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NEW CHALLENGES IN THE CASSAVA TRANSFORMATION IN NIGERIA AND GHANA

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EXECUTIVE SUMMARY

Cassava is Africa's second most important food staple, after maize, in terms of calories consumed. In the early 1960s, Africa accounted for 42 percent of world cassava production. Thirty years later, in the early 1990s, Africa produced half of world cassava output, primarily because Nigeria and Ghana increased their production four fold. In the process, Nigeria replaced Brazil as the world's leading cassava producer.

The cassava transformation involves a shift from production as a low-yielding, famine-reserve crop to a high-yielding cash crop increasingly prepared and consumed as *gari*, a dry cereal. This discussion paper aims to document the key factors which are driving the cassava transformation in Nigeria and Ghana, two of the three largest cassava producing countries in Africa: Nigeria, the Democratic Republic of Congo, and Ghana.

In Nigeria and Ghana, four key factors are driving the cassava transformation. First, the IITA's new high-yielding Tropical Manioc Selection (TMS) varieties boosted cassava yield by 40 percent without fertilizer application. Second, high consumer demand for cassava by rural and urban households fueled the producer incentive to plant more land to cassava. Third, the use of the mechanical grater to prepare *gari* released labor, especially female labor, from processing for planting more cassava. Fourth, the Africa-wide biological control program averted the devastating cassava mealybug epidemic.

In the mid 1980s, the Nigerian government invested in measures to diffuse the TMS varieties that were released to farmers in 1977. By the late 1980s, the TMS diffusion in Nigeria had become an Africa's agricultural success story *par excellence*! In 1989 in Nigeria, IITA researchers conducting the Collaborative Study of Cassava in Africa (COSCA) study found that farmers in 60 percent of the surveyed villages planted the TMS varieties. The COSCA study farmers in Nigeria praised the TMS varieties as being ideal for *gari* preparation but complained that harvesting and peeling the TMS varieties by hand proved laborious.

From the mid 1980s to the early 1990s in Nigeria, during the rapid diffusion of the TMS varieties, cassava production per capita increased significantly and cassava prices to consumers fell dramatically. The dramatic reduction in the cassava prices to consumers represents a significant increase in the real income of the millions of the rural and urban households who consume cassava as the most important staple. Similarly, from the mid 1980s to the early 1990s in Nigeria, cassava served as the main source of cash income for cassava-producing households. From the mid 1980s to the early 1990s, the diffusion of the TMS varieties, by benefiting both consumers and farmers, proved to be a powerful poverty fighter in Nigeria!

But from the early 1990s in Nigeria, the increasing per capita cassava production leveled off and the price of cassava to consumers rose relative to other staples. In the early 1990s in Nigeria, farmers were facing a serious problem in recruiting sufficient labor for harvesting and processing the high-yielding TMS varieties because the planting of the TMS varieties shifted the cassava labor constraint from weeding to harvesting. Developing a labor-saving technology for the smallholder cassava harvesting is now the most critical challenge in the cassava transformation in Nigeria. This challenge is more urgent than further increase in cassava yield.

In Ghana, the cassava transformation has lagged behind Nigeria by about a decade. For example, the dramatic increase in cassava production occurred in Nigeria from 1984 to 1992 and in Ghana from 1990 to 2001. In Ghana, until the drought which occurred in the early 1980s and resulted in the failure of food crops except cassava, government agricultural policies emphasized large scale production of grains by the public sector and neglected cassava as an inferior food whose consumption was destined to decline as incomes increased.

To summarize, the key lesson from the 40 years, form the early 1960s to early 2000s, of the cassava transformation in Nigeria and Ghana is that cassava is a powerful poverty fighter in Africa. Enhancing the value of cassava as a powerful poverty fighter in Africa poses the following challenges to the African political leaders and policy makers and to cassava researchers and donors:

- The resumption of long-term core research funding for cassava research in Africa is critical and urgent.
- If any cassava harvesting or peeling machine designed for smallholders can be identified anywhere in the world it should be urgently put to on-farm test in Africa with a view to adapt, fabricate, and diffuse it to farmers if confirmed suitable in the on-farm testing.
- If available machines cannot be confirmed suitable for the smallholder use, cassava breeding and engineering research should be initiated with engineers and breeders working hand in hand to develop cassava varieties that can be harvested and processed mechanically and the harvesting and the processing machines for the smallholders.
- African governments need to encourage their private sectors, for example with intellectual property rights protection, to make the necessary investments in developing technologies for expanded use of cassava as raw material in the livestock feed, food, and non-food industries within Africa.

Keywords: Cassava, Nigeria, Ghana, Successes in Africa, agriculture, transformation

TABLE OF CONTENTS

NEW CHALLENGES IN THE CASSAVA TRANSFORMATION IN NIGERIA AND GHANA

Felix Nweke

1. INTRODUCTION

Cassava is Africa's second most important food staple, after maize, in terms of calories consumed. Cassava is a major source of calories for roughly two out of every five Africans. In some countries, cassava is consumed daily and sometimes more than once a day. In the Democratic Republic of Congo (hereafter the Congo), cassava contributes more than 1000 calories per person per day to the diet and many families eat cassava for breakfast, lunch, and dinner. Cassava is consumed with a sauce made with ingredients rich in protein, vitamins, and minerals. In the Congo, Madagascar, Sierra Leone, Tanzania and Zambia, cassava leaves are consumed as a vegetable (Jones 1959; Fresco 1986; Dostie et al. 1999; Haggblade and Zulu 2003). Cassava leaves are rich in protein, vitamins, and minerals (Latham 1979).

Nevertheless, in Africa, cassava is a marginalized crop in food policy debates because it is burdened with the stigma of being an inferior, low-protein food that is uncompetitive with the glamour crops such as imported rice and wheat. Many food policy analysts consider cassava an inferior food because it is assumed that its per capita consumption will decline with increasing per capita incomes. In some East and Southern African countries, such as Malawi, Tanzania, and Zambia, British colonial policies forced indigenous farmers to plant cassava as a famine-reserve measure and subsidized maize grown by settler farmers (Jones 1959). That policy has stigmatized cassava in the minds of many African farmers as a "colonial" crop (Marter 1978).

THE CASSAVA TRANSFORMATION IN AFRICA

The dramatic cassava transformation[1] that is under way in Nigeria and Ghana is Africa's best kept secret. The cassava transformation describes how the new TMS varieties have transformed cassava from a low-yielding, famine-reserve crop to a high-yielding cash crop that is

[1] This does not mean transformation in the processing sense from fresh root to processed forms.

prepared and consumed as *gari*, a dry cereal [2]. With the aid of mechanical graters to prepare *gari*, cassava is increasingly being produced and processed as a cash crop for urban consumption in Nigeria and Ghana.

In Africa, traditionally, cassava is produced on small-scale family farms. The roots are processed and prepared as a subsistence crop for home consumption and for sale in village markets and shipment to urban centers.

Over the past 50 years, smallholders in Nigeria and Ghana have increased the production of cassava as a cash crop, primarily for urban markets. This shift to commercial production for urban consumers, livestock feed, and industrial uses can be described as the cassava transformation. During the cassava transformation, high-yielding cassava varieties increase yields while labor-saving and improved processing technologies reduce the cost of producing and processing cassava food products to the point where they are competitive with food grains such as wheat, rice, maize, and sorghum for urban consumers. Looking ahead, as the costs of cassava production, harvesting, processing, and marketing are reduced, one can expect cassava to play an expanded role as a source of livestock feed and industrial raw material in Africa as well as a source of foreign exchange earnings through the export of cassava pellets for livestock feed.

