for agricultural research and development because of its economic, social, institutional and environmental importance.

In 2005, the CARDI Belize unit undertook the pigeonpea production and marketing of quality seed of cultivars they recommend for sale to local farmers. The seed production and marketing activities are confined to those cultivars/varieties for which seed could not normally be purchased from established commercial seed houses. Seed is normally multiplied through two generations, stock seed and commercial seed, using recommended crop production practices along with requisite field sanitation, isolation and rouging. Harvested seed are dried, conditioned and stored; likewise, the viability of the seeds is tested prior to sale/distribution. With this system, CARDI has identified one accession, which has produced 11 kg for distribution (CARDI Annual Report 2006).

Bermuda Island

Geography

Bermuda is the second most remote island in the world. It is an overseas territory of the United Kingdom in the North Atlantic Ocean (Figure 72). Located off the east coast of the United States with geographic coordinates of 32°20' to 32°36' N latitude and 62°73' to 64°45' W longitude or 900 km (570 miles) from the closest landfall in North Carolina, USA. The country is situated around 1,770 km northeast of Miami, Florida and 1,350 km south of Halifax, Nova Scotia (www.bermudaislandfacts.com; en.wikipedia.org/wiki/Geography_of_Bermuda).

Bermuda, with a string of tiny islands, is not located within the tropics, but within the middle latitudes, or temperate zone. The country has a remarkably mild sub-tropical climate that seldom allows extremes of either heat or cold. Although during the summer months Bermuda is warm (up to 90°F in August) and humid, the Island is nearly always fanned by cool sea breezes. Between May and October, average temperatures range between 75° and 85°F. During the winter months (December through March), temperatures average between 60°F and 70°F. Rainfall is spread fairly evenly throughout the year, averaging a little over 101.6 mm a month (www.bermuda.com/aboutbermuda/climate).

Agriculture

Bermuda enjoys one of the highest per capita incomes in the world having successfully exploited its location by providing financial services for international firms and luxury tourist facilities. The industrial sector is small and agriculture is severely limited by a lack of suitable land with only 20% of the land being arable. About 80% of food needs are imported. Agriculture only contributes a measly 1% of GDP and is severely limited to bananas, vegetables, citrus and dairy products (www.montrosetravel.com; www.world66.com; www.theodora.com).

About pigeonpea

Pigeonpea in Bermuda is considered a minor crop by Nene et al. (1989), Nyabyenda (1987) and van der Maesen (1983, 1986). The crop is widely cultivated and can be found in many kitchen gardens. The plants are very

hardy and drought resistant, and have prolific yields of peas, which can be eaten fresh or dried and used in soups and stews (www.hunterpublishing.com/textsamples/Bermuda).

Bolivia

Geography

Bolivia lies 9°52'S to 22°50'S latitude and 57°39'W to 69°36'W longitude is bordered by Brazil on the north and west, Peru and Chile on the west, and Argentina and Paraguay on the south (Figure 72). Most of the population and industry are concentrated in the northern part of the plateau. The southern part of the country is arid. Most of this region becomes swampy during the humid season (December–February); however, the land remains above water and is good grazing ground. The Eastern Plains, which have a tropical climate, cover more than half of the territory and many tributaries of the Amazon cross the region. Being in the tropics, Bolivia has a hot and humid climate but because of its varying altitudes, the country has different climatic conditions. In the regions with the highest elevations, the climate is cold and dry with glacial winds and rarefied air and extremes of temperature. The climate is milder in the lower regions. Annual average temperatures vary between 8°C in the Altiplano, and 26°C in the Llanos. The dry and cold season lasts from April to October and the rainy season extends from November to March. The average temperature at La Paz is 10°C, and at Sucre it is 12°C (www.ciesin.org/decentralization/English/CaseStudies/Bolivia).

Agriculture

Agriculture is an important activity within the Bolivian economy. An estimated 2% of Bolivia's land area is devoted to arable farming and permanent crops. Agricultural development/has been impeded by extremely low productivity, poor distribution of the population in relation to productive land, and a lack of transportation facilities. Practically half of the work force is employed in agriculture and constitutes about 20% of the GNP in 1993. Though Bolivia is currently self-sufficient in sugar, rice and beef, it still has to import certain foodstuffs (www.ciesin.org/decentralization/English/CaseStudies/Bolivia). By 1996, 60% of Bolivian agriculture was channelled to markets, and 40% was subsistence farming. Dry agriculture is the rule, and the most important

crops are potatoes, corn, barley, 'quinoa' (millet like grain), 'habas' (broad beans), wheat, alfalfa, and 'oca' (tuber). The potato is the main staple; dehydrated and frozen to form 'chuño' or 'tunta', it keeps indefinitely. The *Yungas* and *Valles* contain about 40% of the cultivated land. The eastern slopes, however, are too steep to permit the use of machinery, and erosion is a serious problem despite the practice of terracing. The most lucrative crop in the *Yungas* is coca, which is chewed by the local population and from which cocaine is extracted. The leading commercial crops are soybeans, cotton, sugar and coffee. Production for area harvested in 1999 for selected crops was soybeans, 762,000 t produced on 632,000 ha; seed cotton, 56,000 t produced on 50,000 ha; sunflowers, 95,000 t produced on 102,000 ha; wheat, 141,000 t produced on 161,000 ha; coffee, 24,000 t produced on 25,000 ha; sugar, 4.15 Mt produced on 90,000 ha; and rice, 189,000 t produced on 128,000 ha. Droughts and freezing weather in the west during the 1990s caused harvests to fall for basic crops like 'quinoa', potatoes, barley and garden vegetables (www.nationsencyclopedia.com/Americas/Bolivia-Agriculture).

About pigeonpea

According to Nene et al. (1989), Nyabyenda (1987) and van der Maesen (1983, 1986), pigeonpea is a minor crop with 8 accessions documented in Bolivia (Upadhyaya 2007). Agriculture is the main source of livelihood for rural people where 60% of the Bolivian population is indigenous. The introduction of pulse crops such as pigeonpea was an offshoot to battle hunger and poverty of the Tsimane' Bolivian Amazonian. In a study conducted by Jha in 2005, he stated that the incorporation of pigeonpea into the cropping system through the slash and burn method of farming not only enriched protein intake but also augmented their economy through sale of pigeonpea as the crop fetches a higher price in the market than other legumes.

Brazil

Geography

Brazil occupies roughly half of South America bordering the Atlantic Ocean, with geographic coordinates of 33°34'S to 4°12N latitude and 34°58'W to 73°49'W longitude. Brazil covers a total area of 8,514,215 km², which includes 8,456,510 km² of land and 55,455 km² of water (Figure 72).

Brazil's twenty-six states and the Federal District (Distrito Federal) are divided conventionally into five regions--North (Norte), Northeast, Southeast (Sudeste), South and Center-West. Each of the five major regions has a distinct ecosystem. However, administrative boundaries do not necessarily coincide with ecological boundaries. In addition to differences in physical environment, patterns of economic activity and population settlement vary widely among the regions.

Although 90% of the country is within the tropical zone, the climate of Brazil varies considerably from the mostly tropical North to temperate zones below the Tropic of Capricorn. Brazil's five climatic regions are equatorial, tropical, semi-arid, highland tropical and subtropical. High and relatively regular levels of precipitation in the Amazon contrast sharply with the dryness of the semi-arid Northeast, where rainfall is scarce and there are severe droughts in cycles averaging 7 years. The Northeast is the driest part of the country. The region also constitutes the hottest part of Brazil, where during the dry season between May and November, temperatures of more than 38°C have been recorded. However, the '*sertão*', a region of semi-desert vegetation used primarily for low-density ranching, turns green when there is rain. Most of the Center-West/has 1,500 to 2,000 mm of rain per year, with a pronounced dry season in the middle of the year, while the South and most of the Atlantic coast as far north as Salvador and Bahia in the Northeast, have similar amounts of rainfall without a distinct dry season (Library of Congress Country Studies/Area Handbook, modified 2008).

Agriculture

Brazil is a country of enormous contrasts – large economy experiencing enviable growth and vast supply of natural resources amid squalid poverty that is crippling sectors of its society and the growing gap between its rich and poor. The country's agriculture comprises of large farming corporations who represent only 15% of Brazilian farmers while the other 85% are mainly subsistence family farmers (Vijay 2007).

Brazil is endowed with vast agricultural resources. There are two distinct agricultural areas. The first, comprising the southern one-half to two-thirds of the country, has a semi-temperate climate and higher rainfall, better soils, higher technology and input use, adequate infrastructure and more experienced farmers. It produces most of Brazil's grains, oil seeds and

export crops. The second, located in the drought-ridden northeast region and in the Amazon basin, lacks well-distributed rainfall, good soil, adequate infrastructure, and sufficient development capital. Although mostly occupied by subsistence farmers (who practiced the 'slash and burn' technology), the latter regions are increasingly important as exporters of forest products, cocoa and tropical fruits. Central Brazil contains substantial areas of grassland with only scattered trees. The Brazilian grasslands are less fertile than those of North America and are generally more suited for grazing (en.wikipedia.org/wiki/Agriculture_in_Brazil).

Brazilian agriculture is well diversified, and the country is largely self-sufficient in food. At the beginning of the 1990s, the main crops in the modern segment were cocoa, cotton, rice, sugarcane, oranges, corn, soybeans and wheat while those in the traditional segment included beans, manioc (cassava), bananas, peanuts and coffee. Crop production between 1970 and 1990 shows that the components of the modern segment grew considerably, both in production and in yield, while those of the traditional segment stagnated or declined. The growth in export crops allowed Brazil to become one of the world's largest soybean producers and to earn needed foreign exchange. It also allowed the substitution of sugarcane alcohol for imported oil (Library of Congress Country Studies/Area Handbook, modified 2008).

Agriculture accounts for 8% of the country's GDP, and employs about one-quarter of the labor force in more than 6 M agricultural enterprises. Brazil is the world's largest producer of sugarcane and coffee, cocoa, soybeans, orange juice, tobacco, forest products and other tropical fruits and nuts. Livestock production is important in many parts of the country, with rapid growth in the poultry, pork and milk industries reflecting changes in consumer tastes. On a value basis, production is 60% field crop and 40% livestock. Brazil is a net exporter of agricultural and food products, which account for about 35% of the country's exports. The country is the biggest exporter of coffee, soybeans, beef, sugarcane, ethanol, frozen chicken and is also one of the largest exporters of guavas, lemons, mangoes, passion fruit, tangerines and tobacco. (en.wikipedia.org/wiki/Agriculture_in_Brazil; Newsweek International Edition, modified 2008)

In areas where agriculture is more intense and developed, there are serious problems of soil erosion, siltation and sedimentation of streams and rivers, and pollution with pesticides. In parts of the savannas, where irrigated soybean production expanded in the 1980s, the water table has been affected.

Expansion of pastures for cattle raising has reduced natural biodiversity in the savannas. Swine effluents constitute a serious environmental problem in Santa Catarina in the south.

About pigeonpea

Pigeonpea, called 'guando' locally, can be grown well in Northeast Brazil because it is a very large tropical region wherein 28 accessions were recorded (Upadhyaya 2007). It is planted as a minor crop (Nene et al. 1989; Nyabyenda 1987; van der Maesen 1983, 1986), in over 1.5 million km², covering eight of the country's 26 states. The environment is extremely varied, ranging from humid coastal plains to semi-arid interior. According to Andrade (1980), the main feature of this region is the intense diversity at very short distances. The situation in Solânea, Remígio and Lagoa Seca municipalities of the Paraiba State illustrates this well with average annual rainfall approximately 1,100 mm in the easternmost communities, which falls to around 400 mm only 30 km further west (AS-PTA 1997a). The various family farming systems found in the three municipalities mentioned are based on mixed cropping and livestock production. Since the end of the 19th century, smallholder family farming in the region has been, at least partially, market-oriented, stimulated by a succession of cash-crop cycles (tobacco, cotton, sisal, coffee, potatoes, aniseed, etc). The landscape is dominated by annual crops, pasture and, to a lesser extent, orchards (AS-PTA 1997b). Virtually all smallholder families raise a few animals, mainly cattle. The proportion of small ruminants is higher in areas with less rainfall. Family farms are numerically important, but most of them are very small. According to figures from the census conducted by FIBGE in 1986, 77% of farms in the area are smaller than 5 ha.

According to Sabourin et al. (2000), in 1994, a project called *Projeto Paraibas* was organized around the ideas of disseminating innovations; 'experimentation' to develop new agricultural technologies/ideas suitable for local smallholders; and capacity building of local organizations. During this first year, most of the effort was dedicated to the dissemination of planting on the contour, pigeonpea cultivation and banana weevil control. Experimentation started with a couple of rather conventional on-farm trials to compare maize varieties and less structured farmer tests of new fodder crops on a very small-scale. Schaaffhausen (1966) found that the crop is in combination with pangola grass was a good source of fodder.

Pigeonpea dissemination was ‘down-graded’ from dissemination to experimentation, as it became clear that the idea of a more intensive use of this crop was more complex. A few new ideas were introduced for testing: green-manure crops in banana stands and alley cropping with gliricidia (*Gliricidia sepium*) and leucaena (*Leucaena leucocephala*). The authors found that more intensive pigeonpea cultivation needed more experimenting to become an interesting alternative for farming families. Monitoring of the activities to disseminate contour planting brought in interesting information. It was concluded that, although erosion and soil fertility did in fact present a problem, these activities had not looked sufficiently at local (community) conditions. Banana weevil control suffered less from this ‘blinker effect’, but seemed to have reached a sort of ‘dissemination ceiling’. In any case, it became clearer that the mitigation or even complete control of the weevil problem would not make a very big difference in banana yields. Overall, the efforts to promote the initial innovations (contour planting, weevil control and pigeonpea cultivation) were significantly reduced.

In 1995, another study was conducted to test pigeonpea as fodder alternatives for cattle. The study showed remarkable performance due to increased farmers’ participation in 2000 from 8–10 to over 40 farmers. Secondly, farmers do not adopt ready-made practices or technologies they experiment. They try to adapt the technical proposals to the specific conditions of their farms. In fact, innovations introduced by farmers have effects on the farming system at various levels with which farmers must deal. This was seen very clearly with the majority of biomass management practices in which biomass is, at the same time, a forage supply and a source of soil fertility. But experimentation is not the only activity in this small region. In 1995, three community pigeonpea seed banks were started up and have continued ever since. In 1999, the local parish groups were active in several communities by providing technologies for home gardens, medicinal plants and infant nutrition.

In São Paulo, Brazil, pigeonpea can be grazed for up to five years if carefully handled. Schaaffhausen (1965) found that Zebu bulls grazing a pangola grass/pigeonpea pasture gained an average of 35 kg in 90 days during a severe drought, while animals on a control pasture lost 6 kg. On rotation pastures of *Lablab purpureus*, pigeonpea and grasses, 47 bulls gained 40 kg in 63 days. Otero (1952) recorded that in Brazil it made good silage and was very palatable to the animals. If pigeonpea is not frosted, it will stand

over very well for winter and dry-season feeding. In another development, for elevation of 0 to 1,500 masl, farmers plant pigeonpea as green manure (Bunch 1995). In 2007, the practice of integrated zero tillage crop–livestock systems was initiated by the recommendation for crop successions in zero tillage rotations of pigeonpea by preceding and after harvesting the main crops of sorghum, upland rice, wheat and oats (Broch et al. 1997). Moreover, pigeonpea is undersown in maize for stubble grazing, which is a traditional practice in Brazil (Schaffhausen 1949).

Uses

Herbal medicine is practiced by folks in Brazil, the leaves of pigeonpea are infused for coughs, fevers and ulcers; the seeds are prepared in a tea for inflammation and blood disorders; and the flowers are prepared into a tea for upper respiratory infections and pain (Duke 1983). Guandu is the Brazilian name for this perennial woody shrub that grows about 4 m high. Its multi-colored flowers range from yellow, red, purple and orange making it quite a pretty blooming shrub. But it is prized for the food it provides. It produces an edible seed pod with 2 to 9 seeds inside that are shelled and widely eaten as a food, and today it is widely distributed in most tropical countries throughout the world especially South America (Taylor 2005).

Colombia

Geography

Colombia is made up of two major physical regions: the Andes, with its large valleys and basins in the west; and the broad lowlands, which extend over almost two-thirds of the country in the east. With geographic coordinates of 4°7'S to 12°22'N of the equator and 67°24'W to 78°45'W of Greenwich, the country is located in the northwest corner of the South American continent. Colombia is the 26th largest nation in the world and the fourth-largest country in South America after Brazil, Argentina and Peru. The country also has international borders with five Latin American nations: Panama, Venezuela, Brazil, Peru and Ecuador (Figure 72) (en.wikipedia.org/wiki/Geography_of_Colombia). Colombia encompasses an area of more than 1.1 M km². It is the only country in South America with both Caribbean (1,760 km) and Pacific coastlines (1,448 km). About 86% of the country's total area lies in the hot zone and the temperate zone covers about 8% while the cold or cool zone

constitutes about 6% of the total area of the country (www.ddg.com; Library of Congress Country Studies/Area Handbook, Modified 2008a).

The striking variety in temperature and precipitation results principally from differences in elevation. Colombians customarily describe their country in terms of the climatic zones: the area under 900 masl is called the hot zone (tierra caliente), elevations between 900 and 1,980 masl are the temperate zone (tierra templada), and elevations from 1,980 m to about 3,500 m constitute the cold zone (tierra fría). Rainfall in the hot zone is heaviest in the Pacific lowlands and in parts of eastern Colombia, where rain is almost a daily occurrence and rain forests predominate. Precipitation exceeds 7,600 mm annually in most of the Pacific lowlands, making this one of the wettest regions in the world; in eastern Colombia, it decreases from 6350 mm in portions of the Andean piedmont to 2,540 mm eastward. Extensive areas of the Caribbean interior are permanently flooded, more because of poor drainage than because of the moderately heavy precipitation during the rainy season from May through October. Considerable year-to-year variations have been recorded, and Colombia sometimes experiences droughts (Library of Congress Country Studies/Area Handbook, modified 2008a).

Agriculture

Agriculture in Colombia refers to all agricultural activities, essential to food, feed and fiber production, including all techniques for raising and processing livestock. Plant cultivation and livestock production have continuously abandoned subsistence agricultural practices in favor of technological farming resulting in cash crops which contribute to the economy of Colombia. The Colombian agricultural production has significant gaps in domestic and international human and animal sustenance needs. The primary agricultural products of Colombia are coffee (second-largest producer of coffee in the world), cut-flowers, bananas, rice, tobacco, corn, sugarcane, cocoa beans, oilseed, vegetables, fique, panela, forest products and shrimp. In Colombia the agricultural politics and policies are determined by the Ministry of Agriculture and Rural Development (en.wikipedia.org/wiki/Agriculture_in_Colombia).

Cacao, sugarcane, coconuts, bananas, plantains, rice, cotton, tobacco, cassava and most of the nation's beef cattle are produced in the hot regions from sea level to an elevation of 1,000 meters. The temperate regions are

better suited for coffee, certain flowers; maize and other vegetables; and fruits such as citrus, pears, pineapples, and tomatoes. The cooler elevation produces wheat, barley, potatoes, cold-climate vegetables, flowers, dairy cattle and poultry (en.wikipedia.org/wiki/Economy_of_Colombia).

About pigeonpea

Cassava adapts to a wide range of ecological conditions and is known for its tolerance of low soil fertility, drought and pests. This is why the crop holds an important position in traditional tropical cropping systems in Colombia, particularly those of the small-farm and subsistence sectors. In these cropping systems, cassava is often found in mixed stands, together with a variety of other food crops such as pigeonpea, which is considered as a minor crop (Nene et al. 1989; Nyabyenda 1987; and van der Maesen 1983, 1986). For generations the traditional farmer has adopted intercropping as a production system in order to reduce the risk of crop failure, obtain production at different times during the year, make the best use of available land and labor resources, and provide the family with a balanced diet. Estimates indicate that less than one-third of the cassava grown worldwide is intercropped with pigeonpea (Cock 1985). Although pigeonpea is introduced in the country (ILDIS 2005), according to Upadhyaya (2007) there are 8 identified accessions.

The greatest complexity of cassava intercropping systems is probably found in homestead gardens of rural farming families of Africa. In Colombia, when farmers adopt cassava intercropping as a production system, a relatively small plot suffices to provide the family with the basic dietary elements. Cassava provides the carbohydrates while the intercrops such as pigeonpea, contribute to necessary protein. Pigeonpea associations with grain legumes are particularly promising not only because of their aforementioned nutritional advantages but also for their soil-improving potential (CAB International 2002).

In southern Benin, Akonde' et al. (1996) conducted alley cropping research with cassava and maize. Over a six year period, cassava root yields were increased by applying an average of 3 t/ha of pigeonpea dry matter (as mulch) obtained from 4 m spaced hedgerows, but increases were significant only when mulch and a mineral fertilizer were used as compared to *Leucaena leucocephala* hedgerows with cassava. When pigeonpea plants are used

for poultry rations, Colombian farmers cut the plant 0.5 m in height in the first year and 1 m in the second year and cattle are allowed to browse the re-growth. According to Herrera and Crowder (1963), they reported that dry matter of 14,000 kg/ha and more than 2,000 kg/ha of crude protein was obtained from cutting pigeonpea at 15 cm when the plants were 150 cm tall while no re-growth occurred when the plants were cut to ground level. Likewise, around La Nueva, Colombia, pigeonpea is used as medicinal crop to cure bat bites. The leaves are processed for this purpose (www.ars-grin.gov).

Costa Rica

Geography

The eclectic nature of Costa Rica geography is renowned worldwide. Costa Rica is located on the Central American Isthmus, surrounding the point 8°29'N to 11°5N of the equator and 82°62'W to 85°46'W of the Prime Meridian (Figure 72). Costa Rica comprises 51,100 km² of which 50,660 km² is land and 440 km² is water (en.wikipedia.org/wiki/Geography_of_Costa_Rica). The country has a tropical and subtropical climate and is part of the Neotropic ecozone. Costa Rica's dry season in most places is from December to April, while the rainy season is from May to November. On the Caribbean coast, however, December is by far the wettest month. The highlands areas are always cooler. The lowest elevation level in the country is the Pacific Ocean at sea level (en.wikipedia.org/wiki/Geography_of_Costa_Rica).

Agriculture

Costa Rica's basically stable economy depends on tourism, agriculture and electronics exports. The major economic resources are its fertile land and frequent rainfall Costa Rica has two seasons, both of which have their own agricultural resources. The seasons are the basic, wet and dry, tropical seasons (en.wikipedia.org/wiki/Economy_of_Costa_Rica). About 9.9% (505,000 ha) of the total land area is used for crop production. Nearly half of all farms average less than 10 ha in size. Over 327,000 persons, or about 20% of the economically active population, were engaged in farming in 1998. Agriculture accounted for about 9% of the GDP in 2001. The principal cash crops are coffee, bananas, cocoa and sugar. Coffee and bananas together accounted for 31% of exports in 2001. Over 85% of coffee

properties belong to Costa Ricans. The banana industry has been producing more than one million tons annually since the 1970s. Corn, rice, potatoes, beans, sisal, cotton, citrus fruits, pita (used to make hats, baskets and mats), yucca, vegetables, pineapples and other fruits, tobacco, abaca (hemp), and vegetable oils (especially African and coconut palms) are produced primarily for domestic consumption (www.nationsencyclopedia.com/Americas/Costa-Rica-AGRICULTURE).

About pigeonpea

The system of farming by peasant farmers in Costa Rica is as permanent as those of the primeval forest. Land holding is small but there is a balance of livestock and crop production (dominance of food and forage). The farmers use livestock waste to fertilize their fields. Mixed cropping is widely practiced with cereals being the main crop. Leguminous crops, such as pigeonpea are common and grown as a minor crop (Nene et al. 1989; Nyabyenda 1987; van der Maesen 1983, 1986). They are incorporated into the system as a subsoil cultivator aside from its main function as a subsistence crop because its pods are used as food (Howard 1940). According to Upadhyaya (2007), one accession of pigeonpea has been recorded in Costa Rica.

From 1978 to 1982, a research program was initiated by the Tropical Agriculture Research and Training Center to increase crop production in low rainfall and near-drought areas of Costa Rica because agriculture in these areas had failed to provide minimum food requirements for the rapidly increasing population, largely due to a lack of suitable technology for land and water management and crop production. Pigeonpea was tested due to its drought-resistant characteristics into the cropping systems under various conditions. The crop showed a considerable potential (www.catie.ac.cr).

Cuba

Geography

Cuba, the ‘Pearl of the Antilles’, is an archipelago of islands located in the Caribbean Sea, with the geographic coordinates 19°50'N to 23°7'N latitude and 72°33'W to 84°33'W longitude. Cuba, with an area of 110,860 km², is the largest island of the Caribbean Sea. The country lies at the mouth of the Gulf of Mexico, the Atlantic Ocean is to the north and the Caribbean Sea to

the south (Figure 72). Cuba is 170 km southwest of Key West, Florida; 210 km northeast of Yucatán peninsula, Mexico; 77 km away from the east point of the island of Haiti; and Santiago de Cuba is around 270 km northeast of Jamaica (www.wiki-mirror.be; www.suitecuba.com).

Cuba has a pleasant subtropical climate and there are no pronounced seasonal variations, though moderated by trade winds. The seasons can be divided into the rainy summer season from May to October and drier winter season from November to April. The annual average temperature is 25.5°C (an average of 27.4°C in the warmest months July and August and 22.0°C in the coolest February). During the winter, especially from December to February, it can get cool some days but one will never feel uncomfortable with these temperatures. Cuba lies in the path of hurricanes, and these destructive storms are most common in September and October (www.wiki-mirror.be; www.suitecuba.com).

Agriculture

Agriculture in Cuba has played an important part in the economy for several hundred years. Cuban agriculture was based on large-scale, capital-intensive monoculture, more similar in many ways to the Central Valley of California than to the typical Latin American *minifundio* or small-scale farm. More than 90% of fertilizers and pesticides, or the ingredients to make them, were imported from abroad. This demonstrates the degree of dependency exhibited by this style of farming, and the vulnerability of the island's economy to international market forces. When trade relations with the socialist bloc collapsed in 1990, pesticide and fertilizer imports dropped by about 80%. Food imports also fell by more than half. Suddenly, an agricultural system almost as modern and industrialized as that of California was faced with a dual challenge: the need to essentially double food production while more than halving inputs -- and at the same time maintaining export crop production so as not to further erode the country's desperate foreign exchange position (Rosset and Cunningham 1994).

Agriculture contributes less than 10% to the gross domestic product (GDP), but it employs roughly one fifth of the working population. About 30% of the country's land is used for crop cultivation. In Cuba, the development of urban agriculture started as a necessity to face the crisis of food production. A strong movement exists, fundamentally through the development of *organopónicos*

(urban gardens) and *huertos intensivos* (intensive orchards). From 1996 to 1997 the production of these methods of urban agriculture grew by three times. During 1998, the production in patios and parcels was registered too (Castro 1999). In 2002, 140 km² of urban gardens produced 3.4 Mt of food. In Havana, 90% of the city's fresh produce come from local urban farms and gardens. In 2003, more than 200,000 Cubans worked in the expanding urban agriculture sector (en.wikipedia.org/wiki/Agriculture_of_Cuba).

About pigeonpea

In Cuba, pigeonpea is cultivated as a minor crop (Nene et al. 1989; Nyabyenda 1987; van der Maesen 1983, 1986) and according to Upadhyaya (2007), there are 6 identified accessions. In 1968, Fidel Castro transformed an area of 33,000 acres around Havana by planting fruit trees, coffee, and pigeonpea, which was cultivated to provide seeds (lanic.utexas.edu/la/cb/cuba/castro).

Morton (1976) reported that in Cuba, pigeonpea leaves are used as herbal medicine by decoction to cure jaundice and for bronchitis and colds (Taylor 2005). Aside from its medicinal use, Cubans consume pigeonpea by preparing a soup (green pea soup) and pigeonpea rice with tostones and a cool marinated onion and avocado salad. Experimental yields obtained showed biomass yields of 12 MT/ha (NAS 1980).

Dominica

Geography

Dominica is an island in the Caribbean Sea, located about/halfway between Puerto Rico and Trinidad and Tobago (Figure 72). Its coordinates are 15°17'N to 15°25' N latitude, 61°20'W to 61°36'W longitude. Dominica is the largest and most northerly of the Windward Islands. Oblong-shaped and slightly smaller than New York City, Dominica is 750 km² in area. The country has one of the most rugged landscapes in the Caribbean, covered by a largely unexploited, multi-layered rain forest. It is also among the earth's most rain-drenched lands, and the water runoff forms cascading rivers and natural pools (en.wikipedia.org/wiki/Geography_of_Dominica).

Dominica has a tropical wet climate with characteristically warm temperatures and heavy rainfall. Excessive heat and humidity are tempered somewhat

by a steady flow of the northeast trade winds that periodically develop into hurricanes. The steep interior slopes also alter temperatures and winds. Temperature ranges are slight. Average daytime temperatures generally vary from 26°C in January to 32°C in June. Although amounts vary with the location, rain is possible throughout the year, with the greatest monthly totals recorded from June through October. Average yearly rainfall along the windward east coast frequently exceeds 5,000 mm, and exposed mountainsides receive up to 9,000 mm, among the highest accumulations in the world. Totals on the leeward west coast, however, are only about 180 centimeters per year (en.wikipedia.org/wiki/Geography_of_Dominica).