The cassava transformation, as described in detail by Nweke et al. (2002), encompasses four stages: Famine Reserve, Rural Food Staple, Urban Food Staple, and Industrial Uses and Livestock Feed (Table 1.1):

Stage I: Famine Reserve

Today in many countries in Eastern and Southern Africa -- Malawi, Tanzania, and Zambia -- maize is the preferred food and cassava is planted as a famine-reserve crop. In the famine reserve stage, cassava is usually harvested late and often on a meal to meal basis. In fact, farmers in southern Madagascar plant tracts of cassava specifically as a hedge against drought. In normal rainfall years, farmers harvest only part of their cassava crop. But in drought years, when the main rice crop falters, they harvest their entire cassava crop, dry it and ship it throughout the country via a large network of private traders (Dostie et al. 1999).

[2] *Gari* is a granulated and toasted cereal-like cassava food product that is convenient for consumption in urban environments because it is in a ready to eat form and it has an extended shelf life.

Table 1.1--Stages of the cassava transformation

	I. Famine Reserve Crop	II. Rural Food Staple	III. Cash Crop for Urban Consumption	IV. Livestock Feed & Industrial Raw Material
COSCA COUNTRIES	Tanzania	Congo, Cote d'Ivoire, & Uganda	Nigeria and Ghana	________
CASSAVA PRODUCTION OBJECTIVE	* Mostly for home consumption * Cassava is the secondary food staple	* Mostly for home consumption * Cassava is the primary food staple in the Congo * Cassava is a secondary food staple in Cote d'Ivoire & Uganda • Cassava is a family food • staple in households	* Mostly for sale as *guri* in urban centers	* Industrial starch and pellets for export
POLITICAL AND ECONOMIC ENVIRON-MENT	* In areas with uncertain rainfall: --Colonial gov'ts. encouraged cassava production as a famine-reserve crop starting in the 1920s --Since independence, Tanzanian gov't. encouraged cassava production during periods of drought	* The governments of the Congo and Cote d'Ivoire encourage the importation of rice and wheat	* Increasing urban demand for convenient foods * Improved rural roads for easy farmer access to market centers * Government policies encourage the replacement of imported wheat and rice with cassava food products	* Policy of substitution of cassava starch for imported starch * Export promotion

Table 1.1--Stages of the cassava transformation (continued)

	I. Famine Reserve Crop II. Rural Food Staple	III. Cash Crop for Urban Consumption	IV. Livestock Feed & Industrial Raw Material
TECHNOLOGY DEVELOPMENT			
1. Genetic Improvement	* Colonial governments Established research stations in Tanzania, Nigeria, the Congo, etc. • Research priorities focused on controlling cassava mosaic virus & brown streak virus •	* IITA developed high-yielding TMS varieties * IITA organized training programs for national cassava scientists	* Early (under 12 months) bulking varieties * Cassava roots suitable for mechanical harvesting and peeling
2. Seed	* Farmer to farmer exchange of planting materials	* National research and extension programs and private-sector agencies multiply and distribute planting materials of improved varieties	* Private seed companies
3. Agronomic Practices	* Farmers planted at will, compatible with labor demand schedule for cash crop	* Timely planting * High stand density * Low Frequency of inter-cropping	* Timely planting * Optimum stand density * Mono-cropping
4. Weeding	* Occasional weeding using hand-hoe by family labor	* Regular weeding with hand hoe by hired labor	* Regular weeding * Mechanized weeding
5. Harvesting	* Partial harvesting with hand hoe, using family labor	* Complete harvesting * Harvesting at 12 months or less * Harvesting with hand hoe * Use of hired labor	* Harvesting in 12 months or less * Mechanized harvesting
6. Processing	* Manual processing with hand tools	* Partly manual, partly mechanized	* Fully mechanized
7. Food Products	* Roots eaten in fresh form, or as pastes, as well as dried roots * Leaves for food	* Convenient food products	————

Source: Nweke et al. (2002).

In countries where the cassava transformation remains at the famine-reserve stage, government investment in the cassava sector Research and Development (R and D) is in the form of crash programs. In Tanzania, for example, the Ministry of Agriculture usually organizes crash cassava production programs when the maize crop is threatened by drought. But after the drought is over, government curtails these special extension programs. As a result, there is little continuity in research and extension and cassava farmers are typically forced to rely on a farmer-to-farmer exchange of varieties, especially varieties that extend the storage life of cassava in the ground.

Stage II: Rural Food Staple

In the rural food staple stage, cassava becomes the main source of calories in the diets of rural consumers. Farmers plant local varieties with low genetic potential and achieve low yields. In the rural food staple stage, cassava yields are low, around 10 tons per ha. Production, harvesting, and processing tasks are carried out manually and farm households consume most of the output. The Congo is currently in the rural food staple stage because poor roads, grinding poverty, and political chaos have kept the rural people locked into a virtual subsistence agriculture. Cassava is consumed mostly as dried roots and cassava leaves are the main vegetables in rural diets.

In most of Cote d'Ivoire and Uganda, where tree crops such as cocoa and coffee are grown, farmers grow cassava as their main food staple because tree crop production requires peak labor inputs. Cassava roots are boiled and eaten because sun drying of cassava roots is an inefficient way to dry cassava roots in the forest zone.

Stage III: Urban Food Staple

In the urban food staple stage, cassava is primarily produced and processed as a cash crop for sale in urban markets. The technological requirements for a nation to move to the urban food staple stage include high-yielding and early-bulking cassava varieties that can be harvested at 12 months and mechanization of some processing tasks to improve labor productivity[3]. For example, in Nigeria and Ghana, commercial production and processing of cassava products for

[3] Cassava does not have a period of maturity. As the plant grows the root continues to bulk (swell) until after a stage of three or four years when deterioration begins. Cassava does not have a period of maturity. As the plant grows the root continues to bulk (swell) until after a stage of three or four years when deterioration begins.

urban markets is driven by high-yielding cassava varieties, use of mechanized grater to prepare *gari*, increasing urban demand for food, improved rural roads and by government policies which encourage the substitution of cassava products for imported rice and wheat. During the urban food staple stage, cassava is produced and processed into a variety of low cost convenient food products for sale in urban centers and foreign markets. Because of this, private traders assume a greater role in providing mechanized services for the processing tasks and marketing services.

Stage IV: Livestock Feed and Industrial Raw Material

The cassava industry will advance to the livestock feed and industrial raw material stage when the production, processing, and marketing costs are reduced to enable African cassava to compete in global starch markets for industries and cassava pellets for livestock feed. Several preconditions must be met for a country to advance to the livestock feed and industrial raw material stage of the cassava transformation. The development of the labor-saving production and processing technologies which call for breeding research to restructure the cassava plant and roots in order to develop varieties suitable for mechanized harvesting and peeling. The development of early-bulking varieties that can be harvested in less than 12 months without loss in yield is an important precondition for farmers to respond to increase in demand for cassava products in a timely fashion and so that they can plant cassava continuously in the same field under intensive commercial production. An efficient and well integrated production and marketing system is likewise necessary to assure a steady supply of cassava products to domestic industries and European markets. Public and private investments in R and D are required to develop cassava products for industrial uses. Private sector initiative is required to supply planting materials and processing and marketing services.

The fuels that drive this four-stage cassava transformation include:

- development and dissemination of high-yielding TMS varieties,
- the control of the cassava mealy bug,
- use of mechanized grater to prepare *gari*,
- high market demand for cassava, and
- favorable government policies.

The technologies that drive the cassava transformation, namely TMS varieties, mealybug control, and the mechanized grater have introduced new bottlenecks that need to be broken in

order to transform cassava from a cash crop for rural and urban consumption to play an additional role as a livestock feed and industrial raw material. For example, the use of the new high-yielding TMS varieties to increase yield introduced labor bottlenecks in cassava harvesting and processing. The use of a mechanical grater to prepare *gari* has shifted the processing labor bottleneck to the peeling and toasting stages. Likewise, mealybug control shifted attention subsequently to the problem of the cassava green mite.

These new bottlenecks constitute a challenge to African political leaders, policy makers, and cassava scientists and also to the international donors and Non-Governmental Organizations (NGOs). The challenge is to break the new bottlenecks by investing in R and D to develop cassava varieties suitable for mechanized production, harvesting, and processing and to develop labor-saving mechanical technologies suitable for use by small farmers and processors. The goal is to drive down the cassava production cost to enable African cassava to compete in global starch markets for manufacturing and cassava pellets for livestock feed.

Nigeria and Ghana have been chosen to demonstrate this challenge because in both countries, cassava is the most important staple in terms of calories consumed. Nigeria and Ghana are two of the three most important cassava producers in Africa, the other being the Congo. But in Nigeria and Ghana, the cassava transformation has advanced most rapidly and the cassava transformation in other countries can benefit from their experiences.

OBJECTIVES

This discussion paper aims to document the key factors that drive the cassava transformation in Nigeria and Ghana, two of the three largest cassava producing countries in Africa. The paper highlights lessons for other African countries for promoting the cassava transformation, for improving food security and reducing poverty. Differences between Nigeria and Ghana in timing, promotional efforts, and performance over time provide an instructive contrast which help to illuminate the key factors necessary for stimulating significant growth in cassava production elsewhere.

This paper addresses three audiences. First, the paper calls on the Nigerian and Ghanaian political leaders, policy makers, and private entrepreneurs to face up to the challenge of implementing R and D to break the new bottlenecks in order to promote the cassava transformation. Second, this paper calls on Nigerian and Ghanaian cassava scientists including

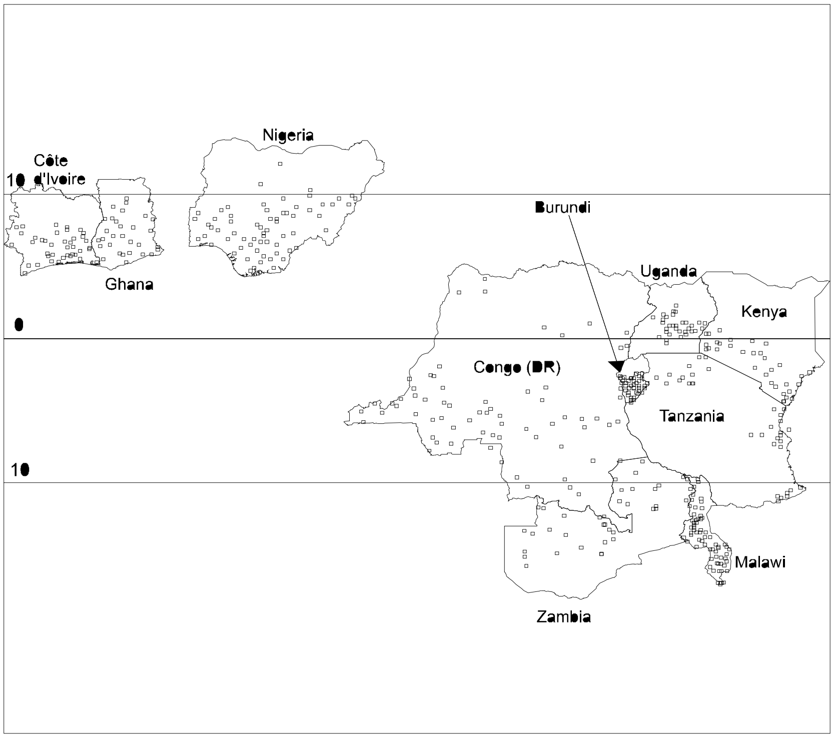
breeders, e7ngineers, and biochemists to develop cassava varieties that can be harvested in less than 12 months without loss in yield and can be mechanically harvested and peeled; develop mechanical technologies for cassava harvesting and peeling; develop an array of new convenient cassava food products; and develop technologies for using cassava as a raw material in various food, beverage, fuel, etc. industries. Third, this paper appeals to the international donor organizations to invest in research and action programs in order to exploit the potential of cassava as a powerful poverty fighter in Africa.

DATA SOURCES

This paper draws on three main sources of data. First are the published results of an eight-year, six-country study of cassava in Africa, the Collaborative Study of Cassava in Africa (COSCA). The COSCA studies were carried out from 1989 to 1997 under the aegis of the IITA (International Institute of Tropical Agriculture) in Ibadan, Nigeria. Over the 1989 to 1992 period, COSCA researchers collected primary data from 281 villages in six countries where roughly 70 percent of the total cassava in Africa is produced: the Congo, Cote d'Ivoire, Ghana, Nigeria, Tanzania, and Uganda (hereafter the six COSCA study countries) (Figure 1.1).

This information included cassava production systems, processing and food preparation methods, market prospects, and consumption patterns. From 1993 to 1997, COSCA researchers analyzed the field data and prepared a series of written reports on cassava production, processing, and consumption in the six COSCA study countries, culminating in a synthesis book, *The Cassava Transformation: Africa's Best Kept Secret (*Nweke, Spencer and Lynam 2002). Secondly, this paper has required fresh analysis of the raw COSCA data pertaining to Nigeria and Ghana. These analyses are reported in a series of tables and graphs in Sections 3 and 4 of this paper. Finally, the author has conducted a series of subsequent field studies in Nigeria and Ghana. In early 2001, he and colleagues from the COSCA team conducted a survey of industrial uses of cassava in Nigeria, financed by the Food an Agriculture Organization of the United Nations (FAO). In early to mid 2002, 10 years after the original COSCA field studies, the author and his COSCA team conducted a follow-up survey of the COSCA farmers in Nigeria, financed by the IFPRI (International Food Policy Research Institute).

Figure 1.1--Locations of the COSCA study villages



Source: Nweke et al. (2002).

PLAN OF THE DISCUSSION PAPER

This discussion paper is divided into six sections. Section 1 introduces the paper while Section 2 pulls together data from Africa, Asia, and South America to highlight the dramatic increase in cassava production in the past 40 to 50 years and the important role of cassava as food in Africa. Section 3 focuses on the cassava transformation in Nigeria, discussing the stages, driving forces and impacts on production, prices and poverty. Section 4 unravels the puzzle of why Ghana's cassava transformation has lagged behind that in Nigeria. Section 5 presents a research agenda which needs to be implemented in Nigeria and Ghana in order to accelerate the cassava transformation while Section 6 synthesizes the highlights of the discussion paper and serves as a wakeup call to the African political leaders, policy makers, and donors identifying ways they can accelerate the cassava transformation and bring to bear more broadly cassava's considerable power as a poverty fighter in Africa.

2. CASSAVA IN AFRICA

CASSAVA: A CONTROVERSIAL CROP[4]

W. O. Jones (1959) reported that advocates of cassava praised it because it produced the largest number of calories per ha of any crop and for its ability to be grown on poor soils and withstand severe attacks of drought, pests, and diseases. These attributes explain why many colonial governments encouraged and, in some cases, forced smallholders to grow the crop. But many critics point out that cassava is a subsistence crop that depletes soil nutrients, a women's crop produced and consumed by impoverished households, and a lethal and nutritionally deficient food. These criticisms explain why some colonial government administrators discouraged cassava cultivation and, in some cases forbade it (White 1990).

Many African policy specialists since independence have been preoccupied with increasing the production of maize, wheat, and rice to feed Africa's urban population. In fact, the historical bias in favor of rice, wheat and maize in food policy circles is palpable and disconcerting. In 1958, for example, Johnston described rice as the 'glamour crop' of West Africa (1958, p. 226). Later, Jones reported that African consumers described wheat flour as a 'delicacy' (Jones 1972, p. 28). In eastern and southern Africa, for the last 50 years maize has held the preferred place in the hearts, minds and pocketbooks of policy makers (Jayne and Smale 2002).