Agriculture

About 22.6% of the total land area is arable. In 1997, the total cultivated area amounted to 15,000 ha, of which 12,000 ha are under permanent crops. The agriculture sector accounted for about 19.8% of the GDP in 1996 and employs about 40% of the labor force (www.wca-infonet.org). Most crops are produced on small farms, the 9,000 owners of which are banded together in about 10 cooperatives; there are also several large farms that produce mostly bananas for export. Other major crops are coconuts and citrus fruits, which are grown in commercial quantities. Production for 1999 included coconuts, grapefruit, lemons, limes and oranges. Fruits and vegetables are produced mostly for local consumption. More recently, Dominica's agricultural development has been towards diversification into the production of non-traditional crops including pineapple, peppers, sweet corn and other fruits and vegetables (www.investdominica.dm/agriculture; en.wikipedia.org/wiki/Economy_of_Dominica).

About pigeonpea

Pigeonpea is cultivated as a minor crop in Dominica (Nene et al. 1989; Nyabyenda 1987; van der Maesen 1983, 1986) but the country has a great potential to grow pigeonpea as a major crop. The indicating factor is the presence of landraces grown by small-scale farmers as subsistence crop although few or no efforts at all have been made to document the status of this crop grown in this country. In 1978, CARDI reported that 5 ha were planted with pigeonpea with a production of 2.5 t. The importance of this crop came to light during a workshop conducted by CARDI in August 2000, where it was evident that Dominica gave priority to pigeonpea because of its economic, social, institutional and environmental importance (Paul 2001).

Ecuador

Geography

Ecuador, with coordinates of 4°54'S to 1°19'N latitude, 76°19'W to 81°2'W longitude, is located on the northwestern coast of South America, between Peru to the south and east and Colombia to the north (Figure 72). Ecuador covers 256,370 km² of land, and is the smallest country in South America after Uruguay and the Guianas. Ecuador comprises four distinct geographical regions: El Oriente (Amazon jungle) in the east, La Sierra (Andes Mountain) in the center, La Costa (the Pacific coastal lowlands) in the west, and the majestic Galapagos Islands off the coast. On account of Ecuador's varied regions and because of its location directly atop the equator, most of Ecuador experiences oscillating wet and dry periods. The general weather trends for each region are as follows: El Oriente (Amazon region) normally has a warm, humid and rainy climate, the average temperature varies from 23 to 26°C (72 to 80°F), the drier season is generally November to February but varies by region; La Sierra (Andes Mountain), though on the equator, is generally cooler than most people would expect, the climate in the Andes varies according to the altitude and the time of the year – in Quito the temperature ranges from 7°C (55°F) at night to 26°C (78°F) at noon, averaging 15°C (64°F); La Costa's (Coastal lowlands) climate is usually very warm with temperatures averaging 25°C (76°F) to 31°C (90°F) during the year, the rainy season (December to May) is warm and very humid, the dry season is less humid but still a little muggy; and the Galapagos islands enjoy warm and dry weather year-round, with an average temperature of 28°C (85°F) (www.ecuadorexplorer.com/html/location_geography).

Agriculture

Although Ecuador's main economic activity has long been in agriculture, only 11% of the land is arable or under permanent crops, and another 18% is permanent pasture. Throughout the 1970s, agricultural development was neglected because of the emphasis on oil exploitation, and the sector showed negative rates of growth, declining by 5.4% in 1978, 2.8% in 1979, and 2% in 1980. During 1985-90, however, agriculture (along with fishing and forestry) showed an average annual increase of 4.8%. Agricultural production had an average annual growth of 1.7% during 1990-2000. Agriculture employed 26.5% of the labor force in 1999 and contributed 11% to GDP in 2000. The

agricultural sector of the economy presents potential for further development and growth. Crops for domestic consumption, particularly rice, barley, maize, African palm and potatoes, continue to show growth due to increased area planted and improved yields. Other segments likely to experience growth are non-traditional agricultural products such as flowers, fresh fruit and vegetables, and processed foods.

Traditionally, agricultural products have included bananas, coffee, tea, rice, sugar, beans, corn, potatoes and tropical fruit. Exported products of more recent prominence include roses and carnations, strawberries, melons, asparagus, heart of palm and tomatoes. The major crops of the highlands are corn, barley, wheat, kidney beans, potatoes, horse beans, peas and soybeans, all for domestic consumption. Agriculture on the coast is largely oriented toward the export market (www.nationsencyclopedia.com/Americas/Ecuador-AGRICULTURE).

About pigeonpea

Pigeonpea, locally called ‘Gandú’, has been identified as one of the minor producing subsistence crops for small-scale farmers of Ecuador (Nene et al. 1989; Nyabyenda 1987; and van der Maesen 1983, 1986). The crop is grown purposely for its green pods as vegetable. ILDIS (2005) reported that the crop was introduced in the country, though according to Upadhyaya (2007), one accession was identified in the country. According to Herbarium records, pigeonpea has been introduced and cultivated in Floreana Island, San Cristobal Island, San Cristóbal Island and Santa Cruz Island in Ecuador (Charles Darwin Research Station 2005).

El Salvador

Geography

The geography of El Salvador is unique among the nations of Central America. With coordinates of 13°10'N to 1°42'N latitude, 87°44'W to 90°70'W longitude, the country borders the North Pacific Ocean to the south and southwest, with Guatemala to the north-northwest and Honduras to the north-northeast (Figure 72). In the southeast, the Golfo de Fonseca separates it from Nicaragua. El Salvador is the smallest Central American country in area and is the only one without a coastline on the Caribbean Sea.

El Salvador has a tropical climate with pronounced wet and dry seasons. Temperatures vary primarily with elevation and show little seasonal change. The Pacific lowlands are uniformly hot; the central plateau and mountain areas are more moderate. The rainy season extends from May to October. Almost all the annual rainfall occurs during this time, and yearly totals, particularly on southern-facing mountain slopes, can be as high as 2,000 mm. From November through April, the northeast trade winds control weather patterns. During these months, air flowing from the Caribbean has had most of the precipitation wrung out of it while passing over the mountains in Honduras. By the time this air reaches El Salvador, it is dry, hot and hazy. This season is known locally as *verano*, or summer. Temperatures vary little with season; elevation is the primary determinant. The Pacific lowlands are the hottest region, with annual averages ranging from 25°C to 29°C. San Salvador is representative of the central plateau, with an annual average temperature of 23°C and absolute high and low readings of 38°C and 6°C, respectively. Mountain areas are the coolest, with annual averages from 12°C to 23°C and minimum temperatures sometimes approaching freezing (en.wikipedia.org/wiki/Geography_of_El_Salvador).

Agriculture

Despite the relative importance of agriculture to El Salvador's economy, absolute levels of production declined dramatically after 1979. Several factors, especially the civil conflict, were blamed for the decline. The impact of the conflict varied, however, depending on the crop. For example, the geographical location of the most important coffee-growing area (the western sector of the country) insulated most coffee producers from the violence. In contrast, cotton production, centered in the eastern part of the country, was devastated by guerrilla activities. Despite the general decline of agricultural output, coffee, which generated half the country's export earnings in 1987, continued as the most important commodity produced in El Salvador.

The agricultural sector accounted for nearly 25% of GDP in 1987 and was responsible for about 80% of the country's export revenue. Although the number of people employed in agriculture increased from 3.5 M in 1970 to 5.7 M in 1986, the share of the economically active population employed in agriculture declined from 56% in 1970 to only 40% in 1986. After coffee, sugar and cotton were the most important agricultural commodities. Basic grains (wheat, rice and corn) were also grown extensively, but for domestic consumption (countrystudies.us/el-salvador).

About pigeonpea

In El Salvador, agricultural areas are subject to low rainfall and near-drought for extensive periods. Agriculture here has failed to provide minimum food requirements for rapidly increasing populations, largely due to a lack of suitable technology for land and water management and crop production. Farmers in El Salvador commonly practiced the maize-sorghum cropping system. Thus from 1978 to 1982, a research project was conducted by the Tropical Agriculture Research and Training Centre by introducing drought resistant crops. The project aims to identify and test promising improved plant material with drought-resistant characteristics of pigeonpea. The integration of pigeonpea into the system has showed considerable potential. But the political situation in the country and changes in personnel at Tropical Agriculture Research and Training Centre limited the project to a national rather than regional scope and hampered the publication of its achievements. It was also noted that not enough germplasm was introduced from outside Central America (www.catie.ac.cr).

French Guyana (Guyane)

Geography

French Guyana or French Guiana is located to the north-east of South America, on the Atlantic Ocean with geographic coordinates of 2°6'N to 5°36'N latitude, 51°35'W to 54°40'W longitude, and comprises 91,000 km² of land area (1,850 km² is water and 89,150 km² is land). Part of this country is bordered by the Atlantic Ocean on the north, Suriname on the west and Brazil on the south and east (Figure 73). The Oyapock (Oiapoque) River on the east and the Tumuc-Humac Mountains on the south separate it from Brazil. The Maroni River on the west forms the border with Suriname (www.bartleby.com). The climate of French Guiana is equatorial, warm and humid with little change in temperatures during the year, the annual average is 27°C. The average minimum temperatures remain stable throughout the year at around 23°C, while average maximum temperatures range between 29°C and 33°C. The dry season is during the months of August to November, while the rainy season is between December and July, with May being the most rainy month. The average annual rainfall is about 2,500-3,000 mm (www.colonialvoyage.com/america/.../frenchguiana/climate).

Agriculture

French Guiana is largely dependent on subsidies and imports. Fishing and forestry are the prime industries, and timber, shrimp and rum made from local sugarcane are the chief exports. Agriculture is largely undeveloped and is mainly confined to the area near the coast. Rice, corn, bananas and other fruits, vegetables and manioc are grown for subsistence. The *Plan Vert* (Green Plan), adopted in the late 1970s to increase production in agriculture and forestry, met with only partial success (en.wikipedia.org/wiki/French_Guyana; www.bartleby.com).

About pigeonpea

Pigeonpea is cultivated in French Guyana as a minor crop (Nene et al. 1989; Nyabyenda 1987; van der Maesen 1983, 1986) by peasant farmers. The pigeonpea is used by peasant farmers as a herbal medicine to cure the following illnesses: Leaf infusion is consumed for pulmonary conditions such as coughs and bronchitis; leaf juice for haemorrhages; leaf decocted for washing ulcers; leaves when mixed with *Dactyloctennum aegyptnum* is to accelerate childbirth; leaves used in a complex liquid with *Plectranthus*, cloves and 'steel drops' for venereal disease; boiled leaves applied to sores and wounds to hasten cicatrisation; shoots and green pods used for a good pectoral infusion; leaves or pods boiled with salt and 'steel drops' (ferric chloride solution) for treatment of leucorrhea; leaves or pods infusion for fever-bath and headaches; leaves or pods macerated/grind for an antiperspirant or deodorant; leaf and flower when boiled is used as a diuretic and a diabetes remedy; flower is pectoral; seeds are used for diuretic; and flour prepared from seeds gets easily dissolved (MedPlantsGui2).

Guadeloupe

Geography

Guadeloupe is an island group or archipelago located in the eastern Caribbean Sea at coordinates 15°57'N to 16°15'N latitude, 61°28'W to 61°47'W longitude, with a land area of 1,628 km² (Figure 73). Guadeloupe is also one of the twenty-six regions of France (being an overseas region) and an integral part of the Republic. As part of France, Guadeloupe is part of the European Union. However, Guadeloupe does not fall under the Schengen

Agreement. The island has two major climate zones: a very arid, semi-hot climate between 0 and 800 meters elevation, with mean annual temperature between 18-22°C, and a very arid, temperate climate above 800 meters elevation with temperatures over 22°C in the hottest month of the year (en.wikipedia.org/wiki/Guadeloupe; www.answers.com/topic/guadalupe).

Agriculture

Guadeloupe's economy is mainly based on agriculture, especially sugarcane, bananas and rum; a growing industrial sector, mainly oriented to local consumption (www.easygolanguages.com/study-abroad/French/Guadeloupe). The traditional sugarcane crop is slowly being replaced by other crops, such as bananas (which supply about 50% of export earnings), eggplant, guinnea, noni, sapotilla, paroka, pikinga, giraumon squash, yam, gourd, plantain, christophine, monbin, prunecafé, cocoa, jackfruit, pomegranate and many varieties of flowers. Other vegetables and root crops are cultivated for local consumption. However, Guadeloupe is still dependent on imported food, mainly from France (www.martinfrost.ws/htmlfiles/july2008/guadeloupe; en.wikipedia.org/wiki/Guadeloupe).

Its volcanic ground allowed the culture of coffee, which was regarded as one of the best in the world, cotton, market-gardening products and banana. Vanilla also added to the richness of Guadeloupe for many years. Today, the economy of the commune is centered around tourism. But agriculture, fishing, the craft industry and geothermics are not negligible activities (www.scubish.com/overview/5944/North_America/Guadeloupe/Bouillante).

About pigeonpea

Pigeonpea in this region is considered as a minor crop but with great potential (Nene et al. 1989; Nyabyenda 1987; van der Maesen 1983, 1986). There are 22 accessions identified (Upadhyaya 2007) and several lines were introduced and suitable lines were identified (Derieux 1971). Though the demand for fresh and canned vegetable in the domestic market and within the Caribbean region is quite high, the country does not list this crop as one of its priority crops. The types of pigeonpea grown are mostly landraces for vegetable purposes. In this part of the Caribbean region, pigeonpea is served as a cuisine combined with other crops as a dish, or mixed with rice. In 2002, the first recorded plant pest of *Melanagromyza obtusa* was found

in Guadalupe. The pest, which is a diptera type, is a pod borer with Asian origin, but since the early 2000s, it has been reported as spreading within the Caribbean region. All immature stages occur within the pod. Larvae mine under the epidermis of the seeds, which are then filled with frass. Adult flies emerge from their puparia inside the pod (but outside the seed) and escape through a thin epidermal window. The pest was first discovered on the island of Marie-Galante (belonging to Guadeloupe) on pigeonpea in 2002 and again in 2003. Studies were then done on the island of Guadeloupe during the growing season of the crop, but the studies failed to detect the pest. *M. obtusa* was in fact found in 2003 after the growing season on a few pods that had remained after harvest. As pigeonpea is widely grown in the Caribbean and *M. obtusa* is a serious pest of *C. cajan* in its area of origin, it is felt that the pest may have the potential to spread rapidly and cause problems within the Caribbean Basin (Etienne et al. 2004).

Guatemala

Geography

Guatemala, with coordinates of 13°40'N to 18°28'N latitude, 88°25'W to 92°6'W longitude, is a country in Central America bordered by Mexico to the north and west, the Pacific Ocean to the southwest, Belize and the Caribbean Sea to the northeast, and Honduras and El Salvador to the southeast (Figure 72). The country has a total land area of 107,940 km². The climate is tropical and is hot and humid in the lowlands and cooler in the highlands (en.wikipedia.org/wiki/Geography_of_Guatemala).

Agriculture

Guatemala's land use has a total arable land of 12% (5% for permanent crops), and 24% for pastures, while forest and woodland comprise 54% of the total land area (en.wikipedia.org/wiki/Geography_of_Guatemala). Some of the main products for export are organic coffee, sugar, bananas, vegetables, flowers, handicrafts and textiles. Agriculture contributed an estimated 22.1% of the country's GDP in 2006 (en.wikipedia.org/wiki/Guatemala).

About pigeonpea

Agriculture in Guatemala is characterized by small subsistence farming (Nene et al. 1989; Nyabyenda 1987; van der Maesen 1983, 1986). According to Cruz and Segarra (1996), pigeonpea is amongst the most important crops grown in Guatemala. The system of farming by peasant farmers is as permanent as those of the primeval forest (Howard 1940). Guatemala's small-scale farmers have benefited from the adoption of sustainable agriculture increasing crop yields from 400-600 kg/ha to 2,000-2,500 kg/ha. Farmers use green manure, cover crops, contour grass strips, in-row tillage, rock bunds and animal manures, which are finely-tuned through experimentation to local conditions.

Peasant farmers practiced the method of 'slash and burn' to clear forest areas to cultivate dominant/primary crops, which are the food and forage crops such as cereals and are intercropped with pigeonpea and other leguminous crops for home consumption. Small-scale farmers integrate livestock and crop production wherein animal waste is important in their farming system (Howard 1940).

Guyana

Geography

Guyana, with geographic coordinates of 4°7'N to 8°29'N latitude, 57°18'W to 61°10'W longitude, is a country in northern South America and part of Caribbean South America, bordering the North Atlantic Ocean, between Suriname and Venezuela (Figure 73), with a land area of approximately 214,970 km². The land comprises three main geographical zones: the coastal plain, the white sand belt and the interior highlands. The country lies near the equator and the climate is tropical. The year has two wet seasons, from December to early February and from late April to mid-August (en.wikipedia.org/wiki/Geography_of_Guyana).

Temperatures are quite constant, with an average high of 32°C and an average low of 24°C in the hottest month (July), and an average range of 23°C to 29°C in February, the coolest month. Humidity averages 70% year-round. Rainfall is heaviest in the northwest and lightest in the southeast and interior areas. Annual averages on the coast near the Venezuelan border

are near 2,500 mm, farther east at 2,000 mm, and in southern Guyana 1,500 mm. Areas on the northeast sides of mountains catch as much as 3,500 mm of precipitation annually. Rain generally falls in heavy afternoon showers or thunderstorms (en.wikipedia.org/wiki/Geography_of_Guyana).

Agriculture

Lying wholly in the tropics, the country has an equatorial climate characterized by high rainfall, high humidity and low variation in temperature. Besides other natural resources, the country is endowed with fertile lands, especially in the coastal plains and the riverine areas. This makes the country agroclimatically suited to the cultivation of a variety of agricultural commodities, particularly tropical fruits and vegetables (Mathur 2002).

Guyana's economy depends on agriculture. Agriculture accounts for about one third of Gross Domestic Product (GDP) and employs approximately one third of the labor force. Traditional crops, namely sugarcane and rice, account for most of the agricultural exports. Sugar is produced by a state-owned enterprise and production is done mainly in the rich fertile soil of the coastal belt, which is home to 90% of the total population. It contributes 16% to total GDP and 30% to the agricultural GDP. Rice is produced by about 12,000 farmers and is a major source of income and employment in rural Guyana. The rice industry contributes 12% to total GDP and 20% to agricultural GDP. Non-traditional crops such as coconut, coffee, cocoa, citrus fruits, corn, manioc (cassava) and other tropical fruits and vegetables are grown primarily for local consumption. The non-traditional agriculture sub-sector is characterized as labor-intensive, small-scale or subsistence farming with low capital and technological inputs. Low productivity is not the only constraint to the development of domestic agriculture. Production is generally unfocused and not linked to marketing, resulting in fluctuations in supply that cause scarcity or glut in the market. The export market for non-traditional agriculture remains relatively untapped. Crops, such as pineapple and plantain, are exported to regional markets (Trinidad and Tobago, and Barbados). There is, however, potential for organic exports, which Guyana is attempting to exploit through production of organic pineapple, cocoa and sugarcane (IICA Guyana Annual Report 2003). In 2001, agriculture, forestry and fisheries sectors contributed around 29% to the nation's gross domestic product. Of the total population of the country, 19% depend directly on agriculture for their livelihood (FAOSTAT 1998).

About pigeonpea

There are 28 accessions (Upadhyaya 2007) in the country although considered as a minor crop (Nene et al. 1989; Nyabyenda 1987; van der Maesen 1983, 1986). Guyana's indigenous people, or Amerindians, now live in reservations mainly in the country's hinterland. The traditional Amerindian agriculture system was based on shifting or fallow cultivation in forested areas through the "slash and burn" method with a short cropping period and long fallow (Dummett 1968). The type of crops grown varies according to tribes, topography of the land, soil type (such as sandy or clay) and the season (rainy or dry). This allowed for crop rotation as well as intercropping, which in turn helped in maintaining the area's soil and biodiversity. In 1960, the government of Guyana introduced change regarding type of crops grown, brought about mainly through an agricultural campaign to influence Amerindians to switch from subsistence to economic production. This was viewed as part of government's (integration) strategy to ensure economical survival of the Amerindian population. Peasant farmers were taught how to cultivate crops, amongst others, pigeonpea (Fox 1996). In 1978, CARDI states that 16 ha of lands were planted with pigeonpea and a total of 7 t were produced with a productivity of 437 kg/ha.

In 2001, the Caribbean Agricultural Research and Development Institute (CARDI) identified pigeonpea as one of the national priority crops for Guyana for agricultural research and development because of its economic (comparative advantage in the domestic, regional and international market), social, institutional and environmental importance due to deteriorating production of main crops such as sugarcane, banana, cocoa, rice, coffee and coconut (Paul 2001).

The implementation of the CARICOM Corn and Soybean Project in 1976 in the 800 ha of the Kibilibiri Savannahs brought about the integration of pigeonpea into the system. Mixed cropping was introduced to farmers from a range of production options including livestock (cattle and small ruminants) grain crops (maize, sorghum, peanut, red pea, soyabean, pigeonpea), fruit crops (citrus, pineapple, passion fruit, sorrel, West Indian cherry) vegetables and cash crops (Stabroek News 2008).

Pigeonpea: Medicinal Plant

'Pigeonpea', 'pea', or 'green pea', local names in Guyana is used as medicinal crop to cure the following illnesses: leaf infusion is consumed for pulmonary conditions such as coughs and bronchitis; leaf juice for haemorrhages; leaf decocted for washing ulcers; leaves when mixed with *Dactyloctennum aegyptnum* is used to accelerate childbirth; leaves used in a complex liquid with *Plectranthus*, cloves and 'steel drops' for venereal disease; boiled leaves applied to sores and wounds to hasten cicatrisation; shoots and green pods used for a good pectoral infusion; leaves or pods boiled with salt and 'steel drops' (ferric chloride solution) for treatment of leucorrhea; leaves or pods infusion for fever-bath and headaches; leaves or pods macerated/ground for an antiperspirant or deodorant; leaf and flower when boiled is used as diuretic and diabetes remedy; flower is pectoral; seeds are used for diuretic; and flour produced from the seeds is easily dissolved (MedPlantsGui2).

In 1997, the Botany Club of the University of Guyana advised readers of its newsletter that besides the fruit of pigeonpea being an important nutritional component of the diet, this plant possesses various medicinal values ranging from cures for the everyday flu to the deadly diabetes (Mohamed 1997).

Honduras

Geography

Geographically located 12°58'N to 15°52'N latitude and 83°24' to 89°12' W longitude, Honduras is a country situated in Central America. Honduras borders the Caribbean Sea and the North Pacific Ocean. Guatemala lies to the west, Nicaragua to the south east and El Salvador to the south west (Figure 73). It is the second largest Central American republic. The triangular-shaped country has a total area of just over 111,369 km². Honduras is tropical in the lowlands and temperate in the mountains. The Pacific coast region is slightly hotter than the Atlantic coast region (en.wikipedia.org/wiki/Geography_of_Honduras).

The climatic types of each of the three physiographic regions differ. The Caribbean lowlands have a tropical wet climate with consistently high temperatures and humidity, and rainfall fairly evenly distributed throughout the year. The Pacific lowlands have a tropical wet and dry climate with high temperatures but a distinct dry season from November through April. The

interior highlands also have a distinct dry season, but, as is characteristic of a tropical highland climate, temperatures in this region decrease as elevation increases. Both the Caribbean and Pacific lowlands are tierra caliente, with daytime highs averaging between 28°C and 32°C throughout the year. Rain falls year round in the Caribbean lowlands but is seasonal throughout the rest of the country. Amounts are copious along the north coast where the average rainfall is 2,400 mm. The interior highlands and Pacific lowlands have a dry season, known locally as ‘summer,’ from November to April. Almost all the rain in these regions falls during the ‘winter,’ from May to September. Total yearly amounts depend on surrounding topography (en.wikipedia.org/wiki/Geography_of_Honduras).

Agriculture

Honduras is one of the poorest countries in Latin America. Land use constitutes the following: arable land, 15%; permanent crops, 3%; pastures, 14%; forest and woodland, 54%; and others, 14% with total irrigated land of 740 km² (en.wikipedia.org/wiki/Geography_of_Honduras). The economy is based mostly on agriculture, which accounted for 22% of its gross domestic product (GDP) in 1999. Coffee is the leading export product, which accounted for 22% of total Honduran export revenues. Bananas were the second-largest export in 2000 with 57%. Cultivated shrimp are another important export sector. Other agriculture products are citrus and beef (en.wikipedia.org/wiki/Economy_of_Honduras).

About pigeonpea

Honduras has one accession of pigeonpea (Upadhyaya 2007) and in line with ILDIS (2005), the crop was purely introduced. According to Nene et al. (1989), Nyabyenda (1987) and van der Maesen (1983, 1986), pigeonpea is cultivated as a minor crop. A five year research program was implemented by the Tropical Agriculture Research and Training Center in 1978-1982 to increase crop production in low rainfall and near-drought areas of Honduras since agriculture in these country had failed to provide minimum food requirements for rapidly increasing populations, largely due to a lack of suitable technology for land and water management and crop production. Pigeonpea was tested due to its drought-resistant characteristics under various conditions to be included in the cropping systems. The crop showed considerable potential (www.catie.ac.cr).

Martinique

Geography

The island of Martinique is an overseas department of France, located in the French West Indies, in the eastern Caribbean Sea, southeast of Puerto Rico and off the northwestern coast of South America (Figure 73) with geographic coordinates of 14°31'N to 14°40'N latitude, 60°57'W to 61°18'W longitude with an area of 1,102 km² (www.nationsonline.org/oneworld/martinique). The island of Martinique has a warm and humid tropical climate, with temperatures constant throughout the year, the average minimum varies between 21°C and 23°C, while the average maximum varies between 28°C and 31°C. The north-east trade winds mitigate the temperature, while the winds from the south are hot and humid and sometimes lead hurricanes. On Martinique there are two distinct seasons, the dry season between December and May and the rainy, humid and hot season, between June and November, the average annual rainfall is around 2,000 mm. The island may be affected by tropical cyclones in the months from June through November (www.colonialvoyage.com/america/.../martinique/climate).

Agriculture

Martinique's economy is based largely on agriculture, and about 18% of the island is cultivable. Fruits, sugarcane, vanilla, pineapples, avocados, flowers, vegetables and tobacco are the island's principal agricultural products (www.nationsonline.org/oneworld/martinique; studentorgs.utexas.edu/csaut/Martinique). But the bulk of meat, vegetable and grain requirements are imported, contributing to a chronic trade deficit that requires large annual transfers of aid from France. Agriculture accounts for about 6% of GDP (www.umsl.edu). Now, most of the agriculture on the island can be found in the hot valleys and along the coastal strips, and large parts of these areas are dedicated to the cultivation of sugarcane and the production of rum, which is the island's greatest export. Bananas and pineapples are also important exports for Martinique. In recent years, the export of bananas has been increasing, with shipments mainly bound for France. Other agricultural exports include avocados, various other vegetables and flowers (martinique-guide.info/past.and.present/economy).

About pigeonpea

According to Nene et al. (1989), Nyabyenda (1987) and van der Maesen (1983, 1986), pigeonpea is considered a minor crop in this country with great potential economically and socially; only one accession has been identified (Upadhyaya 2007).

Berianger, as quoted in www.henriettesherbal.com/eclectic/sturtevant/cajanus.html, states that in Martinique, there are several varieties of pigeonpea greatly used, and that the seeds both fresh and dried are delicious. The variety 'Bicolor' grows from three to six feet high and is called the Congo pea. The variety 'Flavus' grows from five to ten feet high and is called no-eye pea, pigeonpea and Angola pea.

Mexico

Geography

Mexico, with geographic coordinates of 14°56'N to 32°37'N latitude and 86°50'W to 116°53'W longitude has a unique geographical landscape that makes it one of the most biologically diverse countries in the world (Figure 73). Mexico's total area covers 1,972,550 km², including approximately 6,000 km² of islands in the Pacific Ocean, Gulf of Mexico, Caribbean Sea and Gulf of California. Mexico's climate varies from tropical to desert. Mexico is prone to natural disasters throughout its territory, from floods and hurricanes, to earthquakes and volcanic eruptions that threaten the lives of many Mexicans. The Tropic of Cancer effectively divides the country into temperate and tropical zones. In the north, a cooler temperature is experienced during the winter months while in the south with elevations up to 1,000 m a yearly median temperature between 24°C and 28°C is experienced. The temperatures are fairly constant year round. Between 1,000 and 2,000 m, one encounters yearly average temperatures between 16°C and 20°C. Above 2,000 m, temperatures drop as low as an average yearly range between 8°C and 12°C. Mexico has pronounced wet and dry seasons. Most of the country experiences a rainy season from June to mid-October and significantly less rain during the remainder of the year. February and July generally are the driest and wettest months, respectively (en.wikipedia.org/wiki/Geography_of_Mexico).

In Mexico, the arid or semi-arid conditions of the country are encountered in the Baja California Peninsula, the northwestern state of Sonora, the northern altiplano, and also significant portions of the southern altiplano. Rainfall in these regions averages between 300 and 600 mm per year, although even less in some areas, particularly in Baja California Norte. Average rainfall totals are between 600 and 1,000 mm in most of the major populated areas of the southern altiplano, including Mexico City and Guadalajara (en.wikipedia.org/wiki/Geography_of_Mexico).