But these stigmas are myths or half-truths (Nweke et al. 2002). The stigma that cassava is primarily a subsistence crop was valid in the past when 90 to 95 percent of the people of Africa were in farming. But in the 1990s in Ghana, roughly 60 percent of the cassava planted was being sold as a cash crop (Nweke et al. 2002). The stigma that cassava depletes soil nutrient because of the cassava's high yield of carbohydrate is a myth. The COSCA soil studies show that cassava fields, some of which have been under continuous cultivation for at least ten years, are as fertile as soils of other crops. The strongly held stigma by many donor agencies and NGO representatives that cassava is a 'women's crop' is an important half-truth. Equally important is the other half-truth that cassava is also a 'men's crop'. The COSCA studies have shown that both

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[4] Much of this section summarizes material presented in Nweke, Spencer and Lynam (2002). For a more in-depth treatment of this material, the reader may wish to consult the book.

men and women produce cassava. Men are increasingly involved in cassava production, processing, and marketing as the cassava transformation unfolds in Africa.

The common stigma that some cassava varieties contain cyanogens that are lethal is also a half-truth. Today, the cases of cyanide poisoning from cassava consumption are rare; the fear of it should not discourage public or private investment in the cassava food economy. The cyanogens can be eliminated during processing by using well-known traditional processing methods. Several other crops, such as Irish potato and yams, can also be lethal if eaten without proper preparation. The level of carbohydrate in cassava is an advantage in Africa because it makes cassava the cheapest source of food calories. Without question, the challenge ahead is to increase the productivity of cassava production, harvesting, and processing in order to drive down the cost of cassava to consumers, especially the poor. This is an important but a neglected issue in food policy debates. For these reasons, I reject the myth that cassava is a nutritionally inferior food.

These five myths and half-truths constitute a great deal of misinformation. Up to the mid 1980s in Nigeria and Ghana, cassava was marginalized and neglected in development policies because of the five myths and half-truths.

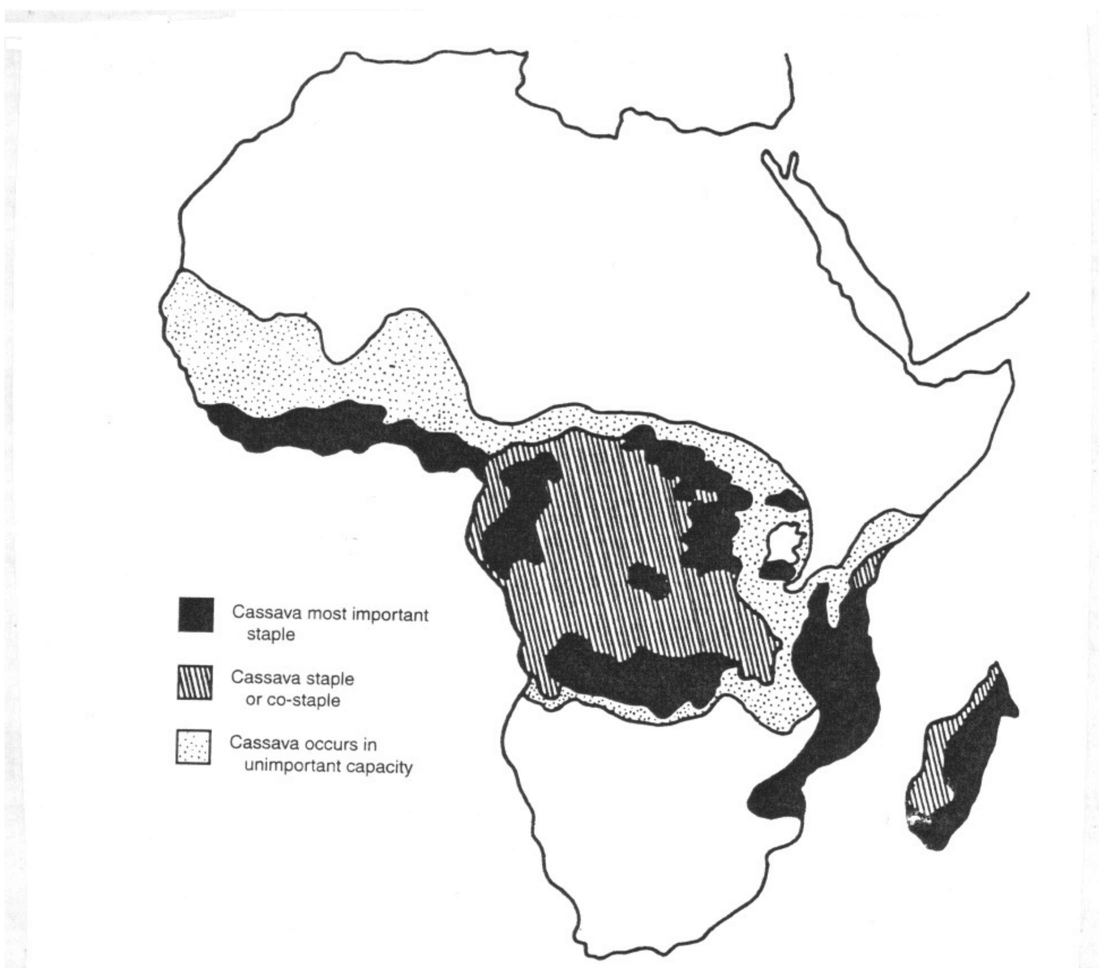
Cassava plays different but important roles in African development depending on the stage of the cassava transformation in a particular country: famine reserve, rural food staple, cash crop and urban food staple, industrial raw material, and livestock feed. The first three roles currently account for 95 percent of Africa's cassava production while the last two account for only 5 percent.

Africa's token use of cassava in its industries and as a foreign exchange earner in European livestock feed markets is basically one of economics. African cassava pellets are not competitive with Asian pellets in the livestock feed industry in Europe. Also, African cassava starch is not competitive with imported corn starch. High cost, irregular supply, and low quality stemming from inefficient traditional production and processing methods limit the ability of African cassava to compete with cassava from Asia or with American and European corn starch in global markets. In Africa, investment is needed in R and D to drive down the cassava production, harvesting and processing costs so that cassava can play an expanded role as a livestock feed and industrial raw material.

CASSAVA PRODUCTION

The diffusion of cassava can be described as a success story *par excellence* in African agriculture. In Africa, cassava was first introduced in the Congo from South America about 400 years ago. Currently, cassava is cultivated in around 40 African countries, stretching through a wide belt from Madagascar in the Southeast to Senegal and to Cape Verde in the Northwest. Throughout the forest and transition zones of Africa, cassava is either a primary staple or a secondary food staple. Cassava is adapted to the zone within latitudes 30°north and south of the equator, at elevations up to 2,000 m above sea level, in temperatures ranging from 18°C to 25°C, to rainfall of 50 to 5,000 mm annually, and to poor soils with a pH from 4 to 9 (Figure 2.1).

Figure 2.1 – Africa: Areas of Cassava Production

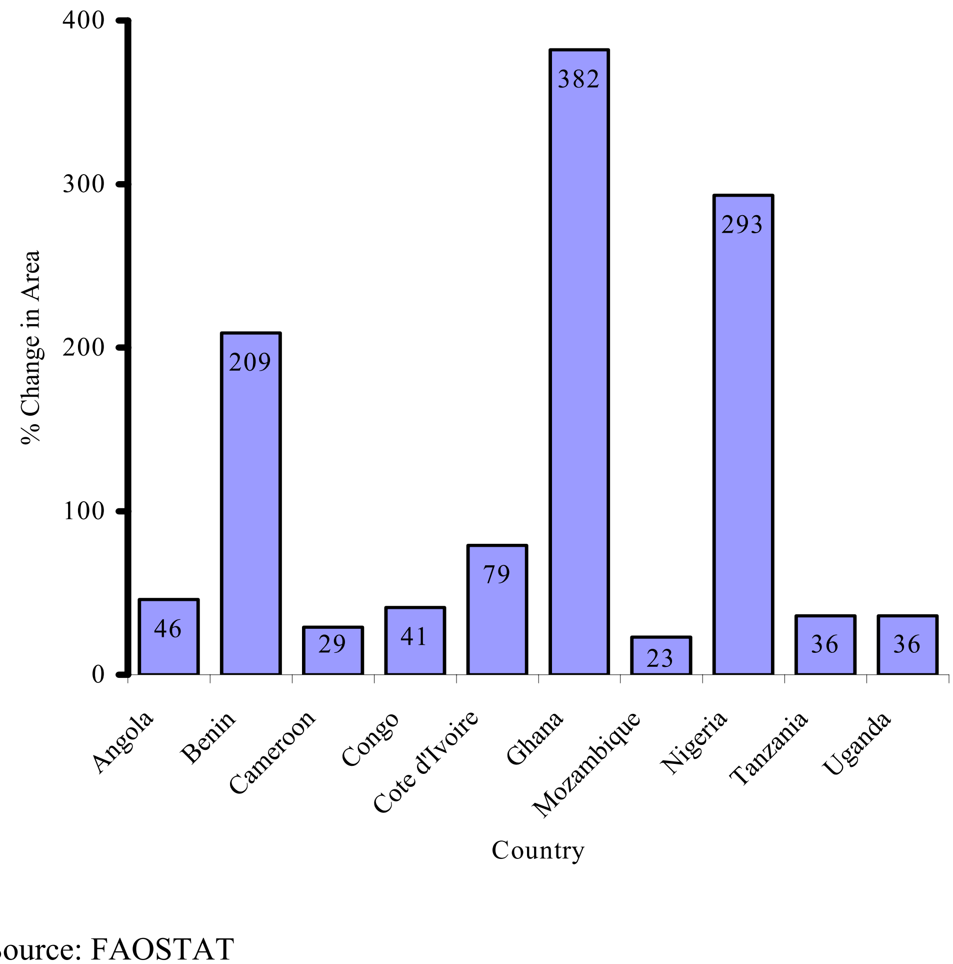


Source: Okibgo (1980).

In the early 1960s, African farmers planted 5.6 million ha per year to cassava. Forty-five years later, in the early 2000s, they nearly doubled that figure, planting 10 million ha in cassava. The six countries which currently account for most of the cassava include Nigeria, the Congo, Ghana, Cote d'Ivoire, Tanzania, and Uganda. The area planted to cassava increased almost four fold in Nigeria and Ghana from the early 1960s to the early 2000s (Figure 2.2).

Marketing of cassava as a cash crop has played a key role in the expansion of cassava production. In fact, farmers in most of the COSCA villages in Ghana and Nigeria cited market access as the principal reason for their expansion of cassava area. In contrast, farmers in most of the villages in the Congo cited difficult road access to market centers as the reason for reducing the area planted to cassava.

Figure 2.2--Ten largest cassava producing countries in Africa: Percentage change in cassava area between 1961-1963 and 2000-2002.



Source: FAOSTAT

A closely related critical variable in the expansion of the cassava area in Nigeria and Ghana is the availability of improved processing equipment to remove water from the roots (the roots are 70 percent water) and thereby reduce the cost of transportation. Improved processing and food preparation methods reduce bulk and make it possible for cassava products to be transported at reduced costs over poor roads to distant urban market centers. One example is the steady shipment of dried cassava roots (*cossettes*) from Bandundu region of the Congo to the capital city, Kinshasa, by boat along the Congo River or by trucks over extremely poor road conditions.

Looking ahead, the future expansion of cassava production will require breaking harvesting and processing labor bottlenecks. In Ghana and Nigeria, all the COSCA study villages where farmers had access to mechanized cassava graters reported an increase in the area planted to cassava. By contrast, only 60 percent of the COSCA study villages where farmers did not have access to a mechanized cassava grater in the two countries reported an increase in the area planted to cassava.

In 1954, the average cassava yield in Africa was between 5 and 10 tons per ha (Jones 1959). In early 1991, the COSCA yield measurements revealed that the average on-farm cassava fresh root yield (hereafter yield) for the six COSCA study countries was 11.9 tons per ha[5]. Therefore, one can safely say that the cassava yield is increasing in Africa in the early 1990s because of the planting of high yielding varieties and the adoption of better agronomic practices. The average farm-level yield was highest in Nigeria where the mean was 14.7 tons per ha followed by Ghana where the mean was 13.1 tons per ha (Figure 2.3). The mean yield was around 10.0 tons per ha in the Congo, Cote d'Ivoire, Tanzania, and Uganda respectively[6].

In the early 1960s, Africa accounted for 42 percent of world production. Thirty years later, in the early 1990s, Africa produced half of world cassava output spearheaded by Nigeria's four-fold increase in production and replacement of Brazil as the world's leading cassava producer (Figure 2.4).

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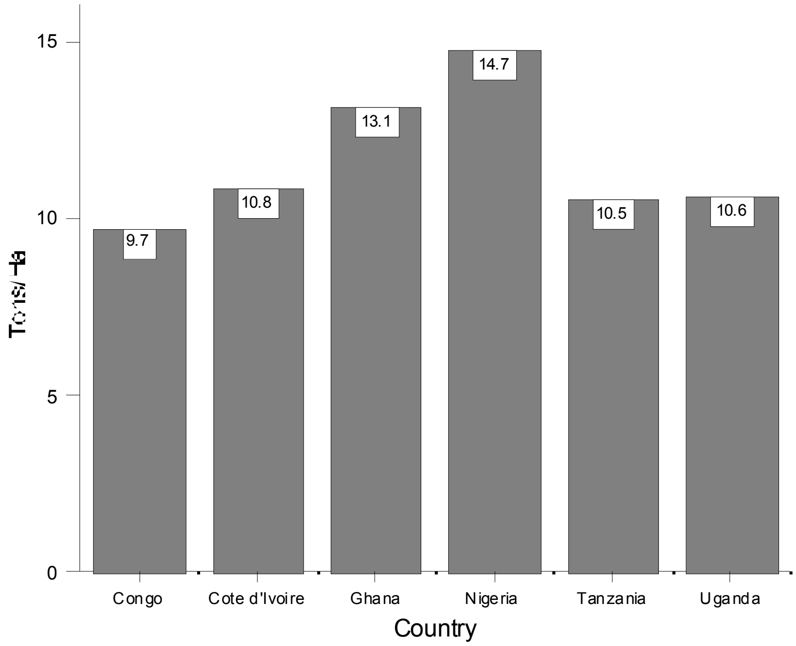
[5] Root yield as distinct from leaf yield; in the Congo and Tanzania cassava leaves are harvested and eaten as a vegetable.

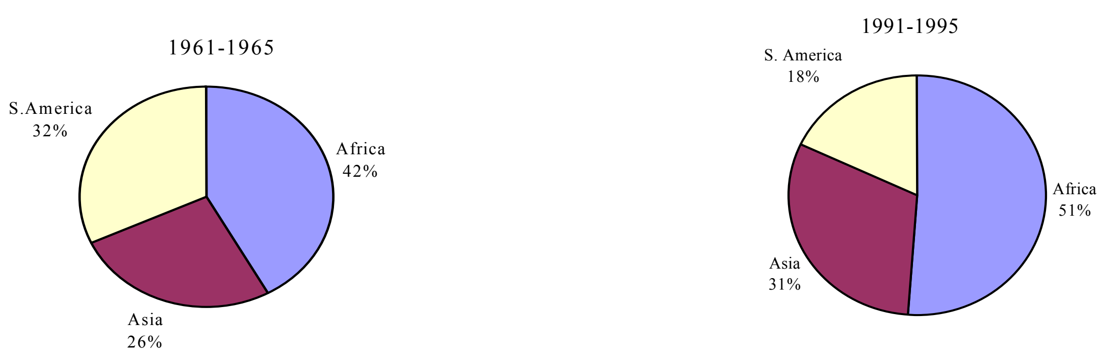
[6] Cassava yield is notoriously difficult to measure because of widely staggered harvesting dates, yield curves that rise appreciably over time, and sequential, partial harvesting that pervades many cassava-growing regions. Appendix 1 discusses these problems and describes methods used by the COSCA study to determine cassava yields.