Agriculture

Agriculture plays a smaller role in the economy of Mexico. Arable land only comprised 12.99% of the total area of Mexico but the food industry represents one of the fastest growing areas for foreign investment. In 2006, agriculture accounted for only 3.9% of GDP, down from 7% in 1980 (Instituto Nacional de Geografia 2007), and 25% in 1970 (Hufbauer and Schott 2005). Nonetheless, given the historic structure of *ejidos*, it still employs a considerably high percentage of the work force: 18% in 2003, most of which grows basic crops for subsistence, compared to 2-5% in developed nations in which production is highly mechanized.

Mexico is still the fourth largest corn producer in the world (Major Food and Agricultural Commodities and Producers 2007). In spite of being a staple in Mexican diet, Mexico's comparative advantage in agriculture is not in corn, but in horticulture, tropical fruits and vegetables. Negotiators of NAFTA expected that through liberalization and mechanization of agriculture, two-thirds of Mexican corn-producers would naturally shift from corn production to horticultural and other labor-intensive crops such as fruits, nuts, vegetables, coffee and sugarcane (Nadal 2002).

Second to corn is the production of sugarcane wherein approximately 160,000 small- and medium-sized farmers grow this crop in 15 Mexican states. But Mexico's sugar industry is characterized by high production costs and lack of investment. Mexico produces more sugar than it consumes (www.signonsandiego.com/news/mexico).

About pigeonpea

In Mexico, small-scale farmers who adopt the conventional tillage use pigeonpea as legume green manures in association with maize on Acrisol soils. The application of earthworms and green manure was recognized and recommended as a promising agricultural practice to increase maize yield. Pigeonpea, ‘frijol de árbol’ in local dialect, has 62 accessions (Upadhyaya 2007) and is considered as a minor crop (Nene et al. 1989; Nyabyenda 1987; van der Maesen 1983, 1986). Duke (1983) and Taylor (2005) identified ethno medical uses of pigeonpea as an astringent, diuretic, laxative, vulnerary and also useful against dysentery.

Montserrat

Geography

The island of Montserrat with geographic coordinates of 16°28'N to 16°43'N latitude, 62°12'W to 62°45'W longitude is located approximately 480 km east-southeast of Puerto Rico and 48 km southwest of Antigua (Figure 73). It comprises only 104 km² and is increasing gradually owing to volcanic deposits on the southeast coast of the island; it is 16 km long and 11 km wide, with dramatic rock faced cliffs rising 15 to 30 masl and smooth bottomed sandy beaches scattered among coves on the west side of the island. The country is a tropical island with a diverse flora and a rich heritage of plant folklore (en.wikipedia.org/wiki/Montserrat). The island of Montserrat has a warm and humid tropical climate, with temperatures constant throughout the year, the minimum average varies between 21°C and 24°C, while the maximum average varies between 28°C and 31°C, the trade winds mitigate temperatures. On the island there are two distinct seasons, the dry season between December and June and the rainy, humid and hot season, between July and November, the average annual rainfall is around 1,250-2,000 mm (www.colonialvoyage.com/america/.../montserrat/climate).

Agriculture

The agriculture sector continued to be affected by the lack of suitable land for farming and the destruction of crops. Prospects for the economy depend largely on developments in relation to the volcanic activity and on public sector construction activity. Twenty percent of total land area in Montserrat

is arable (www.answers.com/topic/montserrat). Agricultural production was greatly affected by the onset of volcanic activity in 1995. Between 1995 and 1997 all the major agricultural producing areas were either destroyed or deemed unsafe for habitation and by extension for crop farming and livestock rearing. One major result of volcanic activity, therefore, has been a decrease in agriculture's contribution to GDP from 5.4% in 1994 to approximately 1.1% in 1998, 0.7% was contributed by agricultural sector and 0.4% was contributed by the fisheries sector. The number of persons employed in agriculture also decreased from approximately 300 crop and livestock farmers and 160 full and part time fishers before 1995 to 150 and 60 farmers and fishers, respectively in 2000. The Government of Montserrat has directed its policy towards achieving self-sufficiency in certain foods and meat products in an effort to reduce the island's dependency on imports and the outflow of foreign currency. Emphasis is being placed on intensifying the rearing of small ruminants and pigs and facilitating poultry production for meat and eggs. Emphasis has also been placed on encouraging agro-processing ventures utilizing local raw materials (www.devunit.gov.ms/agrifish).

About pigeonpea

It has been recorded that there are four accessions identified in Montserrat (Upadhyaya 2007) and that pigeonpea is cultivated as a minor crop (Nene et al. 1989; Nyabyenda 1987; van der Maesen 1983, 1986). Pigeonpeas in this country are eaten like peas and have been grown in kitchen gardens or as a mixed crop.

Netherlands Antilles

Geography

The Netherlands Antilles, 11°36' N to 12°15' N latitude, 69°52'W to 70°13' W longitude covering a total land area of 960 km² are in the Caribbean Sea. It consists of two island groups, one including Curacao and Bonaire, just north of Venezuela, and the other east of the Virgin Islands (Figure 73). The Netherlands Antilles has 960 km² of land. Its only land boundary is with Guadaloupe on the island of Saint Martin, which is 10.2 km in length (en.wikipedia.org/wiki/Geography_of_the_Netherlands_Antilles). The Netherlands Antilles has a tropical maritime climate. Average annual precipitation is 560 mm on the leeward group of islands and 1,000 mm on the

windward group of islands. There is also a short rainy season from October to January. Average temperature ranges are from 24°C (76°F) to 32°C (90°F) all year (www.atlapedia.com/online/countriesnethanti).

Agriculture

Development of agriculture in Netherlands Antilles has been difficult because of poor soil and inadequate water supply. The result is a low contribution at 1% GDP of agriculture towards the economy of the country. However, about 10% of total land area is arable and can be used to cultivate existing crops such as aloes, sorghum, peanuts, vegetables and tropical fruit (www.gocurrency.com/countries/netherland_antilles).

About pigeonpea

Although identified by Nene et al. (1989), Nyabyenda (1987) and van der Maesen (1983, 1986) as a minor producing country for pigeonpea, there are no other supplemental literatures to support their claims.

Nicaragua

Geography

Nicaragua is the largest country in Central America. With geographic coordinates of 10°44' N to 14°56' N latitude, 83°35' W to 87°21' W longitude, the country borders both the Caribbean Sea and the North Pacific Ocean, between Costa Rica and Honduras (Figure 73). The country covers a total area of 129,494 km² (120,254 km² of which is land area) and contains a diversity of climates and terrains. The country's physical geography divides it into three major zones: Pacific lowlands, the wetter, cooler central highlands, and the Caribbean lowlands (en.wikipedia.org/wiki/Geography_of_Nicaragua).

Nicaragua has a tropical climate but is cooler in the highlands. Temperature varies little with the seasons and is largely a function of elevation. The tierra caliente, or the 'hot land', is characteristic of the foothills and lowlands from sea level to about 750 masl. Here, daytime temperatures average 30°C to 33°C, and night temperatures drop to 21°C to 24°C most of the year. The tierra templada, or the 'temperate land', is characteristic of most of the

central highlands, where elevations range between 750 and 1,600 m and daytime temperatures are mild (24°C to 27°C), and nights are cool (15°C to 21°C). Tierra fría, the ‘cold land,’ at elevations above 1,600 m, is found only on and near the highest peaks of the central highlands. Daytime averages in this region are 22°C to 24°C, with night time lows below 15°C (en.wikipedia.org/wiki/Geography_of_Nicaragua).

Rainfall varies greatly in Nicaragua. The Caribbean lowlands are the wettest section of Central America, receiving between 2,500 and 6,500 mm of rain annually. The western slopes of the central highlands and the Pacific lowlands receive considerably less annual rainfall, being protected from moisture laden Caribbean trade winds by the peaks of the central highlands. Mean annual precipitation for the rift valley and western slopes of the highlands ranges from 1,000 to 1,500 mm. Rainfall is seasonal; from May through October is the rainy season, and December through April is the driest period (en.wikipedia.org/wiki/Geography_of_Nicaragua).

Agriculture

Agriculture remained a robust and significant part of Nicaragua’s economy, although its growth slowed somewhat in comparison with the previous post-war decades. Statistics for the next fifteen years, however, show stagnation and then a drop in agricultural production. The nation’s relatively low population density and its wealth of land resources have both held the promise of solutions to poverty and been a major cause of it. In 1989, farm production declined by roughly 7% in comparison with the previous year. Production of basic grains fell as a result of Hurricane Joan in 1988 and a drought in 1989. By 1990 agricultural exports had declined to less than half the level of 1978. The only bright spot was the production of non-traditional export crops such as sesame, tobacco and African palm oil. Self-sufficiency in other dietary necessities was planned for the year 2000. For a variety of reasons, however, including the private sector’s retention of 60% of arable land, the government continued to import food and grow cash crops. The total agricultural land use of this country is estimated at 9% of arable land, with only 1% for permanent crops but 46% devoted to permanent pastures. In 1993, the goal of self-sufficiency in food production was still far from being achieved (en.wikipedia.org/wiki/Agriculture_of_Nicaragua).

The growth and diversification of the agricultural sector drove the nation's economic expansion. The importance of one or two crops has meant that the country's entire economy has undergone boom-or-bust cycles determined primarily by worldwide prices for agricultural exports. Coffee became the country's principal crop in the 1870s, a position it still held in 1992 despite the growing importance of other crops. Cotton gained importance in the late 1940s, and in 1992 was the second biggest export earner. In the early 1900s, Nicaraguan governments were reluctant to give concessions to the large banana companies of the United States, and bananas never attained the level of prominence in Nicaragua that they reached in Nicaragua's Central American neighbors; bananas were grown in the country, however, and were generally the third largest export earner in the post-World War II period. Beef and animal by-products, the most important agricultural export for the three centuries before the coffee boom of the late 1800s, were still important commodities in 1992 (en.wikipedia.org/wiki/Agriculture_of_Nicaragua).

About pigeonpea

From 1978 to 1982, a research program was initiated by the Tropical Agriculture Research and Training Center to increase crop production in low rainfall and near-drought areas of Costa Rica because agriculture in these areas had failed to provide minimum food requirements for rapidly increasing populations, largely due to a lack of suitable technology for land and water management and crop production. Pigeonpea was tested due to its drought-resistant characteristics under various conditions to be included in the cropping systems. The crop showed a considerable potential (www.catie.ac.cr). In this country, Upadhyaya (2007) states that there are four accessions that have no economic importance because it is cultivated as a minor crop (Nene et al. 1989; Nyabyenda 1987; van der Maesen 1983, 1986).

Aside from food, subsistence farmers of Nicaragua fight global warming by restoring forests and one of their strategies is to incorporate pigeonpea as cover crop to fertilize the soil prior to planting cedar and mahogany trees around the community's watershed (Sustainable Harvest International 2007).

Paraguay

Geography

Paraguay, with geographic coordinates of 19°18' S to 27°41' S latitude, 54°18' W to 62°34' W longitude, is a landlocked country situated in South America between Brazil, Argentina and Bolivia (Figure 72). The country, which straddles the Tropic of Capricorn and experiences both subtropical and tropical climates has a total area of 406,750 km² (land: 397,300 km² and water: 9,450 km²) (geography.about.com/library/cia/blcparaguay). Paraguay experiences a subtropical climate in the Paraneña region and a tropical climate in the Chaco. The Paraneña region is humid, with abundant precipitation throughout the year and only moderate seasonal changes in temperature. The Paraneña region has only two distinct seasons: summer from October to March and winter from May to August. April and September are transitional months in which temperatures are below the midsummer averages and minimums may dip below freezing. During the mild winters, July is the coldest month, with a mean temperature of about 18°C in Asunción and 17°C on the Paraná Plateau. Moist tropical air keeps the weather warm in the Paraneña region from October through March. In Asunción, the seasonal average is about 24°C, with January--the warmest month--averaging 29°C. During the summer, daytime temperatures reaching 38°C are fairly common. Rainfall in the Paraneña region is fairly evenly distributed. The least rain falls in August, when averages in various parts of the region range from 20 to 100 mm. The two periods of maximum precipitation are March through May and October to November. For the region as a whole, the difference between the driest and the wettest months ranges from 10 to 180 mm. The annual average rainfall is 1,270 mm, although the average on the Paraná Plateau is 250 to 380 mm higher. In contrast to the Paraneña region, the Chaco has a tropical wet-and-dry climate bordering on semi-arid. The Chaco experiences seasons that alternately flood and parch the land, yet seasonal variations in temperature are modest. Chaco temperatures are usually high, the averages dropping only slightly in winter. Even at night the air is stifling despite the usually present breezes. Rainfall is light, varying from 500 to 1,000 mm/year, except in the higher land to the northwest where it is slightly higher. Rainfall is concentrated in the summer months, and extensive areas that are deserts in winter become summer swamps. Rainwater evaporates very rapidly (en.wikipedia.org/wiki/Geography_of_Paraguay).

Agriculture

Paraguay is a net exporter of primary agricultural products such as soybeans, wheat, corn, sugar, tobacco, cotton, oilseeds, coffee and maize, but a net foodstuff importer. More than 80% of total consumption is brought in from outside (argentina.usembassy.gov/paraguay).

Maize was Paraguay's most rapidly growing food crop. Like manioc, maize was grown throughout the country and white corn was the traditional corn of Paraguay. Yellow high yield hybrids were increasingly common, especially on larger farms. Most corn went to domestic human consumption; roughly a third of domestic corn consumption took place in the form of feed grain for the livestock sector. Other principal food crops included beans, peanuts, sorghum, sweet potatoes and rice. Many types of beans are grown in Paraguay, including lima beans, french beans, and peas. Peanuts, a traditional though marginal crop, expanded in the 1970s and 1980s and often were intercropped with cotton. Peanuts were also processed as an oilseed. Sorghum, a drought-resistant crop, was grown primarily as feed for livestock and was considered a potential crop for the arid Alto Chaco (countrystudies.us/paraguay).

Paraguayans cultivated numerous fruits, vegetables and spices for both domestic consumption and export. Most common were citrus fruits, which were ideal for Paraguay's subtropical and tropical climate. Paraguay also produced pineapples, which according to some sources originated in Paraguay, and peaches, which were farmed commercially by fruit companies from the United States. Bananas, plums, strawberries, pears, avocados, guavas, papayas, mangoes, grapes, apples, watermelon, and other melons were cultivated to varying degrees as well. Vegetable production included gourds, squash, tomatoes and carrots. Onions and garlic were widely grown and commonly used in cooking (countrystudies.us/paraguay).

About pigeonpea

In Paraguay, specifically in San Rafael, Dept. Caazapá, the concept of conservation agriculture (CA) is being introduced to small-scale farmers. One of its strategies is through green manuring whereby pigeonpea is used as a mulch layer or soil cover. The plant is used solely as a green manure cover crop in a soil recovery process for the next crop, which is maize (<mailto:ca@ecoport.org>). Owens (2000) stated that in San Juan Nepomecia, 'kumanda

yvyra'l' or 'cumandái', a local name in this country for pigeonpea, is identified as a tree where the peas are eaten as food and is good as chicken feed. There are five accessions of pigeonpea identified in the country (Upadhyaya 2007), and it is cultivated as a minor crop (Nene et al. 1989; Nyabyenda 1987; van der Maesen 1983, 1986).

Peru

Geography

Peru, with coordinates of 18°13'S to 0°10'N latitude and 68°54'W to 81°7'W longitude, is located in the Southern Hemisphere, with 6,940 km of borders (Bolivia, Brazil, Chile, Colombia and Ecuador) (Figure 72). The total land area is 1,285,216 km². The climate is semi-arid in the valleys and moist in higher elevations and towards the eastern flanks. Rainfall varies from 200 to 1,500 mm/year. The rainy season starts in October and ends in April. The rainiest months are January through March. The western slopes are arid to semi-arid and receive rainfall only between January and March. Below the 2,500 m mark, the temperatures vary between 5 and 15°C in the night versus 18 to 25°C in the day. Between 2,500 and 3,500 m the temperatures vary from 0 to 12°C in the night and from 15 to 25°C during the day. At higher elevations from 3,500 to 4,500 m, the temperature varies from -10 to 8°C during the night and 15°C during the day (en.wikipedia.org/wiki/Geography_of_Peru).

Agriculture

Peru's climate and different geographical zones make it an important agricultural nation. Perhaps the most important fact about the agricultural sector is that its production has not kept up with the growth of population.

Peru has effectively a dual economy with a relatively modern sector on the coastal plains and a predominantly subsistence sector in the sierra. On the river valleys of the coastal desert where irrigation is present, the land is extremely fertile and excellent crops of cotton, rice, sugarcane and fruit are produced on the large agro-industrial estates. Newer crops such as asparagus and broccoli are also proving to be successful. South of Lima, the Ica valley has abundant vineyards. The expansion of agriculture in this region has been facilitated in part by the new land laws, which abolished previously strict limits to the amount

of land one person or group could own. There has also been a significant increase in the level of foreign investment in the agro export sector. The land of the sierra is generally of poor quality. Crops such as potatoes, corn, beans, *quinoa* and *ají* (hot peppers) are grown and llamas, alpacas and sheep are raised, all on predominantly subsistence plots. The northern department of Cajamarca is known for its dairy produce. In the selva, small-scale agriculture thrives along the riverbanks. However, there is the potential to develop production of crops such as rubber, jute, rice, tropical fruits and coffee. Only 3.2% of the land area of Peru is cultivated, while 21.2% is pastureland and 66.3% is forested. Agriculture represents 13% of GDP while approximately 30% of the economically active population works in agriculture (www.lab.org.uk; www.indexmundi.com/peru/agriculture_products).

About pigeonpea

Peru's native pigeonpea is called a 'bean' and is locally known as 'caja', 'puspo-poroto', and 'frijol de palo'. It is cultivated as a minor crop (Nene et al. 1989; Nyabyenda 1987; van der Maesen 1983, 1986) and there are 7 identified accessions in the area (Upadhyaya 2007). The crop is classified by Peru as a tree, which produces pods of up to 50 cm length containing seeds of 4 to 5 cm diameter. It grows between 1,550 to 2,500 meters above sea level. Pigeonpea is consumed in its fresh state; it has a white, delicate and delicious peel. It is used in homemade casseroles or added to soups, giving a rich texture. It has 20% proteins. The plant can yield up to 200 kg year of seed. Interestingly, the pigeonpea appeared beautifully painted on pre-hispanic ceramics of the cultures Moche, Chimu and Vicus, depicting a worship of the land (Alvarez 2008).

In 1986, the country imported around 84,916 kg (10% of total imports) of pigeonpea in its fresh form (Wright 1986). Aside from food, the crop is considered as herbal medicine for tribal minorities where the leaves are prepared in an infusion for anemia, hepatitis, diabetes, urinary infections, menstrual disorder and yellow fever. The flowers are prepared in an infusion for dysentery and menstrual disorders, and the seeds are infused to use as a diuretic (Duke 1983, Taylor 2005).

Saint Croix

Geography

Saint Croix, with geographic coordinates of 17°45'N, 64°45'W, is an island in the Caribbean Sea, a county and constituent district of the United States Virgin Islands (USVI), an unincorporated territory of the United States (Figure 73). It is the largest of the US Virgin Islands, being 45 km by 11 km. However, the territory's capital, Charlotte Amalie, is located on Saint Thomas. The island has an area of a little over 80,207 km². Most of the east end is quite hilly and steep, as is the north side from Christiansted west. From the north side hills, fairly even plain slopes down to the south coast; this was the prime sugar land on the island. The hills of the western part of the island receive more rain than the east end; annual rainfall is on the whole extremely variable, averaging 1,000 mm a year. Fairly severe and extended drought/has always been a problem, particularly considering the lack of fresh groundwater and lack of freshwater streams, rivers, or bays on the island (en.wikipedia.org/wiki/Saint_Croix).

Agriculture

Agriculture is an important economic force in St Croix. The county is a blend of rural and urban areas with a diverse agricultural economy. St. Croix farmers own and manage the resources on 125,525 ha of land comprising 67% of all land in the county, which includes pastures, cropland and tree farms and they implement various conservation practices to protect environmental resources and provide a habitat for wildlife.

St Croix County farmers produce a variety of products. Dairy, grain, cattle and calves, poultry and vegetables are the main commodities. Dairy generates the greatest gross income of the agricultural commodities. However, there are steadily growing grain, vegetable, green and nursery industries. The county also has a growing number of agricultural producers who market their products directly through roadside stands, farmers' markets, pick-your-own operations and retail outlets. A strong infrastructure of agribusinesses supports the agricultural sector, which provides jobs to 4,714 county residents (www.uwex.edu/ces/ag/wisag/documents/St_Croix).

About pigeonpea

St Croix is a minor producer of pigeonpea as attested by Nene et al. (1989), Nyabyenda (1987) and van der Maesen (1983, 1986). There is a high focus on agriculture at St Croix; there are a few farms and cattle. These farms don't produce enough to supply the general population. People grow various crops on a small scale for personal consumption. Pigeonpea is intercropped with pumpkin, potatoes and other ground provisions, limes, peppers, okra, lettuce, tomatoes, seasonings and local fruit trees like soursop, coconut, hog plums, mango, sugar apple, guava, papaya, avocado (www.vinow.com/wwwtalk; Mtvictorycamp.com).

Saint Kitts and Nevis

Geography

Saint Kitts and Nevis is very small for a country with geographic coordinates of 17°14'N to 17°20'N latitude and 62°37'W to 62°45'W longitude. Located in the Leeward Islands in the Caribbean Sea, it is a federal two-island nation in the West Indies, about one-third of the way from Puerto Rico to Trinidad and Tobago. To the north-northwest lie the islands of Saint Eustatius, Saba, Saint Barthelemy and Saint Martin. To the east and northeast is Antigua and Barbuda, and to the southeast are the small-uninhabited island of Redonda, and the island of Montserrat (Figure 73). It is the smallest nation in the Americas, in both area and population. Total land area is 261 km² (Saint Kitts 168 km², Nevis 93 km²). The smaller state of Nevis lies about 3 km southeast of Saint Kitts, across a shallow channel called 'The Narrows' (en.wikipedia.org/wiki/Saint_Kitts_and_Nevis; www.worldlanguage.com/Countries/AnguillaU.K).

The country has a tropical climate with average annual temperature of 26.7°C (80°F), tempered by constant sea breezes, and humidity is low (roughly 71%)., The rainy season extends from May to November (www.nationsonline.org/oneworld/saint_kitts_nevis).

Agriculture

Agriculture is the principal economic activity, although tourism is of increasing importance. Sugar and molasses are the chief products; fish, coconuts, rice,

yams, fruits and vegetables are also produced. Exports depend heavily on the production of sugar, which has dominated the agricultural landscape for the past 300 years (www.caribbeannetnews.com; www.ovayonda.net; www.nationsonline.org/oneworld/saint_kitts_nevis). Rising production costs, low world market prices, and the government's efforts to reduce dependence on sugarcane have led to a growing diversification of the agricultural sector (en.wikipedia.org/wiki/Saint_Kitts_and_Nevis).

About pigeonpea

Upadhyaya (2007) reported that 6 accessions of pigeonpea thrive in St.Kitts/Nevis/Anguilla. Although considered as a minor crop (Nene et al. 1989; Nyabyenda 1987; van der Maesen 1983, 1986), the local community has regarded pigeonpea as an important crop due to its high protein content. According to CARDI (1978), about 3 ha of pigeonpea were cultivated with a production of 1.5 t.

Saint Lucia

Geography

The second largest of the former West Indies Associated States, the avocado-shaped St Lucia having a coordinates of 13°47'N to 14°00'N latitude, 60°46'W to 60°54'W longitude lies between Martinique and St Vincent in the Windward Islands chain of the eastern Caribbean (Figure 73). It sprawls over a total area of 616 km², covered with dense tropical flora, such as hibiscus, frangipani, orchids, jasmine and Poinciana (www.oasismarigot.com/aboutstlucia). St Lucia has a tropical, humid climate moderated by northeast trade winds that allow for pleasant year-round conditions. Mean annual temperatures range from 26°C to 32°C at sea level and drop to an average of 13°C in the mountain peaks. The abundant annual rainfall accumulates to approximately 1,520 to 2,000 mm, with most precipitation occurring during the June to December wet season (www.onlinelearning.net/instructors/smurr/LatAm/Carib/stlucia).

Agriculture

Traditionally dependent on agriculture, St Lucia was dramatically transformed in the 1960s from a sugar-based economy to banana production. This

trend improved the economic situation of the small farmer because banana crops, unlike sugar, could be produced on small plots. Fertile land holdings, which support banana farming, are scattered throughout the island (www.onlinelearning.net/instructors/smurr/LatAm/Carib/stlucia).

Saint Lucia's economy depends primarily on revenue from banana production and tourism with some input from small-scale manufacturing. There are numerous small- and medium-sized agricultural enterprises. Revenue from agriculture has supported the noticeable socioeconomic changes that have taken place in St Lucia since the 1960s when 80% of merchandise trade earnings came from banana exports to the United Kingdom. In view of the European Union's announced phase-out of preferred access to its markets by Windward Island bananas by 2006, agricultural diversification is a priority. An attempt is being made to diversify production by encouraging the establishment of tree crops such as mangoes and avocados. A variety of vegetables are produced for local consumption (en.wikipedia.org/wiki/Economy_of_Saint_Lucia).

About pigeonpea

Although there are 17 accessions thriving in the country (Upadhyaya 2007) pigeonpea is regarded as a minor crop (Nene et al. 1989; Nyabyenda 1987; van der Maesen 1983, 1986). In 1978, only one hectare was recorded planted with pigeonpea by CARDI.

Saint Thomas

Geography

Saint Thomas is located 128.75 km east of Puerto Rico with geographic coordinates of 18°13'N to 18°20'N latitude, 64°49'W to 64°57'W longitude. Saint Thomas is an island in the Caribbean Sea, a county and constituent district of the United States Virgin Islands (USVI), an unincorporated territory of the United States (Figure 73). The district/has a land area of 80.9 km² (en.wikipedia.org/wiki/Saint_Thomas,_U.S._Virgin_Islands). Located inside of twenty degrees from the equator, St Thomas' weather is characterized by lots of sun and warm Caribbean breezes. The county weather is truly tropical, tempered by easterly trade winds, relatively low humidity, and has little seasonal temperature variation – an annual average temperature in the

high twenties (about 30°C) varies little between seasons, keeping winter months hot and sunny though slightly less humid than summer. The weather is best from late November through early April, (the high season for tourism), and becomes increasingly warm during the following months. St Thomas weather does not include an extensive rainy season (May to November) and any showers that do occur are generally short (st-thomas.caribbeanway.com/weather; www.caribbeaninspired.com/caribbean/destination/st-thomas).

Agriculture

St Thomas weather is ill-suited to agriculture, that's why it contributes only 1% of GDP to the economy of the county (thomas.caribbeanway.com/weather.asp). The agricultural sector is small contributing to only 1% of labor force. Most crops cultivated for local consumption are fruits, vegetables and sorghum and senepol cattle for livestock. St Thomas largely imports food products to sustain its food requirement domestically and for tourists. Tourism is the primary economic activity, accounting for 80% of GDP and employment (worldfacts.us/Virgin-Islands).

About pigeonpea

According to Nene et al. (1989), Nyabyenda (1987) and van der Maesen (1983, 1986), pigeonpea is grown as a minor crop in St Thomas. Like St Croix, pigeonpea is cultivated in association with sweet potatoes, okra, eggplants, pumpkins or dumplings. Traditional dishes are served with seasoned rice, pigeonpeas, sweet potatoes or plantains (www.culturegrams.com).

Saint Vincent and the Granadine

Geography

Saint Vincent is 29 km long and 18 km wide with a total land area of 363 km², and is located 161 km west of Barbados (Figure 73). The island is mountainous and well forested, and is dominated by the volcano Mount Soufrière that rises 1,234 m. The country is situated 13°4'N to 13°15'N latitude, 61°12'W to 61°20'W longitude in the Caribbean, north of Trinidad and Tobago (www.scholars.nus.edu.sg/post/caribbean/stvincent/geography). The islands enjoy a pleasant tropical climate all year round, with a yearly average temperature of 26°C (79°F). The warmest month is September,

with an average temperature of 27°C (81°F); the coolest is January, with an average temperature of 25°C (77°F). The average yearly rainfall on St Vincent is 2,310 mm, but in the mountainous areas the average rainfall is more than 3,800 mm a year. May or June through December is the rainy season (www.nationsencyclopedia.com/.../St-Vincent-and-the-Grenadines-CLIMATE).

Agriculture

Saint Vincent's climate is well suited to agriculture, which is an important part of the economy. Tourism is also economically important. The main trading partners are the United States and France (www.infoplease.com).

Agriculture, which employs 26% of the labor force, is dominated by banana production, the most important sector of this lower middle-income economy. Bananas, taro and arrowroot are the chief agricultural exports. Aside from these crops, coconuts, sweet potatoes, spices, cattle, sheep, pigs, goats and fish are locally consumed. The continuing dependence on a single crop represents the biggest obstacle to the islands' development due to tropical storms. However, the contribution of agriculture in the economy of this country is recorded at 12% of GDP. Permanent crops at 18%, arable land at 10% dominated agricultural land use while permanent pastures is estimated at 5% of total land area of St Vincent (www.scholars.nus.edu.sg/post/caribbean/stvincent/geography).

About pigeonpea

Pigeonpea is cultivated as a minor crop in St Vincent (Nene et al. 1989; Nyabyenda 1987; van der Maesen 1983, 1986), and 22 accessions have been recorded (Upadhyaya 2007). These accessions have been the source of food and medicines for peasant farmers in the country. In 1978 (Caribbean Agricultural Research and Development), the total area for pigeonpea was estimated around 218 ha with a total production of 196.5 t with a productivity level of 900 kg/ha.

As globalization began to have a significant impact on Caribbean Agriculture and traditional secured markets for traditional plantation crops such as sugarcane, banana, rice, cocoa, coffee and coconut began to run out, regional agricultural producers realized that they had to become more

efficient in order to remain competitive. It was recognized that a good alternative in St Vincent would be non-traditional crops such as pigeonpea in which the country has a comparative advantage in the domestic, regional and international marketplace. In a workshop conducted by CARDI in August 2000, the country identified pigeonpea as one of the priorities for agricultural research and development because of its economic, social, institutional and environmental importance (Paul 2001).

Suriname

Geography

Suriname was formerly known as *Nederlands Guyana*, Netherlands Guiana or *Dutch Guiana*. With geographic coordinates of 1°50'N to 5°47'N latitude, 53°52'W to 58°16'W longitude, Suriname is situated between French Guiana to the east and Guyana to the west. The southern border is shared with Brazil and the northern border is the Atlantic coast (Figure 73). The country is the smallest sovereign state in terms of area (163,270 km²) and population in South America and is the only independent Dutch-speaking nation in the Western Hemisphere (Aruba and the Netherlands Antilles are still Dutch dependencies). Lying on the equator, Suriname has a very hot tropical climate, and temperatures do not vary a lot throughout the year. The year has two wet seasons, from April to August and from November to February. It also has two dry seasons, from August to November and February to April (en.wikipedia.org/wiki/Suriname).

Agriculture

Agriculture is one of the contributors of economic activity in Suriname. The total arable land recorded is 36% of total landmass while permanent crops are less than 6%. Agricultural products grown are paddy rice, bananas, palm kernels, coconuts, plantains, peanuts; beef, chickens and shrimp (worldfacts.us/Suriname).

About pigeonpea

Pigeonpea has been grown as a minor crop in Suriname (Nene et al. 1989; Nyabyenda 1987; van der Maesen 1983, 1986) but no accession has been identified in the area. *Wandoe*, a local name of pigeonpea in the country,

aside from being a subsistence crop for small-scale farmers, has been used as a medicinal plant to cure numerous illnesses. The leaf infusion is consumed for pulmonary conditions such as coughs and bronchitis. The leaf juice is used for haemorrhages and the leaf is decocted for washing ulcers. When the leaves are mixed with *Dactyloctennum aegyptnum*, this is used to accelerate childbirth. The leaves are used in a complex liquid with *Plectranthus*, cloves and 'steel drops' for venereal disease. When the leaves are boiled, this is applied to sores and wounds to hasten cicatrisation. The shoots and green pods are used for a good pectoral infusion and the leaves or pods boiled with salt and 'steel drops' (ferric chloride solution) are used for treating leucorrhea. Leaves or pods infusion are good for fever-baths and headaches. Leaves or pods macerated/ground are used for antiperspirants or deodorants while the leaf and flower when boiled is used as a diuretic and a diabetes remedy. The flower is pectoral, seeds for diuretic and the flour from seeds is resolute (MedPlantsGui2).

Turks and Caicos Islands

Geography

The Turks and Caicos Islands (TCI) are a British Overseas Territory consisting of two groups of tropical islands in the West Indies, the larger Caicos Island and the smaller Turks Islands known for tourism and as an offshore financial centre. These two islands are located southeast of the Bahamas, north of Haiti, and 914 km from Miami in the United States, at 21°27'N to 21°45'N latitude, 71°35'W to 72°30'W longitude (Figure 73). The islands with a total land area of 430 km² are geographically contiguous to the Bahamas, but are politically a separate entity. The climate is tropical, moderated by trade winds and is sunny and relatively dry, however suffers frequent hurricanes (www.indexmundi.com/turks_and_caicos_islands; en.wikipedia.org/wiki/Turks_and_Caicos_Islands).

Agriculture

The largest island in the Turks & Caicos chain, Middle Caicos has an area of 124 km². However, Middle Caicos is also the least populated island with less than 300 residents. It is a lush island suitable for agriculture. From medicinal herbs to majestic fruit trees, Middle's form of agriculture is a cultural feast to behold: Cassava, okra and guava, tamarinds, *sapidillas* and sugar apples,

to name just a few. But the cornerstone of their crops is maize. Home grown and home ground, they use the pearly hearts to make their fabulous grits (www.turksandcaicos.tc/middlecaicos/index). The primary agricultural products include maize, beans, cassava (tapioca), citrus fruits and fish. Most capital goods and food for domestic consumption are imported from United States and the United Kingdom (www.wikinfo.org/index.php/Turks_and_Caicos_Islands).

About pigeonpea

Pigeonpea is grown as a minor crop in Turks and Caicos Islands (Nene et al. 1989; Nyabyenda 1987; van der Maesen 1983, 1986). Today the inhabitants grow maize and pigeonpeas for their own consumption and subsistence farming (world66.com; depstc.org). The popular local dish includes, amongst others, pigeonpeas and rice (www.caribbeannetnews.com).

United States of America

USA is a federal constitutional republic comprising of fifty states and a federal district. Map of America plots all 50 states and the Federal District of USA, which combine to form one of the technologically advanced, economically rich and powerful nations of the world. USA is the third largest country in the world having a total area of 9,826,630 km², which includes 9,161,923 km² of land area and 664,707 km² of water bodies (Figure 74).

American agriculture is marked by several trends. The first is the continuing decline of small family farms. About two-thirds of the states have had deep reductions in agriculture. Agriculture has declined most significantly in the New England states and New Jersey. In the west and southern plains, some states have had minor declines, while others have had small increases. The only regions of the nation that have seen major expansion of agriculture have been the middle-Atlantic area and the Pacific Northwest. The states with the largest increases in output were Arkansas, Washington, Delaware, Florida and Georgia. Since 1979, 121,408 ha of small farms have disappeared in the United States, and since 1946 the number of people employed in agriculture has been cut in half. Increasingly, large companies have come to dominate American agriculture. Almost 91% of US farms are considered to be small (less than 405 ha). Large farms (more than 405 ha) made up just 9% of farms in 2000. The second trend is the increasing productivity of the sector.



Figure 74. Map of the United States of America.

Agricultural production in the United States has increased by an average of 5% each year since 1990. In addition, the output of each agricultural worker has grown by an average of 0.84% each year. On average, one American farmer produces enough food for 96 people. This improvement is partially as a result of the consolidation of farms and partially a result of new technologies and farming methods. The third trend is the growth in both exports and imports. In 1998, total agricultural exports were \$60.5 billion. That same year, total imports were \$48.9 billion. The fourth and final trend is the loss of agricultural subsidies. Some of these subsidies are in the form of outright payments in exchange for farmers not growing certain crops and are provided to keep the price of crops high (United States Department of Agriculture 2007).

About 40% of the land in the United States is used for agriculture, including livestock grazing. This includes 174.5 M ha of cropland, 160.6 M ha of pasture, and 29 M ha of forests. The largest single crop was maize, which accounted for more than half of the nation's crop output with 247,882,000 Mt. The second largest crop was soybean with 74,598,000 Mt. Wheat is third with 69,327,000 Mt. Other major crops include sugarcane, sugar beets, potatoes, bananas and coffee. Tobacco also provides substantial cash returns, although yields are small when compared with many other crops. Progress in technology and crop yields has made the United States among the most productive agricultural producers in the world. The United States produces about/half of the world's maize and 10% of its wheat. It also accounts for 20% of the globe's beef, pork and lamb. With such progress in increasing output and the efficiency of agriculture, food prices for American consumers have had little increase over the past 20 years (United States Department of Agriculture 2007).

Agriculture production in the southern United States is becoming increasingly challenged by drought conditions. Rainfall quantities and distribution have become more erratic. This creates a challenge for both grain and livestock farmers. Crop yields and forage production can be very good during a year with abundant rainfall, but severely reduced during drought periods. Therefore, there is a need for crops that are drought tolerant and that can also be used for both livestock and human consumption.

About pigeonpea

In the US, pigeonpea is grown as a minor crop with four identified accessions (Nene et al. 1989; Nyabyenda 1987; van der Maesen 1983, 1986) with erect, short-lived shrubs, attaining a height of six to eight feet. Pigeonpea is deep rooted and drought resistant, growing especially well on semi-arid systems. It has poisonous roots, and therefore often planted as a hedge around some crops, such as cassava, to keep out mole rats. There is a potential market in the US for pigeonpeas as fodder, because the pods, seeds and leaves are excellent fodder for cattle. It is also widely used for hay and silage (often with molasses), especially the small-seeded varieties. If cut for hay and when the pods are well developed, the crop should be cut successively higher. The ground seeds can be incorporated as a source of protein in poultry rations (Payne 1998).

Pigeonpea is a common leguminous crop in many countries outside the United States, but it is virtually unknown in the southern US. Pigeonpea has many traits that could make it a useful crop in southern farming systems. It is very drought tolerant due to a large tap root system. It is also able to efficiently use soil nutrients, so it does not require significant fertilization. In addition to its drought resistance, this crop has many potential end-uses. The foliage can be used as a source of forage for cattle or other livestock. The immature green pod and the dried bean can be harvested for human consumption. Pigeonpea is a major staple for Indian and Latin American cultures, two rapidly increasing segments of the population in the southern United States. Pigeonpea is also an excellent cover crop for compacted soils because after harvest, the large decaying taproot opens channels for water movement into the soil. The objective of this research, demonstration and education proposal is to incorporate pigeonpea into farming systems in the Southern United states and to identify plant varieties and planting strategies that ensure a successful farming system (Sloan 2007).

Migrants from these regions who reside in the United States still favor this legume in their diet. Except for Hawaii and Puerto Rico, the pigeonpea is not commercially grown in the US. Although a tropical crop in the Southern Great Plains of the US, pigeonpea production is considered a second crop in a continuous winter wheat production system. The pigeonpea is a weak perennial but performs as an annual where it is killed by freezing temperatures. Grain production has to occur between early spring to early fall and requires a

long growing season. Mixed crop/livestock production systems are common in the small and medium-sized farms of tropical America,

Pigeonpea research initiatives

A pigeonpea cultivar named 'Norman' was released by the North Carolina Experiment Station as a green manure crop, but it has disappeared from seed trade. The experimental pigeonpeas, 76 WW and 99 WW, are the result of a pigeonpea developmental program started in 1976 to develop an adapted pigeonpea cultivar for grain production. 96 lines were obtained from two pigeonpea crosses received from ICRISAT. In 1977, three additional pigeonpea populations were obtained from the University of West Indies, Trinidad. Other pigeonpea accessions were obtained from USDA Plant Introductions. Individual plants and lines were selected for earliness, large seed size and high seed yields, and in later years for light-colored seed coat. Besides selective breeding, various management and seed production trials with various selected pigeonpea lines and populations have been conducted over the years at Gainesville. In recent years, three selected populations, FL 76WW, FL 99WW and FL DO, were evaluated at Florida A&M University at Tallahassee.

Grain yields of pigeonpea lines at Gainesville have varied from 340 to 3,360 kg/ha with most grain yields falling between 1200 and 2000 kg/ha. Pigeonpea yields are not consistent from year to year or location to location. Fall freezes have killed pigeonpea or reduced seed yield and are the reason for the slow development of the crop. In 1996, grain yields at Tallahassee when harvested at the mature green and dried stages were 3,220 and 1,180 kg/ha for FL 76WW, 2,640 and 1,470 kg/ha for FL 99WW and 2,270 and 1,080 kg/ha for FL DO, respectively. Pigeonpeas are a promising home-garden and U-pick vegetable harvested at the mature green pod stage. They are shelled by hand or with a commercial pea sheller. Pigeonpeas are day length sensitive requiring day lengths under 12.5 h for best flowering and seed production. Date of planting has great effect on plant size, earlier planted plants being largest. Planting date may affect grain yields but varies from season to season. June is the best time to plant for combine harvesting for grain but earlier plantings in late April or May are best for home-garden and U-pick operations as a vegetable.

Nematodes, insects and diseases attack pigeonpeas. Rotations and insecticides for controlling insects like corn earworm and stinkbug on flowers

and seedpods are usually all that is needed for successful production. Pigeonpeas are very drought resistant and produce seed where other grain legumes will fail. Pigeonpeas are resistant to most root-knot nematodes but are susceptible to the peanut root-knot nematode *Meloidogyne arenaria* race 1. It is recommended that pigeonpeas not be planted in rotations with other grain legume crops. Pigeonpea will grow on well-drained soils with a wide range of textures and pH. Pigeonpea is a new warm season grain legume for the area on well-drained soils. The availability of land with an excellent climate and several adapted rapid growing bioenergy crops makes the Humid Lower South a likely area for development of bioenergy industries (Prine and French 1999).

Florida

Geography

Florida is the 22nd largest of the 50 states covering 170,312 km². The state is located 25°14'N to 28°32'N latitude and 80°90'W to 82°52'W longitude bordering Georgia and Alabama to the north. On the west, Florida is bordered by Alabama and the Gulf of Mexico. To the south and to the east, Florida is surrounded by the Atlantic Ocean (Figure 74). Part of three geographic land areas makes up the Florida landscape, namely, the Atlantic Coastal Plain, the East Gulf Coastal Plain and the Florida Uplands.

Florida's unique subtropical climate makes it one of the nation's leaders in many industries, and agriculture is no exception. Monthly average temperatures range from a high of 91.7°F to a low of 39.9°F. Plentiful rainfall, rich organic soils and warm temperatures throughout the year create an ideal setting for abundant growth in Florida.

Agriculture

Florida has 43,000 commercial farms having an estimated land area of 4.1 M ha with an average farm size of 95 ha (USDA: National Agriculture Statistics Service 2004). About half of Florida's land area is used in agriculture. Agriculture is the largest water user using 48% of the total freshwater withdrawals from ground and surface water (Florida Agriculture and Water Use 2000).

Over 75% of Florida's total agricultural production falls into the crops group, with greenhouse and nursery products leading the way. Very important crops are oranges, sugarcane and tomatoes followed by grapefruit. Cattle and calves and dairy products are Florida's most important sources of revenue in the livestock and livestock products group. Broilers and eggs follow, with Florida aquaculture (aquarium fish, aquatic plants, shellfish, alligators, catfish, tilapia and hybrid striped bass) rounding out the top five commodities in the livestock group (USDA 2004).

Florida's agriculture industry is second only to its tourism industry. Florida is the top producer in the nation of citrus and sugarcane; second in greenhouse and nursery products, tomatoes, strawberries and aquaculture products and third in honey. Aside from citrus and sugarcane, the main crops grown in Florida are tomatoes, green peppers, strawberries, snap beans, sweet corn and cucumbers. Livestock is also a major sector of Florida agriculture; sales of beef, dairy, poultry and eggs total \$1.24 billion (Florida Agriculture and Water Use 2000).

Agricultural limitations

Most of such problems center on runoff from fertilized lands and the resulting build-up of phosphorus and nitrogen in water bodies. Pollution from agriculture is classified as 'non-point source' pollution, which is not nearly as regulated as 'point source' pollution. Phosphorus that drains from the Everglades Agricultural Area has been determined to be the primary cause of algal blooms in Lake Okeechobee. In a 1994 report by the Environmental Protection Agency (EPA), agriculture was determined to be the leading cause of water quality impairment in the nation's rivers and lakes. The same study found that 49 states report groundwater contamination by nitrates, and 43 states report contamination by pesticides, thus leading the EPA to conclude that agriculture is the leading cause of groundwater pollution.

Florida agriculture is vulnerable to changes in water supply. During the dry season crops require the addition of water (irrigation). Conversely, during the wet season agriculture requires flood control (especially in Florida) to prevent crop and land damage. Aquatic plant management is essential in times of both drought and flooding and is supported by farmers. Moreover, there is not enough land left in Florida for agriculture expansion. In Florida, land is either set aside for conservation, or it becomes part of the 60,703

ha/year of productive farmland that is lost to urban development (Florida Agriculture and Water Use 2000).

About pigeonpea

Florida's experimental pigeonpeas, 76 WW and 99 WW, are the result of a pigeonpea developmental program started in 1976 to develop adapted pigeonpea cultivars for grain production. 96 lines were obtained from two pigeonpea crosses received from ICRISAT. In 1977, three (3) additional pigeonpea populations were obtained from the University of West Indies, Trinidad and the USDA Plant Introductions. Individual plants and lines were selected for earliness, large seed size, and high seed yields, and in later years for light-colored seed coat. Besides selective breeding, various management and seed production trials with various selected pigeonpea lines and populations have been conducted over the years at Gainesville. In recent years, three selected populations, FL 76WW, FL 99WW and FL DO, were evaluated at Florida A&M University at Tallahassee (Prine and French 1999).

According to Prine and French (1999), grain yields of pigeonpea lines at Gainesville vary from 340 to 3,360 kg/ha with most grain yields between 1,200 and 2,000 kg/ha. Pigeonpea yields are not consistent from year to year or location to location. In 1996, grain yields at Tallahassee when harvested at the mature green and dried stages were 3,220 and 1,180 kg/ha for FL 76WW, 2,640 and 1,470 kg/ha for FL 99WW and 2,270 and 1,080 kg/ha for FL DO, respectively. The reported biomass yield of pigeonpea is 7 MT/ha with estimated total nitrogen available of 250 lb/acre (113.4 kg/ha) during the summer planting.

Pigeonpeas are day length sensitive requiring less than 12.5 hours for best flowering and seed production. Date of planting has great effect on plant size, earlier planted plants being largest. Planting date may affect grain yields but varies from season to season. June is the best time to plant for combine harvesting of grain, and earlier plantings in late April or May are best for home-garden and U-pick operations as a vegetable (Prine and French 1999).

Pigeonpea research

Ground covers offer advantages and disadvantages when incorporated into agricultural production systems. Leguminous cover crops can contribute to increased and sustainable crop productivity through erosion and weed control, biological nitrogen fixation, and by providing refuge for natural enemies of arthropod pests (Hokkanen 1991).

A major concern of Florida citrus producers is the highly polyphagous Diaprepes root weevil, *Diaprepes abbreviatus* (L.) (Simpson et al. 1996). Cover crops should not harbor key pests and may be selected to divert or deter pests and contribute to the diversity and abundance of natural enemies (Altieri 1995, Risch 1981). Pigeonpea has been reported to be attractive to *D. abbreviatus* (Barrow 1924). According to a study conducted by Lapointe (2003), *Cajanus cajan* (pigeonpea) was a superior host for development of *D. abbreviatus*. *C. cajan* appeared to be allelopathic; the root mass of non-infested citrus was greatly reduced when grown in association with *C. cajan* compared with citrus grown alone. Thus, *C. cajan* appears to be particularly inappropriate as a cover crop because of its positive effect on larval growth and reduction of citrus root mass.

Oklahoma

Geography

Geographically located 33°43'N to 36°6'N latitude and 94°44'W to 100°1'W longitude, the Geography of Oklahoma is among the most diverse in the United States, encompassing terrain and ecosystems ranging from arid plains to subtropical forests and mountains . Oklahoma (Figure 74), with land area 181,048 km², making it the 20th largest of the 50 states, is a land of flat, fertile plains and low hills. Oil and natural gas wells can be seen throughout much of the state. Oklahoma's plains also host large herds of cattle and vast wheat fields. The geographical landscape of Oklahoma is comprised of 10 separate land regions (Carpenter and Provorse 1998).

Oklahoma is situated in a temperate continental climate between regions of differing prevailing winds, making its weather widely different between relatively short distances. Much of the state is often subjected to extremes in temperature, wind, drought and rainfall. Precipitation and temperatures

fall from east to west accordingly, with areas in the southeast averaging an annual temperature of 62°F (17°C) and an annual rainfall of 1,420 mm, while areas of the panhandle average 58°F (14°C), with an annual rainfall under 430 mm. All of the state frequently experiences temperatures above 100°F (38°C) or below 0°F (-18°C) (Derek 2003).

Agriculture

Agriculture remains one of Oklahoma's largest employment industries. The agriculture industry supplies Oklahoma with important food and non-food products. Moreover, Oklahoma agriculture in the 21st century is much more than beef and wheat. Crops and livestock that were once relatively small in terms of production have grown dramatically in recent years. For example, poultry and swine, respectively, are the second and third largest agricultural industries and Oklahoma is now one of the top states in their production. From the arid High Plains of the panhandle to the forests of southeastern Oklahoma, there aren't many North American crops *not* grown in the state. Fields of wheat and corn are next-door neighbors to vineyards and organically grown specialty crops (Oklahoma Department of Agriculture, Food and Forestry, modified 2008).

About pigeonpea

The main purpose of growing pigeonpea in Oklahoma is its use as forage for cattle. Forage-based livestock production is a significant component of the agricultural economy throughout the southern US Great Plains. However, livestock production in grazing systems is limited by low forage mass and quality from late July to early November. The primary forage resources for livestock production in the Great Plains are winter wheat during early winter and spring, and perennial grasses during spring and summer. But high-quality forage is often scarce from late July through late November, because the quality and quantity of grasses decline and winter wheat forage is not yet available. Livestock producers across the Great Plains could have the benefits of nutritious forages year round with the introduction of pigeonpea. Since no single crop has the potential to provide year-round forage, identifying new forage species that can be grown when others aren't productive makes pigeonpea an important alternative crop (Pons 2002, Arnold 2002).

Rao et al. (2003) found that pigeonpea has the potential to fill a gap in forage availability that affects livestock farms between late summer and fall. In his three years of study, research showed that pigeonpea yields and nutritive values during the summer equalled or exceeded those of other forage crops reported for this region. Early maturing pigeonpea lines can fill the forage deficit period during late summer fallow period of continuous winter wheat production and provide protein supplement for livestock in the southern Great Plains. In addition to this, Cantrell et al. (2001) revealed that diets containing pigeonpea, cotteed meal or alfalfa as the primary source of protein had similar digestion coefficients. Lambs fed with a diet containing pigeonpeas as the primary protein source has gained weight more rapidly than lambs fed with cotteed meal. From these data we concluded that raw, cracked pigeonpeas could be used as a dietary protein source for young ruminants. Likewise, pigeonpea could add to other potential benefits to the farmer, which would include lowered costs of livestock production, improvements in soil fertility, and reduced vulnerability of soils to erosion by wind and water during the summer fallow period between winter wheat crops (Rao et al. 2003).

The two early-maturing varieties, Georgia-2, developed at the University of Georgia, Tifton, GA; and ICPL 85010, which was developed at ICRISAT, Patancheru, Andhra Pradesh, India, did not differ significantly in forage and grain production and nutritive value. At final harvest (118 DAP), total dry biomass was 12.6, 6.4 and 9.3 t/ha in 1996, 1997 and 1998, respectively, while seed yield was 5.4, 1.9 and 1.2 t/ha in 1996, 1997 and 1998, respectively. Nitrogen concentration and in vitro digestible dry matter (IVDDM) at final harvest was 19 and 585 g/kg for total plant biomass, 34 and 758 g/kg for leaves, 9 and 420 g/kg for stems, and 26 and 750 g/kg for seed, respectively. These results show that pigeonpea has the potential to produce moderate-quality forage during the forage-deficit period from August through October when the quality and quantity of perennial warm-season grasses typically decline.

In addition, Rao et al. (2003) revealed that early maturing pigeonpea lines also have the potential to produce grain in the southern Great Plains. Seed yields of up to 5 t/ha represent a significant advantage of early maturing pigeonpea lines over medium - to late-maturing lines because high-quality seed can be harvested and fed as a protein supplement for livestock. A growing season of only 118 days, ending in mid-October, allows the opportunity to grow pigeonpeas to maturity between winter wheat crops.

Medium- and late-maturing varieties require 200 to 220 days to mature, and many of these had not even flowered by the time wheat should have been planted. At final harvest, early maturing pigeonpea had sufficient herbage present with moderate quality that should provide sufficient post-harvest grazing. This finding is in collaboration with Philips and Rao (2001), where pigeonpea grain from early maturing line GA-2 can be used as a protein supplement for livestock.

Oregon

Geography

Oregon, a state divided by mountains, is located in Crook County, 40 km south-southeast of Prineville, 42°5'N to 46°4'N latitude and 116°58'W to 124°11'W longitude. Washington borders Oregon on the north and California and Nevada on the south. On the east, Oregon is bordered by Idaho and on the west, by the Pacific Ocean (Figure 74). Oregon covers 254,819 km², making it the 9th largest of the 50 states. The Cascade Mountains stretch across the entire north/south length of Oregon, producing areas with two entirely different climates. The monthly average temperatures range from a high of 82.6°F to a low of 32.8°F (Carpenter and Provorse 1998).

Oregon's climate, especially in the western part of the state, is heavily influenced by the Pacific Ocean. The climate is generally mild, but periods of extreme hot and cold can affect parts of the state. Precipitation in the state varies widely: the deserts of eastern Oregon, such as the Alvord desert, get as little as 200 mm annually, while some western coastal slopes approach 5,000 mm annually. Oregon's populated areas, which lie mostly in the western part of the state, are generally wet and soggy, while the high deserts of Central and Eastern Oregon are much drier.

Agriculture

Oregon is one of four major world hazelnut growing regions, and produces 95% of the domestic hazelnuts in the United States. While the history of the wine production in Oregon can be traced to before wine became a significant industry beginning in the 1970s. In 2005, Oregon ranked third among US states with 303 wineries. Due to regional similarities in climate and soil, the grapes planted in Oregon are often the same varieties found in the French

regions of Alsace and Burgundy. In the northeastern region of the state, particularly around Pendleton, both irrigated and dryland wheat is grown. Oregon farmers and ranchers also produce cattle, sheep, dairy products, eggs and poultry (en.wikipedia.org/wiki/Oregon#Geography).

About pigeonpea

Because of growing economic and environmental concerns over traditional wheat-based cropping system rotations, there has recently been heightened interest in alternative rotation crops like wheat-pigeonpea in the inland Pacific Northwest. Research has shown for years that the winter wheat/summer fallow rotation, which constitutes the major cropping system in northeastern Oregon, promotes soil organic matter decline and soil erosion. There is a growing perception that there is a need to move on to cropping rotations, which reduce or eliminate fallow, while maintaining or perhaps even increasing profitability (Payne 1998). Payne, likewise, noted that there is a potential market in the US for pigeonpeas as fodder and food because the pods, seeds and leaves are excellent fodder for cattle and food for the increasing Indian population, respectively. The crop is also widely used for hay and silage (often with molasses), especially the small-seeded varieties. If the plant is cut for hay when the pods are well developed, it should be cut successively higher. In addition, the ground seeds can be incorporated as a source of protein in poultry rations. Despite the low yields for pigeonpea and soybeans, the study demonstrated that both these species were able to emerge during the cool spring, and to survive the dry and hot period in late July and August. At Pendleton, pigeonpea has uncharacteristically small size, poor groundcover and an apparent photoperiod response, suggesting that this particular variety was unsuited to the conditions. Nonetheless, the crop continued to flower and its leaves remained turgid throughout the hot season, suggesting there may still be scope for considerable improvement with this crop.

Virginia

Geography

Virginia, a southern state on the Atlantic Ocean, can be divided into five geographical regions: the Atlantic Coastal Plain, the Piedmont, the Blue Ridge, the Appalachian Ridge and Valley Region, and the Appalachian

Plateau. Located at latitude 37°34'N to 39°46'N and longitude 78°50'W to 83°45'W, it is the 35th largest of the 50 states covering 110,771 km² (Figure 74) (www.netstate.com/states/geography/va_geography). Virginia has a temperate climate – a ‘humid, sub-tropical’ climate. Monthly average temperatures range from a high of 88.4°F to a low of 26.2°F with average annual rainfall of 1,085 mm (www.virginiaplaces.org).

Agriculture

Virginia has 47,100 farms covering 3.4 M ha (34% of Virginia’s total land area), which supports the livestock and agricultural products. In 2007, tomatoes replaced soybeans as Virginia’s number one cash crop. Nationally, Virginia ranks third in the production of fresh market tomatoes. The majority of corn grown in Virginia is for grain. Virginia corn feeds the commonwealth’s poultry, equine, dairy and cattle industries. Tobacco is now Virginia’s third ranked cash crop and tenth ranked commodity. Throughout the rest of the 17th century, laws were enacted to force tobacco planters to grow some corn and wheat, in the interest of ensuring an adequate food supply. Hay is an important crop to Virginia’s livestock industries where 501,810 ha of hay was harvested at a value of \$43.6 million in 2006. Cotton ranked fifth as Virginia’s cash crop in 2006. Cotton is a drought resistant plant (www.agclassroom.org/va).

About pigeonpea

The New Crops Program of Virginia State University, established in 1991, has evaluated the production feasibility of a wide array of leguminous crops, including chickpea, faba bean, mungbean and pigeonpea under Virginia’s agro-climatic conditions (Bhardwaj et al. 1996). During 1992, pigeonpea seed yield varied from 349 to 2,042 kg/ha with a mean yield of 1,236 kg/ha. The mean yield of determinate lines (1,751 kg/ha) was significantly superior to that of indeterminate lines (721 kg/ha). However, a mean green bean yield of 13,589 kg/ha was obtained in this study. These results indicated that pigeonpea is successfully grown in Virginia and the mid-Atlantic region. The green immature seeds of pigeonpea are very familiar to the Virginians, as they are used as a vegetable and could be an important source of income for small and part-time farmers. A market for green pods of pigeonpea is known to exist in the Washington, DC metropolitan area. During the summer of 1998, a Virginia farmer grew about 0.4 ha of pigeonpea for marketing of green pods (Bhardwaj et al. 1999).