Figure 2.3--COSCA countries: Cassava yield in 1991.



Source: Nweke et al. (2002)

Figure 2.4--Africa, Asia and South America: Percentage shares of global cassava production, 1961-1965 and 1991-1995



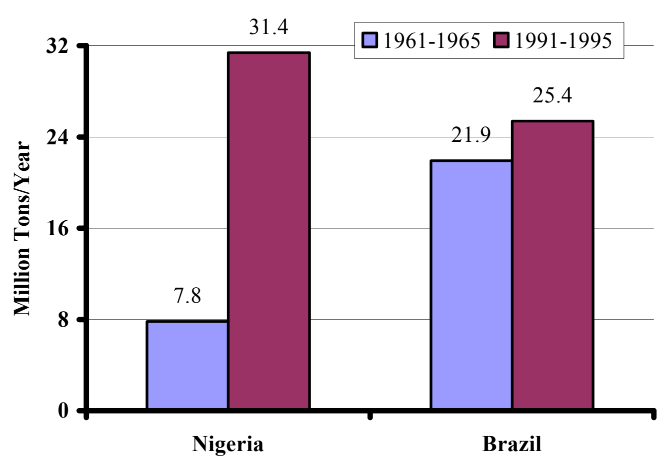
Source: FAOSTAT.

The changes in production shares have proven dramatic. While Brazil produced nearly three times as much cassava as Nigeria in the early 1960s, 21.9 million tons compared to only 7.8 million tons in Nigeria, the standings had reversed thirty years later. In the early 1990s, Nigeria produced 31.4 million tons per year compared with 25.4 million tons per year in Brazil (Figure 2.5).

Ghana, only the seventh largest producer in Africa in the early 1960s, with an annual production of only 1.2 million tons, increased its output six-fold over that same period. By the late 1990s, Ghana produced 7.2 million tons annually and advanced to the position of the third largest producer in Africa after Nigeria and the Congo.

Cassava's low input requirements, a trait that is compatible with Africa's resource endowments (weak rural credit markets, relatively abundant land and seasonal labor scarcity), and the cassava's resistance to pests and diseases explain the expansion in cassava production since the 1960s. Moreover, as the average farm size shrinks under population pressure, farmers are searching for crops with a higher output of energy per ha as a strategy for overcoming hunger. Food shortages precipitated by a combination of political and civil unrest, economic stagnation, erratic rainfall patterns, and rapid population growth have had a much greater influence on cassava production in Africa than anywhere else in the world (Scott et al. 2000).

Figure 2.5--Nigeria and Brazil: Cassava production, 1961-1965 and 1991-1995



Source: FAOSTAT

CASSAVA FOOD PREPARATION AND PROCESSING

In Africa, farmers and food processors market five common groups of cassava products: fresh root, dried roots (called *kokonte* in Ghana and *lafun* in Nigeria), pasty products (called *agblima* in Ghana and *akpu* in Nigeria), a granulated product (called *gari* in both Ghana and Nigeria), and cassava leaves.[7]

The roots of sweet cassava varieties are eaten raw, roasted in an open fire, or boiled in water or oil.[8] Boiled cassava roots may be pounded alone or in combination with other starchy staples such as banana (or plantain), yam, cocoyam, or sweet potato. The preparation of pounded cassava is elaborate and cumbersome because the boiled cassava roots get sticky during pounding.

Dried cassava roots are stored or marketed as chips, balls, and flour. Chips and balls are milled into flour at home by pounding with a pestle and mortar in preparation for a meal. There are two broad types of dried cassava roots: fermented and unfermented. Fermentation is accomplished in one of two ways: stacking in heaps or soaking in water. In Nigeria and Ghana, fermentation by soaking in water for two to five days is the most common method of preparing dried cassava roots. The roots are then peeled (if not peeled prior to soaking) and sun- or smoke-dried directly as whole roots. Alternatively, they can be crushed and pressed to remove the water and molded into balls and dried.

The recent introduction of a mechanized grater in preparing dried cassava root flour has eliminated fermentation and therefore saves time and labor. The roots are simply peeled, washed, and grated.[9] The pulp is placed in a perforated container, covered, and a weight put on it for about three hours. The half-dried pulp is then dried in the sun (Alyanak 1997). Dried cassava roots are common in Tanzania because cassava is used as a famine-reserve crop (Table 2.1).

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[7] It is difficult to separate cassava processing from cassava food preparation because some combinations of the cassava processing and food preparation activities lead to final cassava food products which are in ready to eat forms. Other combinations of the cassava processing and food preparation activities lead to intermediate products which are stored until the need arises for conversion into ready to eat forms.

[8] The customary 'sweet' and 'bitter' cassava varieties depend upon the amount of cyanogens (prussic acid) in the edible parts of the roots (Jones 1959, p. 12). The roots of sweet cassava are low in cyanogens, mealy after cooking, and usually eaten as a raw vegetable, boiled, or roasted in an open fire. Bitter cassava varieties are high in cyanogens, waxy after cooking and are harmful to humans and animals unless they are peeled, grated, and toasted or soaked in water for a few days and boiled or sun-dried.

[9] This method was recently developed at the IITA and it is now widely used by farmers in the major cassava producing countries.

Table 2.1--COSCA countries: Type of cassava food products

CASSAVA FOOD PRODUCT	CONGO	COTE D'IVOIRE	GHANA	NIGERIA	TANZANIA	UGANDA
Dried roots	70	8	27	48	91	21
Gari	0	45	43	39	0	0
Pasty product	25	8	7	13	0	0
Fresh root	5	37	23	0	6	76
Others	0	2	0	0	3	3
TOTAL	100	100	100	100	100	100

Source: Nweke et al. (2002).

To prepare the pasty product, the roots are soaked in water for three to five days, during which time the roots soften and ferment. The soaked roots are manually crushed and sieved in water using a basket or a perforated metal bowl in a sack submerged in water. Preparing cassava as a pasty product extends the shelf-life of the cassava and reduces its volume in comparison with fresh roots. But the pasty product is not a convenient food product because it needs to be cooked and pounded, sometimes twice, before it is ready for a meal. However, it is commonly used to feed hired labor employed in cassava production because the pasty product is less expensive than other cassava products while at the same time it gives a feeling of satiety because it is heavy. In some parts of Nigeria, the cassava pasty product is transported over long distances in truckloads and retailed in urban markets in small plastic or polypropylene bags.

Cooked cassava pasty products have been recently introduced in Nigerian urban markets. Every evening in major cities in Nigeria, it is common to find women selling cooked cassava paste wrapped in plastic bags by the road side leading to market places. Although more research is needed on preparation methods, cooked cassava paste is a promising food for busy urban consumers.

To make *gari*, a dry cereal, cassava roots are peeled, grated, fermented and drained of effluent, then toasted in a pan over an open fire. *Gari* is prepared in Nigeria and Ghana where cassava is produced as a cash crop for urban consumption. In Nigeria and Ghana, *gari* is the most common form in which cassava is marketed (Doku 1969 and Ngoddy 1977).[10] *Gari* is a convenient product because it is stored and marketed in a form in which it is ready to eat. It can

[10] But of late in Nigeria, cassava pasty product is increasing in importance as an urban convenient food because of a new development in its preparation method.

be soaked in hot or cold water depending on the type of meal being prepared. *Gari* has a long shelf-life, a year or more as long as it is not exposed to moisture, it is therefore attractive to urban consumers.