Patenting traditional medicine for pigeonpea

In 2003, the US patent and trademark office (USPTO) has granted patent rights on ancient, traditional knowledge of the usage of pigeonpea extracts for treating several diseases. The USPTO has granted three patent rights (nos. 6,410,596; 6,541,522 and 6,542,511) to the bio-pharmaceutical company Insmed Inc, based in Richmond, Virginia, for its 'novel invention of pigeonpea extracts' for treating diabetes, hypoglycaemia, obesity and atherosclerotic cardiovascular disease (clogged arteries). In the patent applications, Insmed acknowledges only a handful of uses of pigeonpeas in traditional medicines and refers to 1957 and 1968 journal articles that describe the effects of pigeonpea and its extracts on blood sugar. Insmed claims novelty in describing 'a purified plant extract whose dosage is easily measurable'. According to Insmed, the pigeonpea extracts by means of traditional process 'contain a myriad of naturally-occurring organic compounds' that may interfere with medicinal effects. That impurity can result in an effective amount that is too low a concentration, or a toxic amount, too high a concentration, of active compound administered' (www.progress.org, 2003; www.organicconsumers.org/Patent/pigeon_pea).

Oceania

As an ecozone, Oceania includes all of Micronesia, Fiji and all of Polynesia except New Zealand. New Zealand, along with New Guinea and nearby islands, Australia, the Solomon Islands, Vanuatu and New Caledonia constitute the separate Australasia ecozone (Figure 75). However, in geopolitical terms, New Zealand, the Solomon Islands, Vanuatu, New Caledonia, Australia, and Papua New Guinea are considered part of Oceania (en.wikipedia.org/wiki/Geography_of_Oceania).

Agriculture and natural resources constitute only 5% to 10% of Oceania's total jobs, but contributes substantially to export performance. It should be noted that the most populous two nations, Australia and New Zealand are also the most developed and have the majority of the service industries. This dilutes the data from the less developed Pacific Island nations who have major agricultural economies. Most of the Pacific countries, excluding Australia and New Zealand, are primarily agricultural. For instance, 80% of the population of Vanuatu and 70% of the population of Fiji work in agriculture. The main produce from this Pacific is copra or coconut, but timber, beef, palm oil, cocoa, sugar and ginger are also commonly grown across the tropics of the Pacific. Old growth logging is exploited in larger islands, including the Solomon Islands and Papua New Guinea. Fishing provides a major industry for many of the smaller nations in the Pacific, although many fishing areas are exploited by other larger countries, namely Japan (en.wikipedia.org/wiki/Economy_of_Oceania).

Pigeonpea in this part of the region is a minor crop purposely grown for vegetable use. The crop is mostly propagated by small-scale farmers as a subsistence crop for domestic use while in other parts of this region such as Hawaii, pigeonpea is grown primarily as feed supplement for poultry and livestock. Pigeonpea can be seen along roadsides as an intercrop and in backyard gardens mixed with other crops.

Australia

Geography

Australia is the sixth largest country in the world. Australia is in the Indian and Pacific Oceans. It is 4,000 km from the east to west coast and 3,200 km



Figure 75. Map of Oceania.

from north to south. Over 75% of it is called ‘the outback’. The geography of Australia encompasses a wide variety of bio-geographic regions being the world’s smallest continent but the sixth-largest country in the world. Neighboring countries include Indonesia, East Timor and Papua New Guinea to the north, the Solomon Islands, Vanuatu and the French dependency of New Caledonia to the northeast, and New Zealand to the southeast (Figure 75). The country is located between the Indian Ocean and the South Pacific Ocean at 10°29'S to 43°34'S latitude and 133°43'E to 153°27' longitude with total land area of 7.7 M km² (en.wikipedia.org/wiki/Geography_of_Australia).

The greater part of Australia is desert or semi-arid where 40% of the landmass is covered by sand dunes. Only the south-east and south-west corners have a temperate climate and moderately fertile soil. The northern part of the country has a tropical climate and is partly tropical rainforest, grassland and desert. Rainfall is highly variable with frequent droughts. Occasional dust storms blanket a region or even several states and there are reports of occasional large tornados. The rising levels of salinity and desertification in some areas are ravaging the landscape (en.wikipedia.org/wiki/Geography_of_Australia).

Agriculture

Agriculture is a major industry in Australia and it accounts for approximately 3% of its GDP. The country produces a wide variety of crops and livestock and 80% of all agricultural production is exported. Cereals, oilseeds and grain legumes are produced on a large scale for domestic consumption and livestock feed. Wheat is the greatest production in terms of area and value to the Australian economy. Sugarcane is also an important crop. Australia produces a wide variety of fruits (oranges, apples and bananas), nuts (chestnuts) and vegetables (potatoes, carrots, tomatoes) (en.wikipedia.org/wiki/Agriculture_in_Australia).

About pigeonpea

All pigeonpea in Australia is grown as sole crop in the dryland cropping system in rotation with wheat, barley, sorghum and mungbean. The crop was introduced into the country as a fodder crop. However, in recent years, the development of short-duration, high yielding cultivars have opened up its potential as a grain crop for export (RJ Troedson, University of Queensland, personal communication). According to Holland (1987), the crop is still in its

evaluation stage in eastern Australia and the first large-scale commercial planting was made in 1985/86 cropping season under the dryland condition of New South Wales.

According to Upadhyaya (2007), there are 134 accessions in the country. Moreover, Nene et al. (1989), Nyabyenda (1987) and van der Maesen (1983, 1986) stated that pigeonpea is considered a minor crop. This finding is strongly supported by Swarbrick (1997) who said that pigeonpea has been possibly naturalized by the presence of numerous accessions and the introduction of new high yielding cultivars. Meekin et al. (1988) stated that the first cultivar Royes, a long-duration photoperiod sensitive and determinate type was released in 1987. However, this cultivar has a limited scope in Australian farming systems especially in the frost-prone areas. Two more cultivars were released namely, Hunt and Quantum. These varieties are early-flowering (68-70 days), which shows better adaptability and productivity.

In sub-tropical and tropical regions of Australia, pigeonpea has potential as a dual-purpose crop for seed production and grazing from both sown and ratoon crop (Wallis et al. 1981). In Northey Street City Farms, a second approach to using pigeonpea known as slash and mulch is employed in market gardens and has been adopted by developing country farmers to avoid the high cost of imported fertilizers. In this method called the alley cropping system, pigeonpea is planted around the perimeter of the garden or across in alleys, with the vegetable crop grown between the alleys. Periodically, according to the rate of growth of the legume, the foliage is slashed and placed in the garden where it decomposes releasing nitrogen to the root systems of the main crop. When the shrub has re-grown, it is again slashed to a meter or less above the ground. At the city farm, the shrub is grown to near its full height before its woody growth is slashed to about a meter. The foliage is stripped from the cut branches and used as nitrogen-rich mulch in the garden. Pigeonpea grows back, coppicing from the cut branches to form a bushy shrub ([www.communitygarden.org.au/ideas/gardening /tree_legumes](http://www.communitygarden.org.au/ideas/gardening/tree_legumes)).

In southern Queensland in Australia, farmers are now advocating pigeonpea as a good crop for zero-till farming to prevent soil erosion and also to improve soil structure. The method is so easy and the idea was that smaller furrows would leave more stubble in the ground after harvest than direct drill methods (Capricornia Queensland 2007a).

Research breakthrough

The conduct of pigeonpea research for its use as a fodder crop started in 1967. According to Parbery (1967), 25.45 t of dry matter was harvested in 372 days (unfertilized) and 37.96 t/ha when fertilized with 100 kg N/ha on Cunnunurra clay while only 1,071 kg/ha (unfertilized) was harvested on Cockatoo sand in the Kimberley district of northern Australia. One hundred kg N/ha depressed its yield on Cockatoo sand. The yield of 37.96 t when fertilized with 100 kg N/ha on Cunnunurra clay represents 7,704 kg/ha of protein.

In 1975, Akinola and Whiteman recorded a yield of 7.5 t/ha of shelled seed in experimental plots in Queensland, Australia. Furthermore, short-duration types that mature in less than 100 days with a yield potential of over 5,000 kg/ha and can be grown as sole crop in multiple cropping systems have been developed in Australia. In 1978, research for grain product was initiated at the University of Queensland, Brisbane. From this program, four pigeonpea varieties, Royes, Hunt, Quantum and Quest were released but none of the varieties is in cultivation due to their high susceptibility to pod borers.

An evaluation of pigeonpea as an autumn forage for coastal New South Wales was conducted in over five years (1973-74 to 1977-78). Six experiments were carried out at Camden, New South Wales (latitude 34°S). Three cultivar tests were made with a limited range of material from the University of Queensland collection. The cultivars UQ38 and UQ50 were the most satisfactory. A time of sowing experiment with UQ50 indicated that to achieve maximum leaf yield at the end of April, sowing could be made as late as early November. A defoliation study with UQ50 showed pigeonpea to be susceptible to mid-season cutting. Minimum total yields (first cut plus recovery) were obtained by cutting 12 or 15 weeks after sowing. Two experiments involving periodic sampling in autumn and early winter, together with results from the defoliation study, indicated that pigeonpea could only be utilized satisfactorily for grazing from March to May. It was concluded that pigeonpea has some potential as autumn forage. Its main disadvantages were the need for high weed control inputs, a consequence of its slow early growth, and the limited period over which it could be usefully grazed (Norman et al. 1980).

In April 1977, the University of Queensland demonstrated through the conduct of field days that pigeonpea is photosensitive and thus planting dates and density relationships are the most important agronomic consideration in

production. A second field day was conducted in October 1978 to showcase the potential of cv Royes (formerly accession UQ50) variety. Royes was derived from a West Indian accession (Q-8189) identified as '*Cajanus cajan* OP dwarf (4)'. It is a botanically determinate cluster type of medium-late maturity with red flowers, large pods, and white seed. Results revealed that this variety has a number of advantages for mechanized agriculture, the most important of which is its being a determinate and its pods produced on top of the canopy making harvesting and pest control easier. In the 1978/79 season, the University of Queensland made available to farmers these cultivars to gain experience with this crop and to produce a trial shipment to test the prospect for an export market in the Middle East for human consumption. However, they are limited to frost free environments since this variety is susceptible to frost damage due to its long growth period (up to 110 days to flower for December sowing) (Wallis et al. 1981a).

In 1985, a project was initiated to improve pigeonpea production in close collaboration with ICRISAT. A detailed study in two major areas was established, namely, agronomy/physiology and plant breeding/genetics. The results in agronomy and physiology have developed growth model for early-season pigeonpea. The Project has addressed specific factors including nitrogen fixation and its contribution to crop rotations, water stress, low radiation and low temperature. Breeding and genetic studies were likewise addressed for better understanding of inheritance of important characters and ways to incorporate them into improved genotypes (Persley 1988).

Pigeonpea hybrid breakthrough

In a new development, Dillon (2006) reported that Queensland scientists have made a breakthrough they believe will help feed millions of starving people. The Department of Primary Industries and Fisheries (DPIF) at Biloela in central Queensland has developed a hybrid using species of the common Australian wild pigeonpea and commercial cultivated plants or cultivars. The hybrid varieties emerging from the research could hold the key to developing cultivars that are resistant to pests and diseases. DPIF scientist Sally Dillon said that the pigeonpea F1 hybrids held the key to developing better cultivars. According to Dillon, they have identified 13 native pigeonpea species endemic to Queensland, Northern Territory and Western Australia that thrive in the wild and are extremely tolerant in terms of limited soil moisture and soil nutrients. The Australian species of the crop were drought

tolerant, high yielding and palatable, as well as disease and pest resistant. Dillon reiterated that the pigeonpea available commercially is mainly used as a trap-crop because it is prone to insect predation (Capricornia Queensland 2007b).

Caroline Island

Geography

Caroline Island or Caroline Atoll (also known as Millennium Island) with coordinates of 6°25'N to 6°55'N latitude and 158°2'E to 159°15'E longitude is the easternmost of the uninhabited coral atolls, which comprise the southern Line Islands in the central Pacific Ocean. Caroline Atoll lies near the southeastern end of the Line Islands, a string of atolls extending across the equator some 1,500 km south of the Hawaiian Islands in the central Pacific (Figure 75). The slightly crescent-shaped atoll (3.76 km² in land area) consists of 39 separate islets surrounding a narrow lagoon. Extending approximately 9 km from north to south and 2 km from east to west, the islets rise to a height of only 6 m above sea level. The islets, like those of all atolls, share a common geologic origin and consist of sand deposits and limestone rocks set atop a coral reef.

Caroline Island enjoys a tropical maritime climate – consistently hot and humid. Meteorological records are sparse but temperatures generally range between 28 and 32°C (82 and 90°F) year-round. Caroline lies within a region of highly variable precipitation but is estimated to receive an average of 1,500 mm of rain annually (en.wikipedia.org/wiki/Geography_of_Caroline_Island).

Agriculture

In Caroline Island, subsistence farming and copra production are the main agricultural enterprises. The main subsistence crops are banana, breadfruit, coconuts and taro. Products include tapioca, *bonita* and other fish, sugarcane and handicrafts.

About pigeonpea

In Caroline Island, pigeonpea is grown by subsistence farmers (Ahmand and Rai 2005). The study revolved around the damage brought by the *helicoverpa armigera* towards pigeonpea productivity. In this study, it was found that one larva per plant of *helicoverpa armigera* reduces 4.95 green pods, 7.05 dry pods, 18.01 grains, 3.79 g pod weight and 2.05 g grain weight per plant.

Cook Island

Geography

The Cook Islands with geographic coordinates of 21°11'S to 21°15'S latitude, 159°44'W to 159°50'W longitude, which lie roughly east of the Island of Tonga, above the Tropic of Capricorn, are a group of fifteen small islands with a total land area of 237 km², scattered over two million km² of ocean (Figure 75) (Lambert 1982). The climate is tropical with two distinct seasons, hot and humid. The average rainfall is between 2,000 and 3,000 mm/year. Lying at 20° South, the Cook Islands experience cyclones with high winds and intense rain. The mean annual temperature is 24°C with little seasonal variation. The relative humidity is also fairly high throughout the year (Aregheore 2000).

Agriculture

In Cook Islands, subsistence farmers concentrate on rearing monogastric livestock (pigs and poultry). However, there are a few ruminants, cattle and goats. The livestock industry is divided into two sectors; formal and informal (Tokari 2000). The formal or commercial farmers own a large number of animals and raise stock for sale to retailers, restaurants and hotels, etc. This sector is highly organized in goat production. Smallholders keep most of the cattle and goats and raise their animals in pens, backyards and often on free grazing or tethered; animals are raised for domestic consumption and festive occasions such as weddings, traditional celebrations, etc.

About pigeonpea

Cook Islands' pigeonpea production is invasive (meaning large scale naturalized cultivation) and it is grown at 'Atiu and Ma'uke Islands as reported

by McCormack (2007). To date, considerable work is being carried out to identify pasture resources in the Cook Islands because there has been very limited work previously. Most of the available legume species were brought in during colonial times. Some of the legume species available in the Cook Islands today are assumed to be improved legume species. The most noticeable legumes among others are pigeonpeas (Aregheore 2000).

Federated States of Micronesia

Geography

The Federated States of Micronesia (FSM), which comprises four states, namely, Pohnpei, Chuuk, Kosrae and Yap was created from the former US Trust Territory of the Pacific Islands. The country lies approximately between 6°24'N to 7°13'N latitude and 156°50'E to 159°26'E longitude. The total land area is only 4,840 km², scattered over hundreds of thousands of km² of ocean and distributed among hundreds of islands and islets (Figure 75). FSM includes the largest and most diverse part of Micronesia. The population is concentrated on the larger high islands, though a number of smaller islands still support relatively large populations (Crocombe 2001).

Rainfall is high and well distributed with an average of 4,820 mm and 300 rainy days/year (Lambert 1982). At higher interior elevations, rainfall is estimated to reach 7,500 mm with mean temperature of 24–30°C and an average monthly temperature of 27°C year round.

Agriculture

Agriculture is of subsistence type and the main crops are yam, banana, taro, coconut, citrus and cassava, *Colocasia* and *Xanthosoma*. Soils in FSM vary widely in their potential for major land uses. In most of the islands in FSM, at least 30% of available land is used for subsistence tree crops, which comprise mainly bananas, taro, breadfruit, coconuts and small shrubs. Over the years agroforestry has remained the dominant system of food production (Young-Uhk 1999).

Land on many coral islets is sparse and generally infertile. Only coconuts and *pandanus* grow without considerable effort. While land on high volcanic islands is fertile, it is often steep and inaccessible. Agricultural productivity

therefore is rather low, although in traditional times subsistence agriculture was the economic basis of society (Douglas and Douglas 1989).

About pigeonpea

Pigeonpea in Federated States of Micronesia are cultivated mostly in Pohnpei Island. The crop was introduced and is cultivated by small-scale farmers for their subsistence (Glassman 1952, Fosberg et al. 1979, Lorence and Flynn 1998). Moreover, the crop is planted in alternate rows intercropped with the Pacific kava as a shade crop.

Fiji

Geography

Fiji, with geographic coordinates of 17°20'S to 18°20'S latitude, 177°17'E to 178°50'E longitude, is a group of volcanic islands in the South Pacific lying about 4,450 km southwest of Honolulu and 1,770 km north of New Zealand (Figure 75). Of the 322 islands and 522 smaller islets making up the archipelago, about 106 are permanently inhabited. The islands are mountainous with peaks up to 1,300 m rising abruptly from the shore and covered with tropical forests. The climate is tropical marine with only a slight seasonal temperature variation. Maximum summer temperatures average 31°C (88°F) and the mean minimum is 22°C (72°F). The winter average maximum is 29°C (84°F) and the mean minimum is 19°C (66°F). Heavy rains (up to 3,048 mm annually) fall on the windward (southeastern) side covering these sections of the islands with dense tropical forest. Lowlands on the western portions of each of the main islands are sheltered by the mountains and have a well-marked dry season favorable to crops such as sugarcane (en.wikipedia.org/wiki/Geography_of_Fiji).

Agriculture

Agriculture comprises about 30% of Fiji's export earnings. More than three-quarters of all households are engaged in agriculture, livestock production, forestry or fishing. A total of 285,000 ha or over 15.6% of Fiji's land area were used for crop production in 1998. The crops produced are sugarcane, coconuts, cassava (tapioca), rice, sweet potatoes and bananas while the livestock raised include cattle, pigs, horses, goats and fish. Corn, tobacco,

cocoa, ginger, watermelons and other fruits and vegetables are also grown. The sugar industry is also vital to the national economy, hence, the government plays a leading role in all aspects of its production and sale (www.infoplease.com; www.nationsencyclopedia.com/Asia-and-Oceania/Fiji-Agriculture).

About pigeonpea

Pigeonpea is a post-European-contact introduction into Fiji where traditionally long duration pigeonpea is an important pulse crop typically grown on fallow or sloping lands. The late-maturing genotypes are either mixed or intercropped with other upland crops or grown as guard rows or fences around sugarcane fields (Sivan et al. 1987). The plant is an erect, short-lived, perennial pubescent shrub, 1–3 m in height or higher, with pinnately trifoliate leaves, bright yellow flowers marked with dark reddish brown to crimson and linear-oblong, flattened, inflated pods bearing globose, compressed, cream-colored to reddish, brownish or speckled seeds. It is abundant in sugarcane farms and occasionally in home gardens especially in the dry zone of Fiji where it has been widely introduced. The cultivated food plants are a major supplementary staple crop and source of plant protein for the Fiji Indian population. It is an important nitrogen-fixing intercrop or supplementary crop on sugarcane farms. The immature pods are cooked as a vegetable and the mature seeds are dried and cooked as a protein-rich pulse. The plant is used as fodder or green manure and the dried stems are occasionally used as fuel. The cultivation of pigeonpea in Fiji is on a large scale and naturalized so that it can be seen growing wild along roadsides, cane fields and in cultivated areas (Smith 1985). In an earlier development, an ICRISAT germplasm ICP 7035, also known as 'Kamika,' was released and is popular for vegetable as well as dry seed production (Saxena 2008a).

In Fiji, researches to determine the factors causing flower drop and subsequent poor pod retention in some genotypes still continue. The identification of germplasm resistant to stem canker caused by *Botryosphaeria xanthocephala*, the mode of inheritance of this disease and incorporation of resistance into adapted genotypes are high priority research areas. The aspects of management of the crop and its adaptation and productivity on acid low-fertility soils with high aluminum saturation will also receive emphasis (Persley 1988).

Kava (*Piper methysticum* Forst. f.) is a Pacific plant species of the pepper family. Following its initial discovery, domestication and diffusion throughout the Pacific, this plant became an integral part of the Pacific islands' religious, economic, political and social life. At present, however, kava has moved away from being a traditional crop for ceremonial and personal use. It is now an important cash crop for both the local market and for export. In September 1985, the Phase I Project demonstrated that pigeonpea has potential applications in Fiji. It was used as an effective plant for intercropping with kava. Its leaves are used as mulch to enrich the nitrogen content of the soil. Pigeonpea also provided shade to the kava and functioned as a windbreaker. To do this, pigeonpea is planted while the kava seedlings are growing in the nursery. This way the pigeonpea will be large enough to provide shade by the time the kava is planted in the field. The pigeonpea and kava are planted in alternate rows. For good shading, which is needed when the kava is young, the pigeonpea can be planted densely and then thinned as the kava grows (Secretariat of the Pacific Community 2001). Furthermore, Fiji is also investigating the possibility of exporting vegetable type pigeonpea (info@green-seeds.com).

French Polynesia

Geography

French Polynesia is an archipelago located in the South Pacific Ocean about halfway between South America and Australia (Figure 75) with geographic coordinates of 17°26'S to 17°54'S latitude and 149°14' to 149°56'W longitude. The country has an area of 4,167 km² covering 118 islands and atolls. The climate is tropical but moderate. Dry season is from May to October while the rainy season is from November to April. The temperature varies year-round between 28 and 30°C (82.4 and 86°F). Rain in January is at a high of around 330 mm. In August it is down to around 40 mm (en.wikipedia.org/wiki/Geography_of_French_Polynesia; www.fsmitha.com/world/tahiti.htm).

Agriculture

Since 1962 when France stationed military personnel in the region, French Polynesia has changed from a subsistence agricultural economy to one in which a high proportion of the work force is either employed by the military or support the tourist industry. With the halt of French nuclear testing in

1996, the military contribution to the economy fell sharply. Tourism accounts for about one-fourth of the GDP and is a primary source of hard currency earnings. The small manufacturing sector primarily processes agriculture products such as coconuts, coffee, vanilla, fruits, vegetables, fish poultry, beef and dairy products. Other sources of income are pearl farming and deep-sea commercial fishing (www.cia.gov/library/publications/the-world-factbook/geos; en.wikipedia.org/wiki/Economy_of_French_Polynesia).

Pigeonpea: A Potential Crop

Pigeonpea is cultivated in French Polynesia as a minor crop. It was introduced in the island of Raiatea (Havai) and has been growing in the island of Tahiti as a subsistence crop and is used as shade crop for their main crop, kava (Secretariat of the Pacific Community 2001).

Guam

Geography

Guam is the largest and most southern island in the Marianas Islands archipelago in the western North Pacific Ocean. The southern maritime boundary of Guam forms a border with the Federal States of Micronesia while the northern maritime boundary forms a border with the Commonwealth of the Northern Marianas Islands (Figure 75). Guam is a US territory located in Oceania and about three-quarters of the way from Hawaii to the Philippines with geographic coordinates of 13°15'N to 13°40' N latitude and 144°36' E to 144°55'E longitude. Its land area is 541.3 km² with a maximum elevation of approximately 405 masl. The climate is tropical marine, generally warm and humid and moderated by northeast trade winds. The dry season is from January to June while the rainy season is from July to December with little seasonal temperature variation. The average annual rainfall is 2,180 mm (en.wikipedia.org/wiki/Geography_of_Guam; NOAA National Weather Service 2004).

Agriculture

Agriculture in Guam is for local consumption. The estimated area for arable land is 9.09% of the total land area (CIA 2004a). Today, small-scale agriculture provides families and local markets in the capital Agana with

fruits like pineapples, bananas, papayas, mangoes, limes, avocados and melons and vegetables like cucumbers, green beans, squash, peppers and eggplant. Other agriculture products are copra, eggs, pork, poultry and beef (www.pacificislandtravel.com/micronesia/about_destin/guam).

Pigeonpea: A Potential Crop

According to Stone (1970) and Fosberg et al. (1979), pigeonpea is an indigenous crop and cultivated by small-scale farmers for subsistence use.

Hawaii

Geography

Hawaii with latitude of 18°46'N to 22°11'N and longitude of 154°58'W to 160°13'W is the most remote island chain in the world. It is located near the middle of the Pacific Ocean and about 3,850 km from California and 6,195 km from Japan (Figure 75). Formerly known as the ‘Sandwich Islands’, the Hawaiian archipelago spans the distance of 2,451 km from the Big Island of Hawaii in the southeast to the Kure Atoll in the northwest. This makes Hawaii also the world’s longest island chain. The island of Hawaii, at 8,150 km², comprises nearly two-thirds of the state’s total area and it is often referred to as simply the Big Island. Kahoolawe, the smallest of the eight islands, which is 125 km², is uninhabited (en.wikipedia.org/wiki/Hawaiian_Islands).

Hawaii’s oceanic location obviously has a substantial impact on its climate. The ocean moderates the islands’ extreme temperature. Honolulu’s record high of 31°C is matched by a record low of only 13°C. The latitude of Honolulu, which is about 20°N, is the same as Calcutta and Mexico City. As a result, there is little change in the length of daylight or the angle of incidence of the sun’s rays from one season to another. This factor means that there is little seasonal variation in temperature. During summer, Hawaii is under the persistent influence of northeast trade winds that approach the islands over cool waters located to the northeast and create the characteristic Hawaiian breezy sunny warm weather. In winter, these trade winds sometimes disappear for weeks allowing “invasion” of storms from the north and northwest. Honolulu has received as much as 430 mm of rain in a single 24-hour period. Hawaiian weather stations have also recorded 280 mm in an hour and 1,000 mm in a day both of which rank near world records.

Agriculture

Agriculture has continued to show modest gains in income, but its relative importance has declined. Only one in every 30 Hawaiian workers is currently employed in agriculture. Sugarcane, pineapple, macadamia nuts, coffee and livestock form the backbone of the economy of the country. While these are very important commodities for the islands, there are many other crops that help sustain Hawaii's economy. Among these are ginger, banana, onions, sweet potato, lettuce and seed crops.

Moreover, Hawaii continues to provide a substantial share of the world's sugar harvest and its production of pineapples is about 650,000 t annually, making it the world's largest supplier of pineapples. Gross economic statistics overwhelmingly emphasize the position of Oahu where more than 80% of the state's economy is concentrated. The role of agriculture remains great on the other islands. Both Lanai and Molokai depend on pineapples for much of their employment and income (editor@hawaiitravelnewsletter.com 2008). In the year 2000, agriculture contributed 3.3% of the total Hawaii sales, 2.2% of total real GSP, 3.8% of employment and 2.2% of labor income (Cai and Leung 2002).

Pigeonpea cropping system and uses

At the turn of the 19th century, long before the advent of the agricultural chemical industry, agriculturists in Hawaii were growing a hardy, drought-tolerant legume from India known as the pigeonpea (*Cajanus cajan*). First used as a windbreak and livestock feed, the plant became very popular and was eventually grown on over 4,047 ha interplanted with pineapple as a "soil builder". Pigeonpea, locally known as 'Puerto Rican bean' and 'pigeonpea', still offers the same excellent array of features now valued by contemporary farmers who are trying to practice sustainable agriculture (Valenzuela and Smith 2002). The Islands of Hawai'i, Kaua'i, Maui, Moloka'i and O'ahu grow pigeonpea. In 1919, a pigeonpea breeding program was initiated at the University of Hawaii that resulted in the release of the fodder variety 'New Era' (Morton et al. 1982). However, due to the introduction of more efficient forage legumes, pigeonpea research was abandoned.

Since 1932, pigeonpea is grown in rotation with pineapple every five years and as an intercrop. The crop grows well as forage just like rhodes grass *Cynodon dactylon* and molasses grass (www.fao.org). As mentioned by

van der Maesen (1989), pigeonpea performs well as an intercrop with two rows of cereals (millet, sorghum), cotton or groundnut. After the intercrop is harvested, pigeonpea continues to grow, produce and protect the soil. Like in Fiji, the crop is used as an intercrop to kava and used as a shade crop (Secretariat of the Pacific Community 2001).

Cajanus cajan is very heat-tolerant and prefers hot moist conditions. Under Hawaiian conditions the crop grows between 18 and 30°C although the crop grows at temperatures above 35°C under adequate soil conditions of moisture and fertility. It does not tolerate frost but it can grow in temperatures to just above frost level. The plant will form seed as a perennial at 1,840 m down to a minimum night temperature of 10°C (Krause 1932). The crop is cultivated from 25–610 masl and grown on a large scale, and is distributed in areas such as roadsides, pastures and cane fields (Secretariat of the Pacific Community 2001).

In addition, pigeonpeas in Hawaii grow year-round at elevations ranging from sea level to 3,000 ft. According to the USDA Natural Resources Conservation Service (NRCS), pigeonpea grows in an altitude range of 1,250 m except that at heights of 1,230 to 1,500 m, the crop fails to set seeds. A variety of cultivars and the many ways they can be used in farming systems have made pigeonpea popular to small-scale farmers because pigeonpea, which is likewise planted on wastelands, is used primarily as a forage, pasture, shade, or cover crop. Farmers harvest pigeonpea as hay when a large percentage of the pods are matured, such as when two-thirds to three quarters of the pods are in sight because a large part of the nutritive value of the plant is contained in the seed. The farmers harvest not more than the upper third of the plant to avoid the woody base unless the plant is spindly. They then cure on the cut surface of the plant that has just been harvested for six to eight days and then mill it as livestock feed. Pigeonpea hay is an effective substitute for more expensive industrial concentrates (Ripperton and Hosaka 1942).

A mixture of equal quantities of cracked pigeonpea and cracked maize has been proved as the best poultry ration. Because many varieties have been developed with different growth and flowering responses to day-length, numerous types are available to meet growers' situations in terms of location, elevation and season of growth (Valenzuela and Smith 2002). In other developments, Henke et al. (1940) reported that the weight of cattle had increased from 280 kg/yr on pure pigeonpea as compared to 181 kg/

yr in mixed grass pastures over a 6.5 months grazing period. This finding was confirmed by Krause (1932) where liveweight of cattle has increased when fed with 200 to 500 kg/yr of pigeonpea forage. He likewise stated that cattle fed wholly on pigeonpea have gained weight from 0.7 to 1.25 kg/head/day at a carrying capacity of 1 to 3.75 beasts/ha. In addition, Henke (1943) revealed that the use of podded green tops pigeonpea as forage for dairy cattle gave higher milk production than alfalfa.

Although forage production depends on the stage of the crop, growing conditions and management, experimental yields of dry biomass exceeding 50 t/ha/yr have been reported in intensively managed cut and carry sole stands (Whiteman and Norton 1981). In one single harvest in Hawaii, the fully podded tops give 11.2 t of green forage, 4.97 t of dry matter and 400 kg protein/ha (Takahashi and Ripperton 1949).

Pigeonpea cultivars

The pigeonpea cultivars commonly recommended for use as green manure by the Hawaii NRCS are 'Norman' (a selection from an introduction from Pakistan) and 'FL81d'. These cultivars are shorter and shrubbier and resistant to root-knot nematodes. Taller pigeonpea varieties are used as a semi-permanent, perennial component of alley cropping systems. This multi-functional plant can serve as a windbreak and living fence that also produces food and fodder. The leaf litter contributes to mulch that decomposes to add to the soil organic matter, possibly contributing as much as 40 kg/ha of nitrogen to the soil. However, pigeonpea cannot tolerate the frequent severe cutting or heavy defoliation pressure typical of continuous grazing operations. When used as a green manure, the crop produces about 13,619 kg/ha of dry matter and about 23 kg of N/t of dry matter according to NRCS. Fresh weight yields of the top growth can reach up to 190,664 kg/ha, including about 3,813 kg/ha of seed, making it one of the highest yielding food legumes. When planted at College of Tropical Agriculture and Human Resources (CTAHR) low elevation Waimanalo Research Station on Oahu in mid-September, foliage fresh weight was about 16,813 kg/ha after 14 weeks of growth. A summer planting (mid-June) at the same site resulted in foliage fresh weight ranging from 234,244 to 435,892 kg/ha when flail-mowed 23 weeks after planting. In the falls planting, 14-week old pigeonpea plants grow to about 5 ft in height and in the summer planting they grow 8–10 ft. The tissue nitrogen content of pigeonpea foliage is about 2.5% (Valenzuela and Smith 2002).

Green manure management

The seedling of pigeonpea is fairly slow to establish and weed control for the first two months of growth considerably improves its development. Once established, it grows vigorously. To obtain maximum legume when using it as a green manure, pigeonpea is cut at flowering or mid-flowering. Root growth varies depending on variety, a consideration when growing a cover crop to break hard pans or to improve water infiltration. The roots of “early” short duration types will grow only about 1.5 ft deep into the soil while the roots of long-duration types may grow up to 6 ft deep.

Northern Mariana Islands

Geography

Mariana Islands occupy a strategic region in the western Pacific Ocean. It consists of 15 islands about three-quarters of the way from Hawaii to the Philippines at 14°54'N to 15°12'N latitude and 145°33'E to 145°45'E longitude (Figure 75). The United States Census Bureau reports that the total land area of all islands is 463.63 km². The islands have a tropical marine climate moderated by seasonal northeast trade winds. There is little seasonal temperature variation. The dry season runs from December to June and the rainy season from July to November, which can include typhoons (en.wikipedia.org/wiki/Geography_of_the_Northern_Mariana_Islands).

Agriculture

Mariana Islands’ agricultural sector is made up of cattle ranches and small farms producing coconuts, breadfruit, tomatoes, melons, areca palms, yams, sweet potatoes, manioc, coffee, cocoa, sugar, cotton and tobacco. Mother-of-pearl is the chief product and copra is the principal export. Agriculture is neglected in spite of the exceptional advantages offered by the climate and soil ([theodora.com/wfbcurrent/.../northern_mariana_islands_economy](http://theodora.com/wfbccurrent/.../northern_mariana_islands_economy); www.answers.com/topic/mariana-islands).

Pigeonpea: A potential crop

According to Fosberg et al. (1979), pigeonpea in Mariana Islands have been introduced specifically in the islands of Rota and Tinian as garden plant for subsistence use.

Nauru

Geography

Nauru is a tiny oval-shaped phosphate rock island located in the South Pacific Ocean between New Guinea and the Gilbert Islands, south of the Marshall Islands in Oceania (Figure 75). It is 53 km south of the Equator at coordinates 0°29' to 0°33'N latitude, 166°55' to 167°0'E longitude. Nauru is one of the three great phosphate rock islands in the Pacific Ocean - the others are Banaba (Ocean Island) in Kiribati and Makatea in French Polynesia. Its land area is 21 km² and it has a 30 km coastline. Maritime claims are a 370 km exclusive fishing zone, and a 22 km territorial sea. The climate is tropical with a monsoonal rainy season from November to February (en.wikipedia.org/wiki/Geography_of_Nauru).

Agriculture

Though coconuts are the main produce of Nauru, agriculture is not its major employer. The island's only fertile areas are within the narrow coastal belt where there are coconut palms, pandanus trees and indigenous hardwoods. Bananas, pineapples and some vegetables are grown in lands surrounding the inland Buada lagoon on the central plateau. Nauru imports well over 90% of its foodstuffs and other basic goods (www.state.gov/r/pa/ei/bgn/16447; en.wikipedia.org/wiki/Economy_of_Nauru).

About pigeonpea

Pigeonpea was introduced in Nauru (Fosberg et al. 1979) and it is now being cultivated by small-scale farmers as a subsistence crop (Thaman et al. 1994).

New Caledonia

Geography

New Caledonia is a large archipelago located in the heart of the South Pacific, 1,500 km from the Australian coastline and 1,700 km from New Zealand (Figure 75) with geographic coordinates of 20°0'S to 22°33'S latitude, 163°49'E to 167°2'E longitude. Its total land area is 19,060 km². It

is composed principally of the mainland, Isle of Pines and Loyalty Islands (CIA 2008h, www.visitnewcaledonia.com). The climate is tropical, modified by southeasterly trade winds and is hot and humid. Natural hazards include cyclones that occur most frequently between November and March (en.wikipedia.org/wiki/Geography_of_New_Caledonia).

Agriculture

In New Caledonia, only a negligible amount of the land is suitable for cultivation, hence food accounts for about 25% of its imports. Agriculture products are vegetables, beef, deer and other livestock (www.world66.com/australiaandpacific/newcaledonia/economy).

About pigeonpea

Pigeonpea was introduced as a crop in New Caledonia and cultivated on a large scale (invasive) in the islands of Île Art, Îles Ouvéa (Ouvea Atoll) and Île Grande Terre (Mackee 1994). In most cases, pigeonpea is grown naturally on roadsides and in backyard gardens.

Pigeonpea was also tested in this island as feed supplement in raising poultry. Local varieties of pigeonpeas grown had a total of 221 nitrogenous material, 17.7 fats, 103 crude cellulose, 615.8 nitrogen-free extract and 42.5 g/kg minerals, 7.59 Lysine, 2.62 sulphur amino acids, 0.8 tryptophan and 3.98% threonine. From about 20 to 75 kg liveweight for 80 days, 2 groups of 6 barrows and 3 female Large White X Landrace pigs were given a ground feed without or with 45% pigeonpea meal partly replacing wheat and soya bean meal. Mean daily gain was 700 and 675 g and feed conversion indices 3.0 and 3.14, respectively. Differences were not significant. Slaughter indices were not different between groups. From the age of 3 weeks, for 62 days, 200 broiler chickens were given mixed feeds without or with 15, 20, 25 or 30% pigeonpea meal partly replacing wheat and soya bean meal. Mean daily gain was 39.87, 41.76, 38.83, 39.55 and 41.73 g and feed conversion indices 2.63, 2.81, 2.95, 2.72 and 2.89. In the group given 30% pea meal, mortality was 37%. Slaughter indices were not different among groups. Results indicate that up to 15 and 20 to 25% pigeonpea meal can be included in diets for pigs and chickens, respectively, without affecting performance. In chickens given diets with 40% pigeonpea meal for 6 weeks, performances were different from the control group from about the 3rd week

indicating the presence of anti nutritional factors. Weight of pancreas was greater in chickens fed pigeonpea meal (Grimaud 1988).

Niue

Geography

Niue is a very small isolated island in the South Pacific Ocean. It is located northeast of New Zealand, east of Tonga, west of the Cook Islands and south of Samoa (Figure 75), with geographic coordinates of 18°56'S to 19°9'S latitude and 169°46'W to 169°58'W longitude. It has an area of 260 km² and a coastline of 64 km. Niue is one of the world's largest coral islands. Its climate is tropical, modified by southeast trade winds. Typhoons pose a natural hazard (en.wikipedia.org/wiki/Geography_of_Niue).

Agriculture

The estimated arable land of Niue is 19%. Permanent crops are 8% and permanent pasture is 4% of the total land area (en.wikipedia.org/wiki/Geography_of_Niue). The agricultural sector consists mainly of subsistence gardening, although some cash crops are grown for export. Agriculture products are coconuts, passion fruit, honey, limes, taro, yams, cassava (tapioca), sweet potatoes, pigs, poultry and cattle. Industry consists primarily of small factories to process passion fruit, lime oil, honey, and coconut cream. Export commodities are canned coconut cream, copra, honey, vanilla, passion fruit products, pawpaws, root crops and limes (geography.about.com/library/cia/blcniue).

About pigeonpea

Sykes (1970) stated that pigeonpea was introduced in Niue Island and cultivated by subsistence farmers. Space et al. (2004) confirmed the findings of Sykes that the crop was introduced in the island and is naturally cultivated on a large scale.

Papua New Guinea

Geography

The islands of New Ireland, New Britain and Bougainville and nearby smaller islands located at approximately 2°38'S to 10°57'S latitude and 140°53'E to 150°39'E longitude at the western edge of the Pacific Ocean (Figure 75) in tropical Oceania make up the nation of Papua New Guinea (PNG). It is largely mountainous and much of it is covered with tropical rainforest. Papua New Guinea has one land border, which divides New Guinea Island. Across the 820 km border, the western half of New Guinea is officially known as Papua province and governed by Indonesia. There are maritime borders with Australia to the south and Solomon Islands to the south-east (en.wikipedia.org/wiki/Geography_of_Papua_New_Guinea). Papua New Guinea's climate is tropical, as one would expect in a country located just south of the Equator. The wet season is from December to March, and the southeast monsoon from May to October although occasional rain falls year-round. While Port Moresby, the capital, and other towns on the coast are quite hot in the summer months, temperatures are considerably cooler in the Highlands (www.geographia.com/papua-newguinea).

Agriculture

Agriculture is the 'economic backbone' of PNG, being the main provider of livelihood for the large majority of the population and the source of about/half the total export earnings of the country. In fact, over 80% of the population relies on subsistence food systems, either completely or for a very substantial part of their daily diet and nutritional needs. Subsistence agriculture in the country is characterized by shifting cultivation of starchy staples and a variety of other crops in garden areas of 500-2,500 m² cleared by "slash and burn" techniques. Agricultural production in PNG is derived from three main sectors: subsistence cultivation, smallholder cash cropping associated with subsistence and larger holder capital-intensive production of the plantation type (Tacon 1986). Major agriculture products are coffee, cocoa, copra, palm kernels, tea, sugar, rubber, sweet potatoes, fruit, vegetables, vanilla, shell fish, poultry and pork. Cash crops ranked by value are coffee, oil, cocoa, copra, tea, rubber and sugar (www.theodora.com/wfb/papua_new_guinea_economy, Bureau of East Asian and Pacific Affairs 2008).

About pigeonpea

According to ILDIS Co-ordinating Centre (2005), pigeonpea in PNG is an introduced crop. The crop is now grown in the islands of Bismarck Archipelago and Papua New Guinea (eastern New Guinea Island). It is cultivated as kitchen gardens, field gardens and even sighted at school gardens. Moreover, pigeonpea is utilized as an intercrop to kava purposely as a shade crop (Secretariat of the Pacific Community 2001, www.uq.edu.au/_School_Science_Lessons/Foodgardens).

In 2006, the National Agricultural Research Institute (NARI) imported pigeonpea for evaluation under PNG conditions. This leguminous crop is now at Aiyura in Eastern Highland Province. Fourteen pigeonpea varieties were imported from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in India. NARI Aiyura research program leader Dr Akinapally Ramakrishna said that the crop is worthy of attention because it gives a lot of benefits to most of the Highland provinces. He likewise stressed that these provinces are ideal for this crop as they are facing severe soil fertility and erosion problems. In 2006, the South Pacific Agricultural News quoted him as saying, "Planting pigeonpea across the slopes will not only combat this menace but also improve soil fertility by fixing atmospheric nitrogen through biological nitrogen fixation. It also provides protein rich grain for human consumption, fodder for animals and the stems form good fuel wood, thus meeting several needs for people living in the Highlands." Dr Ramakrishna said it was important to carry out evaluation of these cultivars to assess their adaptability, identify suitable cultivars and production practices.

Pitcairn Islands

Geography

The Pitcairn Islands, comprising Pitcairn, Henderson, Ducie and Oeno Islands, are a group of four volcanic islands in the southern Pacific Ocean about midway between Peru and New Zealand (Figure 75). With geographic coordinates of 24°18'S to 24°26'S latitude, 128°15'W to 128°23'W longitude, the country has a tropical, hot and humid climate, modified by southeast trade winds. The rainy season is from November to March. Only Pitcairn Island, the second largest, is inhabited and accessible only by boat through Bounty Bay (en.wikipedia.org/wiki/Geography_of_the_Pitcairn_Islands, en.wikipedia.org/wiki/Pitcairn_Islands).

Agriculture

The fertile soil of the Pitcairn valleys produces a wide variety of fruits and vegetables including citrus, sugarcane, watermelons, bananas, yams and beans. The inhabitants of this tiny economy exist on fishing, subsistence farming and handicrafts and trade (en.wikipedia.org/wiki/Pitcairn_Islands).

About pigeonpea

Among the four islands in Pitcairn, only Pitcairn Island is cited by St John (1987) as growing area for pigeonpea. The crop is introduced and has been cultivated by small-scale subsistence farmers.

Solomon Islands

Geography

The Solomon Islands with coordinates of 8°11'S to 10°57'S latitude, 159°23'E to 162°20'E longitude is a nation consisting of a wide group of islands in the South Pacific Ocean and lies east of Papua New Guinea (Figure 75). The country has an area of 28,450 km². The distance between the most western and most eastern islands is about 1,500 km. The climate is tropical, though temperatures are rarely extreme due to cooling winds blowing off the surrounding seas. Daytime temperatures are normally 25 to 32°C (77 to 90°F), falling about 3°C to 5°C at night. From April to October (the dry season), the Southeast trade winds blow, gusting at times up to 55 km/h or more. November to March is the wet season—the northwest monsoon—typically warmer and wetter (en.wikipedia.org/wiki/Geography_of_the_Solomon_Islands).

Agriculture

The bulk of the population depends on agriculture, fishing and forestry for its livelihood. Eighty-four percent of the population live in rural areas and they derive their livelihood from a combination of subsistence agriculture and small-scale income-generating activities, particularly export cash cropping and marketing of fresh produce. Most of the food consumed by villagers is grown in kitchen gardens. Other sources of food not grown in rural gardens include coconuts, fish, shellfish, mangroves and fruits and nuts obtained from trees in the forests or in villages. Sweet potato is by far the most important source of food energy and contributes an estimated 65% by weight of the

locally grown staple foods. Other important food crops are cassava, banana, 'kongkong' taro, island taro, coconut, *pana* and yam. The main agricultural export crops are copra, coconut oil, palm oil, palm kernel oil and cocoa (Bourke et al. 2006).

About pigeonpea

According to Hancock and Henderson (1988), pigeonpea was introduced in Solomon Islands. The cultivation of this crop is now observed among small-scale farmers as a kitchen garden and field garden crop and as feed supplement to raising poultry.

In Solomon Islands, poultry meat and eggs are an important source of dietary protein. Increasing production and income from eggs and birds is an important goal for many families. It is estimated that the 22,000 families produce a total of 220,000 birds and 2.64 million eggs a year, which is not enough to meet local demand. Improved feedstuffs will help families improve their own dietary intake through better quality meat and eggs. In this aspect, the South Australian Research and Development Institute (SARDI) in collaboration with Kastom Gaden Association (KGA) and Department of Agriculture and Livestock (DAL) in Solomon Islands, National Agricultural Research Institute (NARI) in Papua New Guinea and the Solomon Islands College of Higher Education (SICHE) embarked on a 4-year project from 2005-2008. Crops planted for nutritional evaluation were maize, mungbeans, sorghum, pigeonpeas and cowpeas. A simple Microsoft Excel feed formulation spreadsheet was developed by SARDI to formulate 4 layer diets in village poultry in which there are 3 types of pigeonpea supplement diets. Diet 1 ingredient comprised sorghum (30%), pigeonpea (30%), fresh coconut (20%), pigeonpea leaves (10%) and 'pawpaw' leaves (10%). Diet 2 ingredients comprised corn (25%), pigeonpea (15%), 'pawpaw' fruit (5%), mungbean (30%), fresh coconut (7%), fresh cassava (10%) and lime (8%). Diet 3 ingredients consist of pigeonpea (25%), 'pawpaw' fruit (8%), sorghum (45%), fresh cassava (9%), lime (8%) and fish meal (5%) (Glatz 2008).

Tonga

Geography

Tonga, which is also known as the 'Friendly Islands', is located in Oceania, and is an archipelago in the South Pacific Ocean, directly south of Western

Samoa and about two-thirds of the way from Hawaii to New Zealand (Figure 75) with geographic coordinates of 21°6'S to 21°16'S latitude, 175°3'W to 175°22'W longitude. Its 169 islands, 36 of them inhabited, are divided into three main groups – Vava'u, Ha'apai and Tongatapu – which cover the 800 km long north-south line. Geologically, the Tongan islands are of two types: most/have a limestone base formed from uplifted coral formations and others consist of limestone overlaying a volcanic base. The climate is basically subtropical with a distinct warm period (December-April), during which the temperatures rise above 32°C (90°F) and a cooler period (May-November) with temperatures rarely rising above 27°C (80°F). The temperature increases from 23°C to 27°C (74°F to 80°F) and the annual rainfall is from 1,700 to 2,970 mm (en.wikipedia.org/wiki/Geography_of_Tonga).

Agriculture

Agriculture and fishing are the chief economic activities in Tonga employing about 70% of the population. The principal cash crops are pumpkins, coconuts, bananas and vanilla, which account for one-third of Tonga's exports. Still, much food needs to be imported. The country imports a high proportion of its food mainly from New Zealand. Agricultural products accounted for 67% of exports in 2001. Principal subsistence crops are yams, taro, sweet potatoes and manioc. Vanilla beans have become an important cash crop especially on Vava'u. About 69% of Tonga is agricultural land including small amounts of permanent pasture. With increasing population pressure on the land, more land is being intensively cultivated and less is available for fallow. The use of fertilizers, high-protein strains of corn and similar methods to improve the efficiency of land use has become increasingly necessary (en.wikipedia.org/wiki/Geography_of_Tonga; en.wikipedia.org/wiki/Economy_of_Tonga).

About pigeonpea

Pigeonpea is cultivated as a minor crop in Tonga (Nene et al. 1989; Nyabyenda 1987; van der Maesen 1983, 1986). The crop is locally known as *faka-Tonga* or *pīfisi* and is grown as a subsistence crop in kitchen gardens, field gardens and even in school gardens (www.uq.edu.au/School_Science_Lessons/Foodgardens). According to the Secretariat of the Pacific Community (2001) like Fiji, pigeonpea is intercropped with kava and used as a shade crop.

Conclusions

If information is power, the need to synthesize existing knowledge and package this for easy access by various interest groups is an important element of research, development and extension continuum. This was the primary reason behind this work, where all available information about the pigeonpea production system and its utilization, sourced from hard publications and from the virtual world are integrated to elicit possible recommendation domains for R&D to address. It also includes spatial distribution and cultural consumption of the legume that can indicate prospects for commercialization.

The changing scenario of agriculture over time led farming communities and policy makers to search for more remunerative and viable production portfolios. The diversification of agriculture towards non-food grain and high value commodities has been one of the best prospects because these commodities have the potential for income augmentation, employment generation, poverty alleviation and export promotion (Pingali and Rosegrant 1995, von Braun 1995, Jha 1996, Vyas 1996, Delgado and Siamwalla 1999, Ryan and Spencer 2001 and Joshi et al. 2004). Because of changing dietary patterns (Dorjee et al. 2002, Barghouti et al. 2003) among farming communities, the production portfolio has to be in sync with this change.

In developing countries, almost 80% of their protein requirements are derived from plants. Legumes rank second in importance to cereals as human food sources because they contain protein almost comparable to what is derived from animal and fish meat. Legumes, regarded as poor man's meat, are the cheapest sources of protein among the underprivileged that cannot afford animal and fish proteins. Pulses contain more protein than any other vegetable and thus are akin to animal and fish meat in food value. Fats , carbohydrates, and minerals are also present.

Pigeonpea, one of the legumes regarded as an orphan crop, plays a major dietary role among households in India and subsistence farm households in the dry tropics of the world like Africa. However, it has still a huge untapped potential for improving quantity and quality of production due to its high genetic variability that exists within the cultivated and wild relatives (Odeny 2007). The crop's wide adaptability and numerous uses besides food, account for its popularity. The crop has a high-energy content highly suited as food in cold weather or where physical exertion is pronounced. Immature fruits have

also been used as food like the garden beans and peas. At present, a total of 13,632 accessions from 74 countries are stored at the ICRISAT genebank (Uphadyaya 2007). Of this, 13,077 accessions belong to primary gene pool (Harlan and de Wit 1971). Pigeonpea is a hardy crop, widely adaptable and tolerant to temperatures as high as 35°C. The plant can survive as high as 2,500 to 3,000 masl. An average annual rainfall between 600 and 1,000 mm is most suitable. The crop cannot withstand heavy frost. However, it can be grown in humid areas, even over 2,500 mm of rainfall and is renowned for its drought tolerance. It gives economic yields of seeds in areas where rainfall averages about 400 mm annually. Although it cannot withstand water logging, it can be grown in a wide range of soils, as it tolerates low fertility. Some cultivars are tolerant of salinity and aluminum. A pH range of 4.5-8.4 is tolerated.

In plant production where nitrogen is the primary limiting factor, pigeonpea cultivation can add nitrogen to the soil that can improve a damaged ecosystem, such as the damage caused by fire (Arianoutsou and Thanos 1996). Nitrogen fixed by plants like pigeonpea is essentially 'free' for use by the host plant or by associated or subsequent crops. With nitrogen fertilizer costing a lot and often unavailable to subsistence farmers, dependency on N₂ fixation legumes or other N₂-fixing organisms are excellent alternatives.

Area, production and productivity

Area, production and productivity of pigeonpea show positive growth over the last 20 years as gleaned from literatures. Area and production of pigeonpea have increased in China, India and Myanmar. Productivity levels, however, have remained low compared to world averages. Secondary statistics show that increased production of pigeonpea was attributed to increase in area cultivated and price trend for the crop has shown slight decrease but often offset by significantly higher yields from improved cultivars. From 1961 to 1988, FAO identified 19 major producing countries from the arid and semi-arid tropics and from 1989 to present, 20 countries were documented. Pakistan was a major producer from 1961-1988. In the years 1989 to 2006, Kenya and Comoros were considered as major pigeonpea producers. Different authors across the globe have contradictory data as to the legume's yield per hectare, which explains the difficulty to calculate the actual data of each country. Using the FAO data as the reference for calculating the area for pigeonpea, the global area cultivated is approximately 4,630,865 ha.

The productivity per hectare of pigeonpea varieties has not substantially increased in spite of the advent of improved varieties produced by different research institutions like ICRISAT. To this writing, ICRISAT has bred the first cytoplasmic male-sterility system (CMS) that is anticipated to revolutionize pigeonpea's production globally. This CMS hybrid is mass-produced by members of the consortium instituted by ICRISAT such as the private seed companies and the public sector, specifically the national agricultural research system (NARS) partners. Likewise, taking advantage of pigeonpea's attributes such as slow-intensity production system can eliminate the costs of irrigation and reduce input (ie, fertilizers, land preparation, etc). The introduction of disease/insect-resistant lines can reduce a major cost component in high intensity production systems. For ICRISAT, developing a disease/insect-resistant genetic material in pigeonpea also presents a potential research prospect. Pigeonpea as a ratoon crop also presents a possible area for reducing costs.

Economic potential of pigeonpea

In spite of the great potential of pigeonpea's use as a food crop, improvement in technologies for creating value addition in pigeonpea-based products and innovations in marketing can significantly improve the crop's global economic prospects. According to Ryan and Spencer (2001), pigeonpea is emerging as an international crop. With the world facing water crisis, its popularity has become more pronounced in the last decade. Current predictions estimate that by the year 2050, at least 1 in every 4 persons is likely to live in a water deficient area. An important challenge facing scientists is to increase food production with less water. Several reviews on procedures for improving water efficiency use have recently been published (Zwart and Bastiaanssen 2005). And even successful approaches to achieve high yielding drought tolerant crops through biotechnology have also been documented and reviewed (Van Camp 2005). Crops that were once considered 'orphan' are now being incorporated into major breeding programs, as they seem to hold the key to the future's food security. The importance of a drought-tolerant legume such as pigeonpea, which combines several desirable traits for addressing climate change without jeopardizing its economics, cannot therefore be left unnoticed.

The increasing demand of pigeonpea worldwide can result in minor producing countries like the Oceania region and Africa (Table 6) to become major

producers because of the crop's attractiveness in the world market. India, the world's leading producer of pigeonpea in area and production cannot even meet its domestic demand for *toor/tur*. India imports from Myanmar, the second largest producer, to satisfy its requirements. In Kenya, pigeonpea (as green pods and green peas) is exported to Europe, Asia and Caribbean. These two countries (Myanmar and Kenya) consider pigeonpea as a major dollar earner.

Adoption and production constraints of pigeonpea

a. Constraints to Farmers' Adoption

Two of the major constraints for the low uptake of pigeonpea cultivation are:

- *Low productivity.* Across regions and countries where pigeonpea is one of their major crops, yield per unit area has not increased. The reports made on pigeonpea's high productivity are based on the increase in area cultivated. Intensive cultivation among subsistence farmers may be induced by an assured productivity per unit area.
Even in India, where pigeonpea production and area is the world's largest, the crop is not even considered as a cash crop because of poor yield performance. In the present cropping system, pigeonpea is a secondary crop; intercropped with main crops such as maize, sorghum, cotton and other plantation crops.
- *Socio-economic constraints.* Constraints that relate to economic attributes of the crop like the lack of reliable markets and support specifically on market information and poor extension service contribute to low adoption. Such is the case of the farmers in Thailand according to a survey by TechnoServe in 1998. The development of market linkages especially for dried peas and crafting green peas export, improving processing, and improving agri-support such as research, extension, including credit are the key recommendations identified by Massawe (2001). This is corollary with the findings of Janboome et al (2007) where uptake of new technologies on this legume can be encouraged by increasing domestic consumption through the creation of preference for pigeonpea-based food products. One other important area that can push for greater adoption is related to insect control that has become a big constraint among pigeonpea growers. The data collected from three years of on-

farm trials showed that the cost of insect control alone is calculated at 34% of total cost. Increasing the use of pigeonpea as a green manure can also be a major niche. However, non-availability of quality seeds and the lack of knowledge on pigeonpea's use as green manure and techniques of seed multiplication are critical issues towards adoption.