Cassava leaves are edible and highly nutritious. Like other dark green leaves, they are an extremely valuable source of vitamins A (carotene) and C, iron, calcium, and protein (Latham 1979). Cassava leaves are prepared by leaching them in hot water, pounding them into pulp with a pestle and mortar before boiling in water along with groundnuts, fish, and oil. This process eliminates cyanogens from the leaves, making them safe for human consumption. Cassava leaves are an important vegetable in the Congo, Madagascar, Sierra Leone, Tanzania and Zambia. In countries where cassava leaves are eaten as vegetables, producers earn additional income by selling cassava leaves. Truckloads of cassava leaves, locally called *pondu* in the Congo, are a common sight plying the roads from the provinces to Kinshasa.

Cassava leaves are not eaten in Uganda because their consumption indicates a low economic status (Otim-Nape 1995). Cassava leaves are not eaten in West Africa, except in Sierra Leone, because several indigenous plants supply vegetables traditionally consumed with yam (Okigbo 1980). Most of these vegetables are however, available only during the rainy season. Therefore, in West Africa, there is a seasonal gap in the availability of vegetables which cassava leaves could fill. In West Africa, the consumption of cassava leaves as a vegetable will make cassava production more profitable and increase the food security and nutritional status of African families. Cassava leaf harvesting, if properly scheduled, does not adversely affect cassava root yield (Dahniya 1983 and Lutaladio and Ezumah undated).

CASSAVA CONSUMPTION

In Africa, cassava is used almost exclusively as food. In fact, 95 percent of the total cassava production, after accounting for waste, was used as food in Africa in the early 2000s.[11] By contrast, 55 percent of total production in Asia and 40 percent in South America are used as food (Figure 2.6).

Many international agencies and bi-lateral donors are hesitant to extend loans and grants to African nations to help them increase the production of root crops such as cassava because of

[11] Waste was estimated to be 28 percent of the total cassava production in Africa from 1994 to 1998 (FAOSTAT).

the longstanding wrongly held belief that cassava is "inferior good," i.e. the per capita consumption of cassava declines as per capita income increases. For example, soon after the International Food Policy Research Institute (IFPRI) was established in 1975, it reported that since these root crops require much larger bulk to provide calories than do cereals, and are low in protein, in Africa demand may shift towards cereals as has occurred in other countries" (IFPRI 1976, p. 35). Today, the low status accorded cassava by the international organizations and donor agencies flows from two misleading myths: that cassava is an inferior food produced by and for rural households and that because of its low protein content cassava is a nutritionally inferior food crop. However, IFPRI recently concluded that the root crops such as cassava are important for smallholders in the marginal areas of Africa, Asia, and South America and that special steps should be taken to boost cassava production, especially in Africa (Pinstrup-Anderson et al. 1999).

Figure 2.6--Africa, Asia, and South America: Percentage of cassava utilization

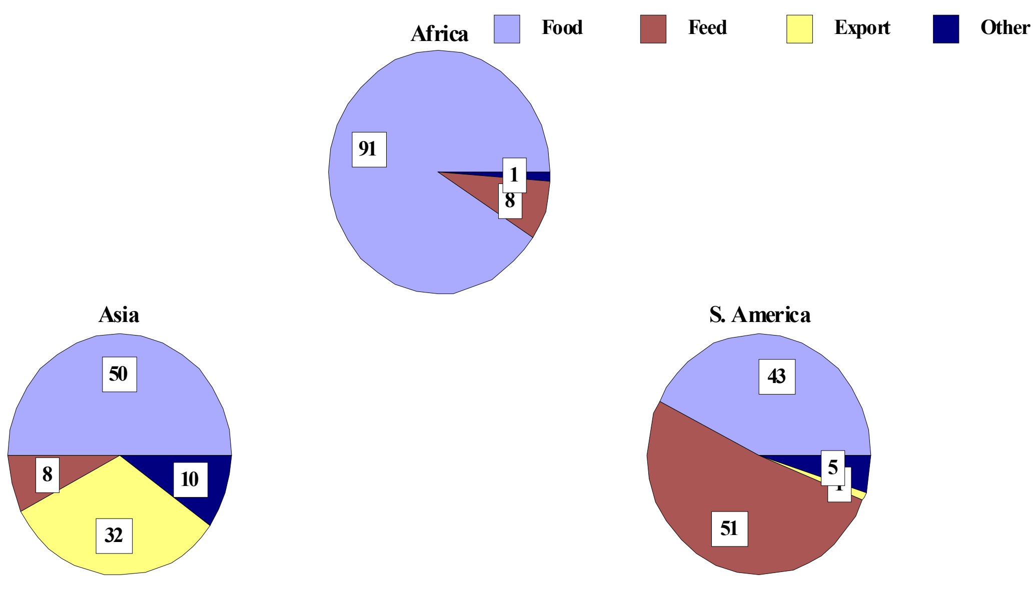


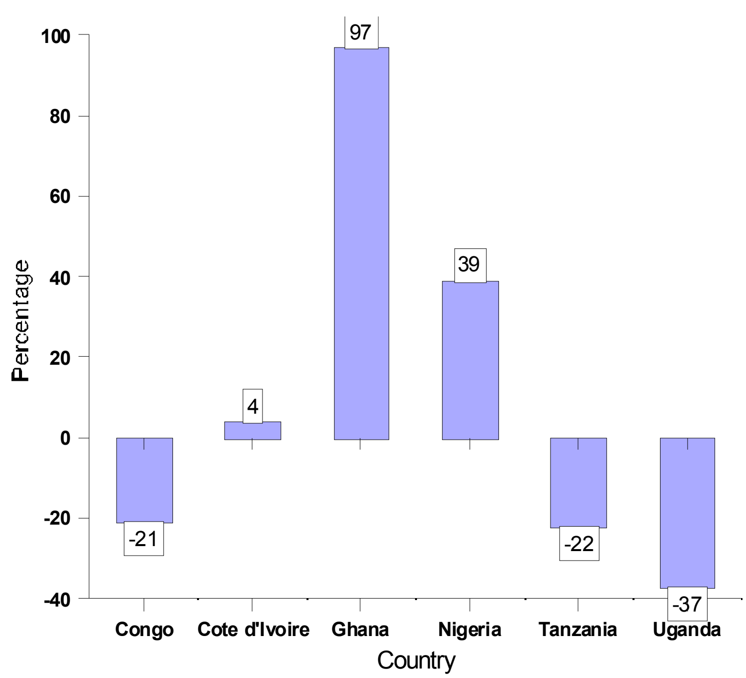
Figure 2.6. Africa, Asia, and South America: Percentage cassava utilization

Source:FAOSTAT

In Africa, total cassava consumption more than doubled from 24 million tons per year in the early 1960s to 58 million tons per year in the early 2000s, after accounting for waste (FAOSTAT). The large increase in the total cassava consumption in Africa is due to a significant increase in per capita consumption in countries such as Nigeria and Ghana where cassava is produced as a cash crop for urban consumption. For example, in Ghana, per capita cassava consumption increased by nearly 100 percent from 130 kg per person per year in the early 1960s to 255 kg per person per year in the early 2000s (Figure 2.7).

In Nigeria, per capita consumption increased by 40 percent from 88 kg per person per year in the early 1960s to 120 kg per person per year in the early 2000s. The availability of cassava in a convenient food form, such as *gari*, played a major role in the increase in the per capita cassava consumption in Nigeria and Ghana. Future increases in cassava consumption in other African countries will depend on how well cassava is prepared into food forms which make it an alternative to wheat, rice, maize and sorghum for urban consumers.