- Among minor producing areas, the need for training and education is a major concern. A deliberate and continuous advocacy on the importance and uses of the crop especially for addressing environmental and nutritional issues are needed. For instance, pigeonpea as green manure is monocropped and then incorporated into the soil at the flowering stage to improve soil fertility. This system is a valid use of biological resources but by large, it has not worked for smallholder farmers. A growing number of smallholder farmers are finding it beneficial to grow plants that not only improve the soil but also at the same time provide other benefits. These plants may be intercropped with regular crops and are often harvested before being used as mulch.

b. Constraints to productivity

- The fact that pigeonpea's productivity has remained static over the last several years can be explained by constraints revolving around the availability of good materials and the effects of the changing environment. Odeny (2006) identified six constraints, which can be translated as recommendation domains for improving the crop's production system.
- In the semi-arid tropics (SAT), pigeonpea's role is very significant. However, productivity is still quite low because of farmers' practice of continuously growing traditional landraces, which frequently suffer from several biotic and abiotic stresses. The current research initiatives by ICRISAT on hybrids has shown that yield advantage of pigeonpea hybrids can range from 20-150% as compared to existing varieties with yield of about 700 kg/ha. How to influence the farmers who have been traditionally planting varieties for the last five decades to switch to hybrids is a major challenge. Poor production practices such as low plant density, poor soil fertility, weed competition and insufficient/inappropriate use of fungicides and herbicides exacerbate the situation. Sanchez (2002) reported that the average annual nutrient depletion rates across 37 African countries are 22 kg N/ha, 2.5 kg P/ha, and 15 kg K/ha. Soil acidity affects more than 1.5 billion hectare worldwide, with acid soil constraints to legume production likely to increase as the result of acid

rain, long-term N fertilization, and natural weathering (Graham and Vance 2000). Hydrogen ion concentration, Al and Mn toxicity, and P, Mo or Ca deficiency all contribute to the problem (Graham 1992). Nodulation and N fixation and survival of rhizobia in soil are particularly affected under low P, acid soil conditions.

- Environmental (frequent and extreme droughts, easily eroded soils with poor water holding capacity) and socio-economic (lack of roads, marketing infrastructure and exploitation by middlemen) factors are equally important to reckon with. Drought problems for legumes are likely to worsen with the projected rapid expansion of water-stressed areas of the world from 28 to 30 countries today to 50 countries encompassing 3 billion people by 2030 (Postel 2000). There is a crucial need to increase drought tolerance in legumes; increasing salinity tolerance is a parallel requirement in many areas. Pigeonpea cultivation is the best bet option for farming communities coping with climate change like in the drylands of Africa, which covers about 40% of the arable landmass and where 25% of the population lives (Dar 2009).
- Major insect pests that include the pod boring Lepidoptera (*Helicoverpa armigera* Hübner, *Maruca vitrata* Geyer and *Etiella zinckenella* Treitsche), pod sucking bugs (*Clavigralla tomentosicollis* Ståll and *Clavigralla horrida* Germar) and podfly (*Melanagromyza chalcosoma* Spencer) (Minja et al. 2000) have contributed to poor productivity. Though pigeonpea diseases have been reported to be of minor importance in the past, recent surveys indicate that *Fusarium* wilt (*Fusarium udum* Butler), sterility mosaic disease (SMD), leaf spot (*Mycovellosiella cajani*) and to a lesser extent powdery mildew (*Leveillula taurica*) are diseases of economic concern. *Fusarium* wilt is especially prevalent in India and East Africa, where field losses of over 50% are common (Marley and Hillocks 1996). Pests and diseases considerably affect the yield of legumes in the third world countries (Kelly et al. 2003). This requires an integrated approach that takes into account certified seed program, fallow period to reduce vector population, plowing to bury infected plant tissue, biological control of root disease, chemical application, and breeding for resistance (Beaver et al. 2003, Coyne et al. 2003).
- The crop's long life cycle and a heterozygous genome structure conserved by out-crossing of up to 70% (Saxena et al. 1990) make breeding slow and expensive. Historically, desirable traits in pigeonpea have been selected by farmers from landraces to suit their production systems and uses. The establishment of ICRISAT in 1972 created a new focus and

research interest leading to the recent development of cytoplasmic male sterile (CMS) lines (Saxena and Kumar 2003, Mallikarjuna and Saxena 2005) for commercial hybrid breeding of pigeonpea. However, specific cultivar improvement has been difficult due to the limited knowledge on the inheritance of important traits and lack of understanding on the level of inter- and intra-specific genetic diversity.

- Wild relatives have been reported to possess many agronomical important traits such as resistance to pests and diseases (Reddy et al. 1996, Sharma et al. 2003), salinity tolerance (Subbarao et al. 1991) and high protein content (Saxena et al. 1996), all of which would be useful in cultivated pigeonpea. As different needs and opportunities surface, pigeonpea breeders need to incorporate new genetic sources using various breeding methods aided with modern tools such as molecular-assisted selection (Ribaut and Hoisington 1998).
- Cultivating pigeonpea in traditional legume growing areas and using the same technology means lower output cost. In this situation, promoting pigeonpea will not happen unless outstanding yield performance can be demonstrated and a market at remunerative prices is available.

The aforementioned recommendation domains require stronger and more adventurous breeding program, better use of marker-assisted technologies, and with emphasis on disease resistance, enhanced N fixation, and tolerance to edaphic soil constraints.

The ability of pigeonpea to provide nutrient rich-grain as well as increase soil nutrition should be considered and given research priority since this is anticipated to promote impact in the lives of poor smallholder farmers. There is also great potential in marketing organic pigeonpea since its production hardly requires any external inputs. As international markets are strengthened, introducing pigeonpea in various forms and creating awareness of its nutritional benefits will encourage consumption of pigeonpea (Odeny 2007). Likewise, research on pigeonpea pre-harvest factors for the canning and drying markets (Bidlack et al. 2001, Khattra et al. 2000, Durairaj and Ganapathy 2000, Echavez and Bosques 1998) needs attention.

Among the most important aspects of pigeonpea production that breeding work might be able to address as synthesized from the existing literatures are:

- In regions where pigeonpea is consumed as vegetable (green peas or pods) most of the planting materials used are of long duration type. Hence, there is the need to do breeding work for high yielding short or medium duration varieties or hybrids.
- For pigeonpea to be cultivated anytime of the year will require breeding for short duration and non-photosensitive varieties of both vegetable and pulse type.
- Varieties/hybrids resistant to major pests such as pod borers (*Helicoverpa armigera* and *Maruca vitrata*), pod sucking bug (*Clavigralla*), and pod fly (*Melanogromyza obtusa*); and diseases like Fusarium wilt and Phytopthora blight is an essential research domain since these are the pests and diseases that can cause severe yield reduction and grain quality or even total crop loss.
- Re-engineer the existing flower structure to enable cross-pollination by wind, which will avoid problems in seed multiplication of hybrid pigeonpea that is dependant on pollinators that are vulnerable to pesticides.

As gleaned in this consolidated review of literature, there are several aspects to harness the potential of pigeonpea cultivation. This rationalized the preparation of this material that was not meant to just review existing literature related to pre- and post-production system of pigeonpea, but to create a public good for various interest groups.

Appendices

Appendix 1. Vernacular names of pigeonpea across countries.

Country	Vernacular Names
ASIA	
Afghanistan	arhar, tuver (Duke 1981)
Armenia	yewof-aten (Westphal 1974)
Bangladesh	arhar, tur, tuver (Pathak 1970); toor (Duke 1981)
Bhutan	rahar (Krishnaswami 1959), rohor
Cambodia	sândaèk dai, sândaèk kroëb sâ, sândaèk klöng (Barlow and Porcher 2000)
China	chi dou, chi xiao dou, huang dou shu, mu dou, chieh tu, chieh tu tzu (Barlow and Porcher 2000); muk tau (McClure 8355 K); tan shue (McClure 2316 BM); shan tou ken (Kirtikar and Basu 1933); ki-mame (Kay 1979)
Hong Kong	shu dou, chi dou, mu dou (Barlow and Porcher 2000)
India	tuvari (Gathasaptasati 300 AD); tuvarica (Amarkosa 600 AD); adhaki (Susrutasamhiti 600 AD); arhuku (Piddington ex DC 1883); kakshi, karvitabhuja, mritana, pitapusha, shakhil, shakull, shanapushpika, supya, surashtaja, tuvarika, vritabija, dangri, tuer, turdal, tuvero, dhingra, kundi, tori, tuvara, rari, horodo, kandulo, kehu, kohlo, adagam, adagi, iyavai, paruppu, tuvarai, dalu, kariyudu, thogari (Kirtikar and Basu 1933); tangum, da-yil (Burkill 1925); gelooah-mah (F. von Mueller 1876); rahar, nandu (Krishnaswami 1959); arhar, arahar, tur, tuver, red gram, ihora, oror, thuvaran (Pathak 1970); urur, dhal urur (Drury 1858); oroha, laher, rahir (Wood 1902); turuku-togari, supiya, tuvarika, cegapputtuvurai, malaittuvarai, vellaittuvarai, ettakandulu, kandi, kondakandi, peddakandi, peddakondakandi, potukandi, sinnakandi (Lushington 1915); arhi, (Haines 1920); thora-paerou (Rheede 1686); tohar, dinger (Stewart 1869); arahara, arhur, urhur, tuver, tuvar, toovar, dal, dahl, dhal, tuur, tur, toor, tor, yellow dhal, red gram, kandulu, toovaram paruppu, togari (Duke 1981); kandi pappu

Continued

Appendix 1. Vernacular names of pigeonpea across countries *continued*.

Country	Vernacular Names
Indonesia	kacang bali, kacang gude, kacang kacang dal, kacang hiris (Barow and Porcher 2000); kachang hiris, kachang iris, kachang, kachang turis, turis, tunis, kachang puh, kachang puuh, kekatji, undis, kantje, kachang bali, kachang kadju, kachang kayo, tulis, lebuwi, kachang gude (De Clerq 1909); kayu (Backer 1911); sarupapa, ritik lias, bantatuin, puwe jai (Heyne 1927); kachang gar (Junghuhn cf Bentham 1852); bindatoe, bindatoin (Rumphius 1747); buntis (Toroes 2416 MICH); kasang bukuang (Bocca 9545 US); kasang kayu (Bocca 8511 US); gude (Backer 1911); arthar, kacang kayu, kacang turis, hiris, kace, kacang goode
Japan	pijonpii (Barlow and Porcher 2000); ki-mame (Kay 1979)
Laos	thwàx h'ê (Barlow and Porcher 2000); me ne nok (Kerr 2911 BM)
Malaysia	kachang (De 1974); kachang dal, kachang hiris (Kay 1979); kachang kayu (Ridley 1922); kacang eeris
Myanmar (Burma)	pai-sigong, pay-in-chong, pesigon (Kurz 1877, De 1974); pay-yen-khyung (Blanco cf Pickering 1879); pheang (Rai Lium Sum 1980); hpunlasi (Hundley et al. 1961); pe zin ngoun; pay-in-chong, pe-singon, pesingon, toor whole
Nepal	rahar (Barlow and Porcher 2000); adhad, arhar, rar (V.S. Doherty 1979)
Pakistan	arhar (Ali 1977); dal, rahas, thohar, thor, thur (Kirtikar and Basu 1933); akbar
Philippines	tabios, kardis, kudis, kaldis, kagyos, kagyus, kalios, kidis (R.B. Fox 90 PNH); caguios (Merill 1912); callos, gablos (Merill 256 PNH US); cadios, kadyos, kadios (Kay 1979); kagyas, kusia, bunga
Singapore	tuvaram paruppu
Sri Lanka	parippu, paripu (Gunawardena 1968); rata-tora (Thwaites 1864); thavarai (Trimen 1894); tora-parippu, waelundu, warlunduwael, witrawinansa (Hermann 1717); thovaray; dal, toor dhal, thora parippu; tuvaram paruppu
Taiwan	shu dou, mu dou (Barlow and Porcher 2000)
Thailand	ma hae, thua maetaai, thua rae (Barlow and Porcher 2000), togare, tua ma hae, tua mae tay, tua rad; togare, togari, tovarai, tua-re (Kay 1979); tua-he, tua-mahe (Pathanothai 1979)
United Arab Emirates	bisillah hindîyah, lûbyâ sùdânî (Barlow and Porcher 2000)

Continued

Appendix 1. Vernacular names of pigeonpea across countries *continued*.

Country	Vernacular Names
Vietnam	dau thong (Hô Pham-Hoang 1991); cay dau chieu, dau sang, dau thong dok thua he, dom san dek day, mak thona he (Gagnepain 1916); dau trieu, dau xay (Kay 1979)
Yemen	qishta (Blatter 1921)
AFRICA	
Angola	ervilha do congo (van der Maesen 1985); gibuapo (Gossweiler 4263 BM); jinsonge, quinsonge (Watt 1908, aranjo 77 LISC); angola pea (Lunan 1814), pois d' angole (Boisseaux 1967)
Benin	adoua, adjagui, klekloun, ambrevade, pois d' angole, waken maser, waken turawa, ekloui, otili, yepetoun, otiri (Boisseaux 1967); ohele
Botswana	pigeonpea, pois de angole, pois de congo (van der Maesen 1985)
Burkina Faso	pigeonpea, pois de angole, pois de congo (van der Maesen 1985)
Burundi	pigeonpea, pois de angole, pois de congo (van der Maesen 1985)
Cameroon	pigeonpea, pois de angole, pois de congo (van der Maesen 1985)
Cape Verde	pigeonpea, pois de angole, pois de congo (van der Maesen 1985)
Comoros	pigeonpea, pois de angole, pois de congo (van der Maesen 1985)
Congo	congo pea, no eye pea, ohota-farengota (Robyns 1954)
Côte d'Ivoire	pigeonpea, pois de angole, pois de congo (van der Maesen 1985)
Egypt	ads sudani (El Baradi 1978); lubia hadjeri sudani (Letourneux 251 W); lubie el narh (Kotschy 1013 W); shakhil, shaz (Kirtikar and Basu 1933); gandoles
Eritrea	pigeonpea, pois de angole, pois de congo (van der Maesen 1985)
Ethiopia	yewof-ater, ohota-farengota, salboca-ghed (Westphal 1974); ringa (Fukui 309 EAH)
Gabon	besange-be-djеле, uhange-mwa-mulungu, modjangi-a-getete, osange-werere, osange w'orungu, mutsangi-a-mwiri, osange-w'erere, osang'erere (Raponda-Walker et al. 1961); ossanga, butsangi-bu-muri, osang-eli, oando (Harms 1915)
Gambia	pigeonpea, pois de angole, pois de congo (van der Maesen 1985)
Ghana	adua, blorfoyor, blofo-yo yor, yo (Dalziel 1937, Kirtikar and Basu 1933)
Guinea	pois de guinea (Gerth v. Wijk 1911); red gram, congo pea, congo bean
Guinea-Bissau	pois de guinea (Gerth v. Wijk 1911); crioulo, feijão, congo pea
Kenya	bazar (Grant cf Pickering 1879); njogu (Kathrass 871 EAH); mbas (Kokwara 2024 EAH), mbaazi (Williams 1949); pigeonpea

Continued

Appendix 1. Vernacular names of pigeonpea across countries *continued*.

Country	Vernacular Names
Liberia	pigeonpea, pois de angole, pois de congo (van der Maesen 1985)
Madagascar	ambatribe, ambaty, amberivatry, ambote, ambraty, ambrevate (Du Puy et al. 2002); antsotry, ambaty, ambarivatry (Kirtikar and Basu 1933); pois cajan, ambrevade (Frenée 104 MPU)
Madeira	pigeonpea, pois de angole, pois de congo (van der Maesen 1985)
Malawi	nandolo, imbange, epweri, mbwete, mtambe za miti, mbenge, nyandolo, mbelemende (Williamson 1955)
Mali	pigeonpea, pois de angole, pois de congo (van der Maesen 1985)
Mauritius	ambrevade, ambrevatte (Cordemoy 1895)
Mozambique	dozi (Edwards V4225PRE); feijao boer (Torre 3523 LISC)
Niger	pigeonpea, pois de angole, pois de congo (van der Maesen 1985)
Nigeria	olele, orele, shingwazo, aduwa, waken yan mata (girl's bean), waken tantabani (pigeon's bean), waken damfani (fence bean), viovio, iofio, alev a batur, otili, otylie (Dalziel 1937); dan mata (Lely 109 K); waken maser (Egyptian bean), waken stambul (Turkish bean), waken turawa (white man's bean) (Kirtikar and Basu 1933); ohele, olhene
Rwanda	pigeonpea, pois de angole, pois de congo (van der Maesen 1985)
Saint Helena	pigeonpea, pois de angole, pois de congo (van der Maesen 1985)
São Tome and Principe	feijao congo (Esp. Santo 4132 LISC)
Senegal	cajan des indes, pois d' ambrevade, pois d' angole (Berhaut 1976)
Senegambia	cajan des indes, pois d' ambrevade, pois d' angole (Berhaut 1976)
Seychelles	pigeon pea (Robertson 1989); pois de angole, pois de congo (van der Maesen 1985)
Sierra Leone	konsin (Thomas 5155 B); konsho, e-konson, konsoba, soimese, yawendo (Dalziel 1037); bulom sitil (afzelius), fula-pulaar
Somalia	salboco-ghed, salboca-ghed (Westphal 1974)
South Africa	lidodze (Menne s.n. PRE); dhal, dhul (Wissell s.n. PRE); moswekane, tindhotsse, tindhotschi (van der Maesen 1985); oil-dal
Sudan	adassi (Bos 1427 WAG); ads sudani (Kay 1979); lubia el nach (Kotschy s.n.W); labia addasy
Swaziland	pigeonpea, pois de angole, pois de congo (van der Maesen 1985)
Tanzania	kalabama (Kakeya 5 EAH); mbaazi (Williams 1949); baazi, mbalassi, mbarasi, mbasi, mbazi (Harms 1915); mbani (Kay 1979)

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Appendix 1. Vernacular names of pigeonpea across countries *continued.*

Country	Vernacular Names
Togo	adua (Dalziel 1937)
Uganda	apena, burusa, burusu, lopena (Kay 1979); nogugu (Greenway 1828 EAH)
Zaire	ndeda, kindolia, omokunde, umukemde, lwando, zangizingungu, ngunde, wandu, wiandu, wuandu (Hauman 1954); osokgna (Germain 4086 EAH); n'ledika (Gersson 76 BR); lukunda (Hendricx 3817 EAH); mbaazi, kakunda bakishi, nkol (De 1974)
Zambia	Imposo (Kay 1979)
Zimbabwe	pigeonpea, pois de angole!, pois de congo (van der Maesen 1985)
Americas and Caribbean	
Anguilla	bipiccaa, ouandou, quingongi (Pickering 1879)
Antigua and Barbuda	bipiccaa, ouandou, quingongi (Pickering 1879)
Argentina	gandules, gandules verdes, quando, guandu, guandú, guandul, guisante de angola, guisante de paloma, guisante gunga, guisante gungo, planta de guandú (Barlow and Porcher 2000); poroto poroto paraguayo, sachacafé, falso café, arveja
Bahamas	bipiccaa, ouandou, quingongi (Pickering 1879); pigeon pea (Correll and Correll 1982)
Barbados	pigeonpea (Plukenet 1692); bipiccaa, ouandou, quingongi (Pickering 1879)
Belize	bipiccaa, ouandou, quingongi (Pickering 1879)
Bolivia	guandul, guandu (Barlow and Porcher 2000); pigeon pea
Brazil	fajao andu (Mexia 5318 US); feijao guandu (Archer 8019 US); guandu guendul, guendu (Bentham 1859); guandu de fava larga (Kay 1979); quando
Cayman Islands	gungo pea, pigeon pea (Proctor 1984)
Colombia	chicharo de paloma (Kay 1979); frijol del ano (Lehmann 8660K); frijol paloma (Arnay 324 CANB); frijol quinchoncho (Fernandez 1325 US); frisol guandus (Barriga 8378 US); guandua (Daniel 1484 US)
Costa Rica	frijol de palo, petipoa (Standley 48376 US); quimbolillo, timbolillo (van der Maesen 1985)
Cuba	gandul, gandur (Leon and Alain 1951); gadul (El Baradi 1978)
Dominica	bipiccaa, ouandou, quingongi (Pickering 1879)
Dominican Republic	guandul, guandula (Urban 1920)

Continued

Appendix 1. Vernacular names of pigeonpea across countries *continued*.

Country	Vernacular Names
Ecuador	frejol de palo (Charles Darwin Foundation 2005); guandú (Charles Darwin Foundation 2008); frujol da palo (van der Maesen 1985)
El Salvador	alberga, alverja (Calderon 529 US); frijol de palo (no author); red gram, sacha poroto, shantouken, tuver, yellow dhal, chilpite
French Guyana	bipiccaa, ouandou, quingongi (Pickering 1879)
Guadaloupe	pois d' angole, pois de sept ans (Duss 26 US); pois de bois, pois de l'Inde, pois de lisiere (Duss 1897)
Guatemala	cachito, frijol chino, frijol japones (Kay 1979)
Guyana	bipiccaa, ouandou, quingongi (Pickering 1879); pigeonpea, pea, green pea
Haiti	pois congo (Barker and Dardeau 1930); gandule ((Britton and Wilson 1924))
Honduras	chicharo (Standley 53645 US)
Jamaica	christmas pea (Lunan 1814); congo pea, gungo pea, pigeon pea (Adams 1972); gungo (Vernon Royes 1976); googoo beans, no-eye pea, angola pea (Lunan 1814); goongo pea
Martinique	pois d' angole, pois de sept ans (Duss 26 US); pois de bois, pois de l'Inde, pois de lisiere (Duss 1897)
Mexico	frijol de árbol (Mc Vaugh 1987); chicharo de arbol (Kay 1979); chicharo (Hernandez 99 MICH)
Montserrat	bipiccaa, ouandou, quingongi (Pickering 1879)
Netherland Antilles	wandoe (Gerth v. Wijk 1911)
Nicaragua	garbanzo falso (Kay 1979)
Panama	frizol de palo, guandu (Celestine 120 US)
Paraguay	kumanda yvyra'l, cumandáí
Peru	puso-poroto, pusporoto (Belshaw 3209 US); adhaki, ambrévade, arhar, cachito, caja, chieh tu tzu, chieh tu, chivatillo, congo-pea, feijao guandu, feijão-guandu, frijol de palo, gandul, guaduli, guandul, guisante-de-angola, kachang gude, kachang kayu, katjang bali, pigeon-pea, pois d'angole, pois cajan, puspo-poroto, chivatito
Puerto Rico	gandul, gandule, gandures (Britton and Wilson 1924); congo pea (Liogier 1988); gandal (Kay 1979); cachito, gandul, puerto rican pea, eode de árbol, frijol de la india, frijol guandul, frijol quinchancho (Barlow, S 2000)
Saint Kitts and Nevis	bipiccaa, ouandou, quingongi (Pickering 1879)

Continued

Appendix 1. Vernacular names of pigeonpea across countries *continued*.

Country	Vernacular Names
Saint Lucia	bipicaa, ouandou, quingongi (Pickering 1879)
Saint Vincent	bipicaa, ouandou, quingongi (Pickering 1879)
Suriname	wandoe, duivenbonen, arhar, dal, dhal, dhol, geode (Gert v. Wijk 1911)
Trinidad and Tobago	bipicaa, ouandou, quingongi (Pickering 1879)
Turks and Caicos Islands	bipicaa, ouandou, quingongi (Pickering 1879)
USA	pigeonpea (Plukenet 1692, Miller 1747); angola pea, seven year pea (Lunan 1814); cadjan pea (Harms 1915); goongo, gungo pea, no-eye pea (Fawcett and Rendle 1920)
Venezuela	quinchoncho (Pittier 1944); quinchonchillo (Steyermark and Huber 1978); quinchonchos (Duke 1981); quinchocho (Barlow S 2000)
Virgin Island	bipicaa, ouandou, quingongi (Pickering 1879)
<hr/>	
OCEANIA	
Australia	pigeonpea (van der Maesen 1985)
Caroline Islands	pigeonpea, puerto rican pea (Krauss 1911)
Cook Islands	pigeonpea, puerto rican pea (Krauss 1911)
Federated States of Micronesia	pigeonpea, puerto rican pea (Krauss 1911)
Fiji	congo pea, dahl, pigeon pea, rahar, red gram (Parham 1972); nggiringgiri, pi (Smith 1985)
French Polynesia	pigeonpea, puerto rican pea (Krauss 1911)
Guam	lenteha franchesa, lenteja francesa (Stone 1970);
Hawaii	pigeonpea, puerto rican pea (Krauss 1911); pī nūnū, pī pokoliko (Wagner et al. 1999); eode, eode bean, pigeon pea, arahar, ihora, laher, oroha, oror, tur, tuver
Mariana Islands	pigeonpea, puerto rican pea (Krauss 1911)
Nauru	pigeonpea, puerto rican pea (Krauss 1911)
New Caledonia	pigeonpea, puerto rican pea (Krauss 1911)
New Guinea	congo pea, dhal, pigeon pea (Verdcourt 1979)
Niue	puerto rican pea (Krauss 1911); pigeon pea (Sykes 1979)
Papua New Guinea	pigeonpea, puerto rican pea (Krauss 1911)
Pitcairn Island	pigeonpea, puerto rican pea (Krauss 1911)
Solomon Islands	pigeonpea, puerto rican pea (Krauss 1911)
Tonga	faka-tonga, pīfisi

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Appendix 1. Vernacular names of pigeonpea across countries *continued*.

Country	Vernacular Names
EUROPE	
Denmark	Ærtebønne, Ærteboenne (Duke 1981)
Estonia	harilik tuvihernes (Barlow and Porcher 2000)
Finland	Kyyhkynherne (Barlow and Porcher 2000)
France	ambarvasti, ambarvati, ambrevade, ambrevadier, ambrevale, ambrevate, ambrevatte, ambrevete, cajan, cytése cajan, cystése des indes, embrevade, lentille du soudan, pois d' angole, pois de bois, pois cajan, pois de congo, pois de guinea, pois de lisiere, pois négre, pois de pigeon, pois de saint-christophe, pois de sept ans, voteravate (Gerth v. Wijk 1911); pois d'angola, pois du congo, pois congo
Germany	angolische erbse, bohnenstrauch, catjangfasel, congoerbse, gelbe wallbohne, taubenerbsenbaum (Gerth v. Wijk 1911); brasiliанische angolaerbse, erbsenbohne, straucherbse, taubenerbsenbohne (Harms 1915); taubenerbse, strauchbohne (Balashev 1970); indianischer geissklee, indisches bohnenstrauch (van der Maesen 1985); anglische erbse, toor linsen
Great Britain	pigeonpea (Plukenet 1692, Miller 1747); angola pea, seven year pea (Lunan 1814); cadjan pea (Harms 1915); goongo, gungo pea, no-eye pea (Fawcett and Rendle 1920); eode pea,
Italy	pisello d'angola, pisello del tropico, caiano (Barlow and Porcher 2000)
Netherlands	balische boon (Rumphius 1747); duivenbonen (Gerth v. Wijk 1911); struikerwt, katjang geode (Barlow and Porcher 2000);
Poland	jinsonge (Balashev 1970), nicla indyjska (Duke 1981)
Portugal	feijão-guandu, guandú, guisante-de-angola, ervilha de Angola, ervilha do Congo (Duke 1981); tantaraca, tantaraga (Kirtikar and Basu 1933); feijão boere
Spain	guisante de paloma (Terra 1966); guisante enano (Kay 1979); cachito, frijol del monte, gandul, guando (Duke 1981); guandul (Liogier 1985); guandu (van der Maesen 1985); frejol de palo, gandures, fríjol de árbol, vaina del guandú (Barlow and Porcher 2000)
Sweden	duwärt (Barlow and Porcher 2000)
Turkey	guvercin bezelyesi, tohum (van der Maesen 1985)
Russia	golubinyi gorokh (Palibin 1948), kayanus (Palibin 1948); golubnii gorokh (Zhukovsky 1964)

Appendix 2. Global trend of pigeonpea cultivated area by region and by country (2000-2006).

Region/ Country	Cultivated area (ha)						
	2000	2001	2002	2003	2004	2005	2006
Asia							
Bangladesh	4,218,540	3,661,742	3,836,466	3,779,684	4,067,706	4,048,908	4,116,060
India	4,477	3,077	3,226	4,000	3,252	3,241	3,237
Myanmar	3,842,857	3,284,671	3,299,270	3,226,277	3,547,445	3,503,649	3,543,823
Nepal	341,909	344,086	501,075	521,505	487,329	513,000	540,000
Africa							
Burundi	29,297	29,908	32,895	27,902	29,680	29,018	29,000
Comoros	453,361	406,635	455,303	471,345	485,339	485,520	485,440
Congo	1,729	1,800	2,000	1,800	2,022	2,000	2,000
Kenya	8,340	8,574	7,814	8,198	8,066	8,000	8,000
Malawi	187,440	138,609	172,598	187,200	201,087	200,000	200,000
Tanzania	122,861	123,000	123,053	123,053	123,053	123,053	123,000
Uganda	66,197	66,197	67,416	66,667	66,667	68,027	68,000
Americas & Caribbean							
Bahamas	25,667	26,737	27,879	32,476	28,836	29,408	29,365
Dominican Republic	164	155	164	171	180	180	180
Grenada	11,903	12,683	13,000	15,662	13,000	13,000	13,000
Haiti	510	510	425	588	521	520	520
Jamaica	6,522	5,361	5,408	6,500	5,581	6,004	6,000
Panama	1,277	1,348	1,101	1,092	1,097	1,100	1,100
Puerto Rico	2,358	4,059	3,927	4,048	4,687	4,801	4,800
Trinidad & Tobago	143	100	244	200	168	165	165
Venezuela	302	653	1,000	969	1,102	1,138	1,100
Total	2,488	1,868	2,610	3,246	2,500	2,500	2,500

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Appendix 2. Global trend of pigeonpea cultivated area by region and by country (continued (1990-1999).

Regions/ Country	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	Cultivated area (ha)
Asia	4,158,696	3,598,495	3,294,640	4,136,803	4,717,201	3,812,099	3,705,089	4,318,022	3,067,239	4,369,071	
Bangladesh	5,857	5,344	5,380	4,603	3,989	4,054	5,660	6,000	6,000	5,656	
India	4,073,261	3,584,151	3,163,280	3,885,000	4,486,667	3,573,333	3,466,967	3,993,985	2,761,194	4,044,776	
Myanmar	59,845	67,734	99,200	219,200	204,379	208,759	207,299	292,006	275,398	293,862	
Nepal	19,733	17,848	16,780	28,000	22,166	25,953	25,163	26,031	24,647	24,777	
Africa	320,344	278,216	273,520	342,584	343,082	383,844	316,627	423,673	450,794	466,857	
Burundi	2,300	2,230	2,396	2,474	2,165	2,577	2,371	2,400	2,300	2,062	
Comoros	352	352	359	366	379	389	394	408	408	408	
Congo	6,400	6,400	6,400	6,400	6,400	7,361	7,835	7,832	8,144	8,307	
Kenya	95,272	57,163	77,593	138,461	147,288	121,730	71,307	179,592	185,108	201,860	
Malawi	102,369	87,745	73,121	92,063	87,301	139,535	103,897	101,892	115,227	124,416	
Tanzania	51,990	63,874	51,990	55,072	50,000	60,000	78,571	59,334	65,217	65,278	
Uganda	61,661	60,452	61,661	47,748	49,549	52,252	52,252	72,215	74,390	64,526	
Americas & Caribbean	63,679	72,456	52,921	22,349	39,537	44,505	39,749	38,149	45,094	36,252	
Bahamas	857	714	571	428	198	200	200	200	200	186	
Dominican Republic	33,497	41,200	25,770	22,086	19,202	26,749	20,856	18,411	24,431	19,614	
Grenada	433	442	442	467	476	476	484	493	425	425	
Haiti	8,667	8,444	6,667	6,250	4,054	6,250	7,500	7,500	6,250	6,250	
Jamaica	1,623	1,718	2,074	1,390	1,469	1,478	1,626	1,608	1,357	1,521	
Panama	3,591	4,246	4,302	3,542	3,750	4,052	4,587	4,414	4,585	4,392	
Puerto Rico	3,225	3,870	2,661	1,422	609	396	305	833	1,741	134	
Trinidad & Tobago	1,294	1,169	864	919	1,047	1,654	1,591	939	317	1,306	
Venezuela	10,492	10,653	9,570	7,845	6,536	5,446	3,850	3,751	4,538	2,424	
Total	4,542,719	3,949,167	3,621,081	4,501,736	5,099,820	4,240,448	4,061,465	4,779,784	3,563,127	4,972,180	

Appendix 2. Global trend of pigeonpea cultivated area by region and by country continued (1980-1989).

Regions/ Country	Cultivated area (ha)					
	1980	1981	1982	1983	1984	1985
Asia	2,598,883	2,900,075	3,329,256	3,407,943	4,377,336	4,405,892
Bangladesh	9,665	9,268	9,268	9,238	9,238	8,512
India	2,532,430	2,821,130	3,223,551	3,314,833	4,293,333	4,308,667
Myanmar	38,155	49,461	75,336	49,023	54,179	71,990
Nepal	15,833	17,416	18,208	31,830	17,567	14,189
Pakistan	2,800	2,800	2,893	3,019	3,019	662
Africa	209,710	208,705	219,286	208,157	199,539	220,952
Burundi	2,524	2,112	2,688	2,680	1,855	2,577
Congo	3,423	3,423	3,423	6,080	6,080	6,400
Kenya	-	-	-	-	-	-
Malawi	113,823	115,321	115,819	126,984	111,111	114,286
Tanzania	35,570	35,570	38,803	46,377	57,971	72,464
Uganda	54,370	52,279	58,553	26,036	22,522	25,225
Americas & Caribbean	48,616	44,549	43,466	35,813\	43,751	38,454
Bahamas	743	786	828	886	914	928
Dominican Republic	19,424	15,415	14,542	9,601	17,884	12,094
Grenada	765	704	634	548	550	535
Haiti	8,292	8,499	8,706	8,958	8,958	8,958
Jamaica	2,450	2,649	2,302	1,768	1,807	1,797
Panama	2,290	2,363	2,439	4,589	4,735	4,887
Puerto Rico	6,085	5,662	5,044	3,044	2,435	2,222
Trinidad & Tobago	1,870	1,827	1,685	1,250	958	1,108
Venezuela	6,697	6,644	7,286	5,169	5,510	5,925
Total	2,857,209	3,153,329	3,592,008	3,651,913	4,620,626	4,665,298
					4,404,472	4,118,847
						4,163,361
						4,994,365

Appendix 2. Global trend of pigeonpea cultivated area by region and by country continued (1970-1979).

Regions/ Country	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
Asia	2,648,325	3,194,237	2,865,768	3,264,726	2,728,670	2,599,064	3,561,779	2,929,101	3,268,485	3,203,521
Bangladesh	3,808	4,350	3,504	3,376	4,181	5,099	9,400	11,667	17,828	12,155
India	2,598,307	3,138,833	2,805,000	3,212,667	2,646,616	2,540,000	3,498,833	2,875,500	3,216,617	3,145,666
Myanmar	33,385	37,651	44,337	33,263	59,358	40,066	35,629	28,009	19,159	29,436
Nepal	11,380	11,486	11,486	12,162	16,981	12,748	16,000	12,838	13,513	13,513
Pakistan	1,445	1,917	1,441	3,258	1,534	1,151	1,917	1,087	1,368	2,751
Africa	223,280	179,618	181,626	171,158	249,025	299,508	195,572	201,989	207,005	173,728
Burundi	3,878	2,371	2,371	2,371	3,893	5,665	2,371	2,371	2,680	2,680
Congo	5,565	5,280	5,600	5,600	6,194	9,360	6,080	6,080	6,080	6,080
Malawi	118,044	114,286	115,873	119,047	134,513	182,266	120,635	123,809	126,984	119,048
Tanzania	28,340	21,645	14,359	15,942	24,779	39,409	33,333	33,333	33,333	28,803
Uganda	67,453	36,036	43,423	28,198	79,646	62,808	33,153	36,396	37,928	17,117
Americas & Caribbean	43,001	47,426	48,231	45,737	45,184	36,729	34,848	35,681	35,291	37,586
Bahamas	771	800	821	850	871	893	914	936	656	700
Dominican Republic	22,522	23,423	24,324	24,339	25,558	13,425	13,074	13,935	14,915	13,237
Grenada	552	442	552	572	578	595	624	675	728	655
Haiti	6,771	6,875	6,979	7,292	7,500	7,708	7,917	7,500	7,908	7,917
Jamaica	1,677	1,586	2,439	1,482	1,445	2,550	1,151	872	1,733	2,062
Panama	2,917	2,916	3,125	3,056	3,087	3,119	3,150	3,183	3,235	3,300
Puerto Rico	2,131	2,283	2,100	1,978	2,313	2,892	2,588	2,745	3,135	3,684
Trinidad & Tobago	907	1,711	1,797	1,231	1,246	1,270	1,270	1,500	1,837	1,800
Venezuela	4,753	7,390	6,094	4,937	2,586	4,277	4,160	4,335	4,279	4,231
Total	2,914,606	3,421,281	3,095,625	3,481,621	3,022,879	2,935,301	3,792,199	3,166,771	3,310,781	3,414,835

Appendix 2. Global trend of pigeonpea cultivated area by region and by country continued (1961-1969).

Regions/ Country	Cultivated area (ha)					
	1961	1962	1963	1964	1965	1966
Asia	3,505,975	2,328,866	2,686,648	2,368,770	3,204,814	2,948,149
Bangladesh	7,668	4,940	4,940	4,940	4,940	4,940
India	3,443,333	2,278,333	2,636,667	2,300,000	3,150,000	2,888,333
Myanmar	46,489	35,598	34,480	53,366	39,203	43,409
Nepal	8,108	8,108	8,108	8,180	8,784	8,784
Pakistan	377	1,887	2,453	2,264	1,887	2,683
Africa	119,679	123,754	148,971	137,256	145,885	128,245
Burundi	2,371	2,371	2,371	2,371	2,371	2,371
Congo	4,960	4,960	4,960	4,960	4,960	4,960
Malawi	82,540	85,714	88,889	98,413	111,111	98,413
Tanzania	14,493	14,493	33,832	7,188	9,425	13,348
Uganda	15,315	16,216	18,919	24,324	18,018	9,153
Americas & Caribbean	35,915	37,754	39,841	40,496	40,653	42,721
Bahamas	457	500	543	571	614	657
Dominican Republic	18,649	18,243	18,694	18,725	18,919	19,054
Grenada	637	637	646	646	654	663
Haiti	5,833	5,937	6,042	6,146	6,250	6,354
Jamaica	838	870	916	849	731	1,344
Panama	2,917	2,917	2,917	2,708	2,708	2,708
Puerto Rico	3,348	3,531	3,348	3,531	2,825	3,443
Trinidad & Tobago	750	800	1,066	1,134	1,202	1,134
Venezuela	2,486	4,319	5,669	6,186	6,750	7,364
Total	3,661,569	2,490,374	2,875,460	2,546,522	3,391,352	3,119,115
						3,150,499
						3,308,947

Appendix 3. Global production trend by region and by country (2000-2006).

Regions		2000	2001	2002	2003	2004	2005	2006
Asia								
Bangladesh	2,904,205	2,645,463	2,753,000	2,722,000	2,958,000	3,077,971	3,108,971	
India	3,000	2,000	2,000	2,000	2,000	2,000	2,000	3,000
Myanmar	2,690,000	2,250,000	2,260,000	2,210,000	2,430,000	2,400,000	2,430,000	
Nepal	188,734	320,000	466,000	485,000	500,000	649,971	649,971	
Africa								
Burundi	1,800	1,800	1,800	1,800	1,800	1,800	1,800	
Comoros	290	300	300	320	320	320	320	
Congo	5,296	5,402	5,001	5,001	5,001	5,000	5,000	
Kenya	65,604	73,463	93,203	98,280	105,571	105,000	105,000	
Malawi	79,000	79,000	79,000	79,000	79,000	79,000	79,000	
Tanzania	47,000	47,000	48,000	49,000	49,000	50,000	50,000	
Uganda	78,000	80,000	82,000	84,000	84,000	84,000	84,000	
Americas & Caribbean								
Bahamas	22,992	22,733	24,593	24,948	24,725	25,075	25,075	
Dominican Republic	115	110	115	120	125	125	125	
Grenada	13,213	13,000	13,000	13,000	13,000	13,000	13,000	
Haiti	500	500	500	500	500	500	500	
Jamaica	3,000	2,600	2,650	2,600	2,400	2,600	2,600	
Panama	1,226	1,348	1,300	1,300	1,300	1,300	1,300	
Puerto Rico	2,063	1,908	1,940	1,943	2,250	2,300	2,300	
Trinidad & Tobago	100	150	350	250	250	250	250	
Venezuela	785	1,642	2,780	2,800	2,900	3,000	3,000	
Total	3,204,187	2,955,161	3,086,897	3,064,349	3,307,417	3,428,166	3,459,166	

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Appendix 3. Global production trend by region and by country continued (1990-1999).

Regions	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	Production (t)
Asia	2,800,205	2,474,079	2,209,245	2,487,360	2,851,403	2,309,205	2,473,300	2,865,824	2,048,233	2,890,902	
Bangladesh	3,195	2,915	2,935	2,840	3,000	3,000	3,000	3,000	3,000	3,000	
India	2,746,600	2,416,800	2,133,000	2,331,000	2,692,000	2,144,000	2,309,000	2,656,000	1,850,000	2,710,000	
Myanmar	37,110	42,334	62,000	137,000	149,000	143,000	142,000	186,884	176,255	159,567	
Nepal	13,300	12,030	11,310	16,520	16,403	19,205	19,300	19,940	18,978	18,335	
Africa	243,650	208,250	208,725	227,660	226,959	230,677	223,012	232,181	249,460	281,133	
Burundi	2,400	2,400	2,500	2,400	2,100	2,500	2,300	2,400	2,300	2,000	
Comoros	250	250	255	260	269	276	280	290	290	290	
Congo	4,000	4,000	4,000	4,000	4,000	4,601	4,897	4,895	5,090	5,192	
Kenya	81,000	48,600	65,970	72,000	76,590	63,300	37,080	54,586	56,273	70,651	
Malawi	70,000	60,000	50,000	58,000	55,000	60,000	65,455	70,000	79,507	80,000	
Tanzania	35,0005	43,000	35,000	38,000	34,000	42,000	55,000	41,000	45,000	47,000	
Uganda	1,000	50,000	51,000	53,000	55,000	58,000	58,000	59,000	61,000	76,000	
Americas & Caribbean	56,432	65,762	45,687	41,954	37,792	45,361	37,752	29,484	31,916	33,783	
Bahamas	600	500	400	300	139	140	140	140	140	130	
Dominican Republic	38,596	47,471	29,692	24,516	21,314	29,692	23,150	15,226	20,078	21,772	
Grenada	510	520	520	550	560	570	570	580	500	500	
Haiti	3,900	3,800	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	
Jamaica	1,533	1,623	1,959	1,654	1,748	1,759	1,932	1,909	1,615	1,521	
Panama	1,616	1,911	1,936	1,700	1,800	1,945	2,243	2,154	2,201	2,108	
Puerto Rico	1,814	2,177	1,497	2,119	907	590	454	750	1,062	200	
Trinidad & Tobago	2,000	1,807	1,335	1,839	2,095	3,308	3,183	2,724	915	2613	
Venezuela	5,863	5,953	5,348	6,276	5,229	4,357	3,080	3,001	2,405	1,939	
Total	3,100,287	2,748,091	2,463,657	2,756,974	3,116,154	2,585,243	2,734,064	3,127,489	2,329,609	3,205,818	

Appendix 3. Global production trend by region and by country continued (1980-1989).

Appendix 3. Global production trend by region and by country continued (1970-1979).

Regions	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	Production (t)
Asia	1,877,363	1,921,291	1,724,497	1,963,195	1,451,489	1,875,900	2,140,022	1,761,762	1,964,549	1,926,522	
Bangladesh	2,677	2,684	2,162	2,083	2,216	3,600	5,800	7,200	11,000	7,500	
India	1,842,200	1,883,300	1,683,000	1,927,600	1,408,000	1,834,200	2,099,300	1,725,300	1,929,700	1,887,400	
Myanmar	23,470	25,791	30,071	22,785	31,460	28,287	24,406	19,186	13,124	20,164	
Nepal	8,000	8,500	8,500	9,000	9,000	9,000	9,500	9,500	10,000	10,000	
Pakistan	1,016	1,016	764	1,727	813	813	1,016	576	725	1,458	
Africa	132,406	132,535	136,908	123,100	141,600	121,600	141,900	147,500	151,500	120,274	
Burundi	2,300	2,300	2,300	2,300	2,200	2,300	2,300	2,300	2,600	2,600	
Congo	3,300	3,300	3,500	3,500	3,500	3,500	3,800	3,800	3,800	3,800	
Malawi	70,000	72,000	73,000	75,000	76,000	74,000	76,000	76,000	80,000	75,000	
Tanzania	16,806	14,935	9,908	11,000	14,000	16,000	23,000	23,000	23,000	19,874	
Uganda	40,000	40,000	48,200	31,300	45,900	25,500	36,800	40,400	42,100	19,000	
Americas & Caribbean	45,444	46,403	47,578	44,376	45,050	48,390	32,293	33,642	37,053	36,266	
Bahamas	540	560	575	595	610	625	640	655	459	490	
Dominican Republic	25,000	26,000	27,000	27,016	28,369	29,454	14,512	15,468	16,556	14,693	
Grenada	650	520	650	673	680	700	735	795	857	771	
Haiti	3,250	3,300	3,350	3,500	3,600	3,700	3,800	3,600	3,796	3,800	
Jamaica	1,996	1,887	2,903	1,764	1,720	2,143	1,370	1,038	2,062	2,454	
Panama	1,400	1,400	1,500	1,467	1,482	1,497	1,512	1,528	1,553	1,584	
Puerto Rico	3,175	3,402	3,130	2,948	3,447	4,309	3,856	4,090	4,672	5,489	
Trinidad & Tobago	1,814	3,422	3,595	2,463	2,493	2,540	2,540	3,000	3,675	3,600	
Venezuela	7,619	5,912	4,875	3,950	3,649	3,422	3,328	3,468	3,423	3,385	
Total	2,055,213	2,100,229	1,908,983	2,130,671	1,639,139	2,045,890	2,314,215	1,942,904	2,153,102	2,083,062	

Appendix 3. Global production trend by region and by country continued (1961-1969).

Regions	1961	1962	1963	1964	1965	1966	1967	1968	1969
Asia									
Bangladesh	2,108,109	1,401,433	1,615,967	1,426,804	1,927,402	1,773,705	1,158,355	1,774,041	1,855,633
India	4,064	3,048	3,048	3,048	3,048	3,048	3,048	3,048	3,050
Myanmar	2,066,000	1,367,000	1,582,000	1,380,000	1,890,000	1,733,000	1,129,700	1,741,100	1,815,800
Nepal	31,845	24,385	23,619	36,556	26,865	29,735	17,091	21,072	28,377
Pakistan	6,000	6,000	6,000	6,000	6,500	6,500	7,500	7,500	8,000
Africa	200	1,000	1,300	1,200	1,000	1,422	1,016	1,321	406
Burundi	84,400	87,400	105,744	99,360	101,903	86,770	105,928	111,544	136,188
Congo	2,300	2,300	2,300	2,300	2,300	2,300	2,300	2,300	2,300
Malawi	3,100	3,100	3,100	3,100	3,100	3,100	3,100	3,100	3,300
Tanzania	52,000	54,000	56,000	62,000	70,000	62,000	64,000	66,000	68,000
Uganda	10,000	10,000	23,344	4,950	6,503	9,210	9,328	12,944	12,268
Americas & Caribbean	17,000	18,000	21,000	27,000	20,000	10,160	27,000	27,000	50,320
Bahamas	35,446	36,952	38,936	39,684	39,383	41,488	42,774	43,325	44,199
Dominican Republic	320	350	380	400	430	460	480	500	520
Grenada	20,700	20,250	20,750	20,785	21,000	21,150	17,091	21,500	23,000
Haiti	750	750	760	760	770	780	750	750	700
Jamaica	2,800	2,850	2,900	2,950	3,000	3,050	3,100	3,150	3,200
Panama	998	1,035	1,090	1,010	870	1,600	2,260	2,497	2,038
Puerto Rico	1,400	1,400	1,400	1,300	1,300	1,300	1,300	1,300	1,200
Trinidad & Tobago	4,989	5,262	4,989	5,262	4,209	4,989	4,264	4,400	4,264
Venezuela	1,500	1,600	2,132	2,268	2,404	2,268	2,858	2,313	1,905
Total	2,227,955	1,525,785	1,760,647	1,565,848	2,068,688	1,901,963	1,307,057	1,928,910	2,036,020

Appendix 4. Global average yield per hectare by region and country (2000-2006).

Region/ Country		2000	2001	2002	2003	2004	2005	2006
Asia		665	741.25	748.75	752.75	805.50	866.25	850.75
Bangladesh		670	650	620	500	615	617	618
India		700	685	685	685	685	685	686
Myanmar		525	930	930	930	1026	1267	1203
Nepal		767	700	760	896	896	896	896
Africa		751.43	770	735	752	733.14	736.28	736.28
Burundi		1041	1000	900	1000	890	900	900
Comoros		705	700	710	750	720	727	727
Congo		635	630	640	610	620	625	625
Kenya		350	530	540	525	525	525	525
Malawi		643	643	642	642	642	642	642
Tanzania		710	710	712	735	735	735	735
Uganda		1176	1176	1000	1000	1000	1000	1000
Americas & Caribbean		1020.55	1051.17	1111.33	1037.78	1074.44	1077.67	1087.89
Bahamas		700	710	698	700	695	694	694
Dominican Republic		1110	1025	1000	830	1000	1000	1000
Grenada		980	980	1177	850	960	961	961
Haiti		460	485	490	400	430	433	433
Jamaica		960	1000	1181	1190	1185	1181	1182
Panama		875	470	494	480	480	479	479
Puerto Rico		700	1500	1432	1250	1490	1515	1515
Trinidad & Tobago		2600	2515	2780	2890	2630	2636	2727
Venezuela		800	780	750	750	800	800	800
Average Yield/Hectare		812.33	854.14	865.03	847.51	871.03	893.40	891.64

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Appendix 4. Global average yield per hectare by region and country continued (1990-1999).

Region/ Country		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Asia		628.25	629.50	629.50	608	694.25	691.25	662	642.75	645	678.25
Bangladesh		545	545	545	617	752	740	530	500	500	760
India		674	674	674	600	600	600	666	665	670	670
Myanmar		620	625	625	625	685	685	685	640	640	543
Nepal		674	674	674	590	740	740	767	766	770	740
Africa		773.14	901.71	773.14	750.71	749.28	723.57	752.14	690.57	691.28	742
Burundi		1043	1943	1043	970	970	970	970	1000	1000	970
Comoros		710	710	710	710	710	710	710	710	710	710
Congo		625	625	625	625	625	625	625	625	625	625
Kenya		850	850	850	520	520	520	520	520	304	350
Malawi		684	684	684	630	630	430	630	687	690	643
Tanzania		673	673	673	690	680	700	700	691	690	720
Uganda		827	827	827	1110	1110	1110	1110	817	820	1176
Americas & Caribbean		838.78	838.78	838.78	1048.55	1048.55	1050.78	1049.33	1013.67	979.67	1027.44
Bahamas		710	710	710	710	710	710	710	710	710	710
Dominican Republic		1152	1152	1152	1110	1110	1110	1110	827	830	1110
Grenada		1177	1177	1177	1177	1177	1197	1177	1177	1177	1177
Haiti		450	450	450	480	480	480	480	400	400	480
Jamaica		944	944	944	1190	1190	1190	1188	1187	1190	1000
Panama		450	450	450	480	480	480	489	488	480	480
Puerto Rico		562	562	562	1490	1490	1490	1490	625	610	1490
Trinidad & Tobago		1545	1545	1545	2000	2000	2000	2000	2909	2890	2000
Venezuela		559	559	559	800	800	800	800	800	530	800
Average Yield/Hectare		746.72	790	747.14	812.42	830.69	821.87	821.16	782.33	771.98	815.90

Appendix 4. Global average yield per hectare by region and country continued (1980-1989).

Region/ Country	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Asia										
Bangladesh	631	630.80	631	561.80	634.40	613	611	615	587	575
India	755	755	755	617	617	520	510	520	530	530
Myanmar	694	694	694	600	600	600	600	600	600	600
Nepal	538	538	538	685	685	675	675	685	685	685
Pakistan	632	631	632	377	740	740	740	740	590	530
Africa	536	536	536	530	530	530	530	530	530	530
Burundi	783.20	783.20	783.20	806.80	805	805	805	805	805	757.5
Congo	1042	1042	1042	970	970	970	970	970	970	970
Kenya	-	-	-	-	-	-	-	-	-	520
Malawi	668	668	668	639	630	630	630	630	630	630
Tanzania	618	618	618	690	690	690	690	690	690	690
Uganda	478	478	478	1110	1110	1110	1110	1110	1110	1110
Americas & Caribbean										
Bahamas	923.22	923.22	923.22	1047.44	1047.44	1047.44	1047.44	1047.44	1047.44	1047.44
Dominican Republic	700	700	700	700	700	700	700	700	700	700
Grenada	854	854	854	1110	1110	1110	1110	1110	1110	1110
Haiti	1177	1177	1177	1177	1177	1177	1177	1177	1177	1177
Jamaica	482	482	482	480	480	480	480	480	480	480
Panama	960	960	960	1190	1190	1190	1190	1190	1190	1190
Puerto Rico	875	875	875	480	480	480	480	480	480	480
Trinidad & Tobago	857	857	857	1490	1490	1490	1490	1490	1490	1490
Venezuela	1889	1889	1889	2000	2000	2000	2000	2000	2000	2000
Average Yield/Hectare	779.14	779.07	779.14	805.35	828.95	821.81	821.15	822.48	813.15	793.31

Appendix 4. Global average yield per hectare by region and country continued (1970-1979).

Region/ Country		Yield per hectare (kg)								
	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
Asia	669.60	634.40	634.40	544	709.20	605.20	634.40	634.40	634.40	634.40
Bangladesh	703	617	617	530	706	617	617	617	617	617
India	709	600	600	600	722	600	600	600	600	600
Myanmar	703	685	685	530	706	685	685	685	685	685
Nepal	703	740	740	530	706	594	740	740	740	740
Pakistan	530	530	530	530	706	530	530	530	530	530
Africa	593	805	805	799	406	805	805	805	805	805
Burundi	593	970	970	565	406	970	970	970	970	970
Congo	593	625	625	565	406	625	625	625	625	625
Malawi	593	630	630	565	406	630	630	630	630	630
Tanzania	593	690	690	565	406	690	690	690	690	690
Uganda	593	1110	1110	1735	406	1110	1110	1110	1110	1110
Americas & Caribbean	1136.67	1047.44	1047.44	1115.33	1167.89	1047.44	1047.44	1047.44	1047.44	1047.44
Bahamas	700	700	700	700	700	700	700	700	700	700
Dominican Republic	1110	1110	1110	1110	2194	1110	1110	1110	1110	1110
Grenada	1177	1177	1177	1177	1177	1177	1177	1177	1177	1177
Haiti	480	480	480	480	480	480	480	480	480	480
Jamaica	1190	1190	1190	1190	1190	1190	1190	1190	1190	1190
Panama	480	480	480	480	480	480	480	480	480	480
Puerto Rico	1490	1490	1490	1490	1490	1490	1490	1490	1490	1490
Trinidad & Tobago	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
Venezuela	1603	800	800	1411	800	800	800	800	800	800
Average Yield/Hectare	799.77	828.95	828.95	819.44	761.03	819.21	828.95	828.95	828.95	828.95

Appendix 4. Global average yield per hectare by region and country continued (1961-1969).

Region/ Country	Yield per hectare (kg)					1969		
	1961	1962	1963	1964	1965	1966	1967	1968
Asia	634.40	634.40	634.40	634.40	634.40	634.40	634.40	634.40
Bangladesh	617	617	617	617	617	617	617	617
India	600	600	600	600	600	600	600	600
Myanmar	685	685	685	685	685	685	685	685
Nepal	740	740	740	740	740	740	740	740
Pakistan	530	530	530	530	530	530	530	530
Africa	805	805	805	805	805	805	805	805
Burundi	970	970	970	970	970	970	970	970
Congo	625	625	625	625	625	625	625	625
Malawi	630	630	630	630	630	630	630	630
Tanzania	690	690	690	690	690	690	690	690
Uganda	1110	1110	1110	1110	1110	1110	1110	1110
Americas & Caribbean	1047.44	1047.44	1047.44	1047.44	1047.44	1047.44	1047.44	1047.44
Bahamas	700	700	700	700	700	700	700	700
Dominican Republic	1110	1110	1110	1110	1110	1110	1110	1110
Grenada	1177	1177	1177	1177	1177	1177	1177	1177
Haiti	480	480	480	480	480	480	480	480
Jamaica	1190	1190	1190	1190	1190	1190	1190	1190
Panama	480	480	480	480	480	480	480	480
Puerto Rico	1490	1490	1490	1490	1490	1490	1490	1490
Trinidad & Tobago	2000	2000	2000	2000	2000	2000	2000	2000
Venezuela	800	800	800	800	800	800	800	800
Average Yield/Hectare	828.95	828.95	828.95	828.95	828.95	828.95	828.95	828.95

Appendix 5. FAO Database for Pigeonpea Area, Yield and Production in Eastern and Southern African Region.

Country	Area (ha)			Yield (kg/ha)			Production (t)		
	1980-82	1990-92	2000-02	1980-82	1990-92	2000-02	1980-82	1990-92	2000-02
Burundi	2,350	2,300	2,000	1,080	1,058	900	2,543	2,433	1,800
Kenya	-	-	155,667	-	-	365	-	-	57,000
Malawi	115,333	100,000	123,000	668	597	642	77,000	60,000	79,000
Tanzania	36,667	56,000	66,000	618	676	712	22,667	37,667	47,000
Uganda	55,000	61,333	78,000	480	826	1,000	26,333	50,667	78,000

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Appendix 6. Pigeonpea Area, Yield and Production in Eastern and Southern African Region.

Country	Area (ha)			Yield (kg/ha)			Production (t)		
	1980-82	1990-92	2000-02	1980-82	1990-92	2000-02	1980-82	1990-92	2000-02
Burundi	2,441	2,301	1,843	1,042	1,343	980	2,543	2,433	1,800
Kenya	-	76,676	166,216	-	850	473	-	65,190	77,423
Malawi	114,988	87,745	122,971	668	684	643	77,000	60,000	79,000
Tanzania	36,648	55,951	66,603	618	673	711	22,667	37,667	47,333
Uganda	55,067	61,258	72,137	478	827	1,117	26,333	50,667	80,000

FAOStat 2008.

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About ICRISAT



The International Crops Research Institute for the Semi-Arid-Tropics (ICRISAT) is a non-profit, non-political organization that conducts agricultural research for development in Asia and sub-Saharan Africa with a wide array of partners throughout the world. Covering 6.5 million square kilometers of land in 55 countries, the semi-arid tropics have over 2 billion people, and 644 million of these are the poorest of the poor. ICRISAT and its partners help empower these poor people to overcome poverty, hunger and a degraded environment through better agriculture.

ICRISAT is headquartered in Hyderabad, Andhra Pradesh, India, with two regional hubs and four country offices in sub-Saharan Africa. It belongs to the Consortium of Centers supported by the Consultative Group on International Agricultural Research (CGIAR).

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