Figure 2.7--COSCA countries: Percentage change in per capita consumption of cassava from 1961 to 2000



Source: FAOSTAT

Table 2.2--Africa: Countries where cassava is the most important or second most important staple in terms of calories consumed; total population and calorie per capita per day in 2001

Most Important Staple			Second Most Important Staple		
Country	Population (million)	Cals/Cap/Day	Country	Population (million)	Cals/Cap/Day
Angola	13.5	595	Benin	6.4	502
Central African Republic	5.8	417	Cameroon	15.2	268
Congo, Democratic Republic	52.4	1043	Cote d'Ivoire	16.2	303
Congo, People's Republic	3.1	785	Guinea	7.6	207
Ghana	19.7	662	Liberia	3.2	335
Mozambique	18.6	603	Madagascar	16.0	332
Nigeria	129.9	396	Sierra Leone	5.1	139
			Tanzania	34.5	409
			Togo	4.7	365
			Uganda	22.8	237
			Zambia	10.3	193
Total/Ave*	241.0	591	Total/Ave	142.1	311

*Note: Ave is average calories per capita per day weighted with population.
Sources: Population from The Word Bank 2003 and calorie per capita per day from FAOSTAT

FAO data show that cassava roots constitute the single largest source of calories in seven countries with a total population of 240 million or 40 percent of the population of Africa in the late 1990s (Table 2.2). In these seven countries, cassava contributed an average of 590 calories per person per day. The COSCA study shows that 87 percent of the study households in Ghana and 80 percent in Nigeria prepared and ate a cassava meal at least once in a week before the households were interviewed. In another 11 countries with 23 percent of Africa's population, cassava was the second largest source of calories. In those countries, cassava provided an average of 311 calories per person per day in the late 1990s. But these averages underestimate the importance of cassava in specific countries.

For example, in the Congo, cassava contributed over 1000 calories per person per day or about 55 percent of the average daily calorie intake in the late 1990s (FAOSTAT). While the FAO data do not account for the consumption of cassava leaves, the COSCA study shows that cassava leaves are widely consumed as a vegetable in the Congo. Since cassava leaves are rich in protein, vitamins A and C, and some minerals (iron and calcium) they partially compensate for the shortage of these nutrients in the roots (Latham 1979, p. 172).

Table 2.3--Nigeria and Ghana: Retail price of 1000 calories from fresh roots of sweet cassava, dried roots, and maize in rural market centers, 1992

Nigeria (Naira/1000 calories)			Ghana (Cedis/1000 calories)		
Rural Market Center	Fresh Cassava Roots	Maize	Rural Market Center	Fresh Cassava Roots	Maize
Donga	0.36	0.95	Sagboi	34	49
Garbabi	0.38	0.85	Tafiano	35	53
Suwabarki	1.09	1.37	Nkurakan	44	71
Guyuki	0.85	1.60	Koluedor	32	83
Namtaringure	0.80	1.20			
Yaburawa	0.63	1.11			
Wuse	0.81	1.07			
Busanfung	0.71	3.20			
Ofabe	0.24	0.60			

Source: Nweke et al. (2002).

Cassava appeals to low income households because it offers the cheapest source of food calories. Compared with grains, fresh and dried cassava roots are very cheap sources of calories. Calories are significantly cheaper from fresh roots of sweet cassava varieties than from maize in various rural village market centers in Nigeria (Table 2.3). Similarly, calories derived from dried cassava roots are significantly cheaper than when they are derived from maize in various rural market centers in Ghana.

Processed cassava food products are eaten as pasty dough balls with a seasoned sauce. Bits of the dough balls are dipped into the sauce and eaten, sometimes swallowed without chewing. Ingredients of the sauce vary greatly depending on the availability of vegetables, meat, fish, melon seeds, peas, peppers, and other spices (Johnston 1958; Jones 1959; Grace 1977). In places where cassava is consumed every day, variation in the diet is achieved by varying the ingredients of the sauce.

3. THE CASSAVA TRANSFORMATION IN NIGERIA

This section traces the evolution of Nigeria's cassava transformation and shows how the various technologies and policies helped transform cassava from a famine-reserve crop through rural food staple to the stage of cash crop for urban consumption at different time periods. Discussion highlights emerging bottlenecks that to date have prevented the cassava transformation from advancing to play the additional roles of livestock feed and industrial raw material in Nigeria. The section concludes with an assessment of the impact of the cassava transformation on production, prices and incomes in Nigeria.

PHASES OF THE CASSAVA TRANSFORMATION

Early Diffusion as a Famine-Reserve Crop

In the late sixteenth century, Portuguese traders introduced cassava into the West Coast of Africa from South America. By 1700, cassava had become an important food crop in Sao Tome, a small island Portuguese colony off the Coast of Guinea, in Principe or Fernando Po, and at Warri (Jones 1959). But cassava did not spread much further until early in the twentieth century because the people of West Africa enjoyed a comfortable food security based on yam, cocoyam, and plantain in the forest zone and on millet and sorghum in the savanna zone. Early in the twentieth century, several factors spurred a rapid diffusion of cassava in different places.

In the Lagos area, market demand was the fuel that drove the diffusion of cassava. After the arrival of the emancipated slaves in 1840 in Western Nigeria[12], cassava and its products began to appear in the Lagos market. In 1849, missionaries traveling into Western Nigerian purchased cassava in the Lagos market before heading out into the hinterland (Agboola 1968).

Elsewhere in Western Nigeria, cassava was spreading as a famine-reserve crop. Between 1930 and 1939 in Oyo and Ondo Provinces north of Lagos, an invasion of locusts caused considerable damage to the yam crop. Cassava was used to replace yams because farmers found it difficult to replace yam losses with other yam sets. In 1945 and 1946 in the Ondo Province,

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[12] The emancipated slaves arrived in large numbers to make a considerable impact on the spread of cassava in Western Nigeria. For example, between 1840s an 1880s, more than 4,000 emancipated slaves settled within the 40 years in Lagos. The emancipated slaves arrived in large numbers to make a considerable impact on the spread of cassava in Western Nigeria. For example, between 1840s an 1880s, more than 4,000 emancipated slaves settled within the 40 years in Lagos.

farmers planted cassava in heaps in which yams failed to sprout because of the long dry season (Agboola 1968)[13].

In the Lower Niger (the Niger basin from just above the Niger Delta on the coast to Lokoja), a series of three tragedies which befell the people of the area -- a war of resistance against the imposition of the British rule (1899 to 1914), the First World War (1914 to 1918), and the influenza epidemic (1918) -- fueled the early diffusion of the cassava in the area. It was difficult for the people of the Lower Niger to sustain their food security by producing yam. Yam production that requires a great deal of manual labor was adversely affected by the withdrawal of men from the villages. Consequently, the people of the Lower Niger embraced cassava that was hitherto unacceptable as inferior to yam. By the late 1920s, cassava had spread to most parts of the Lower Niger (Ohadike 1981 and Chiwona-Karltun 2001).[14]

Rural Food Staple

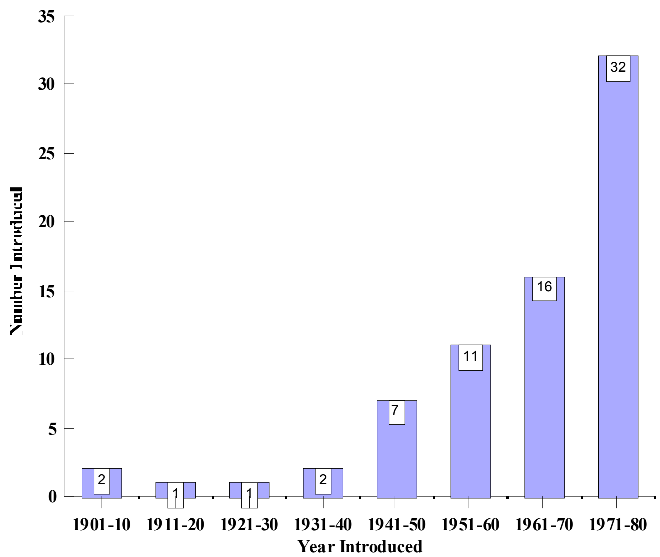
In 1927 in the Ngwa area of the Lower Niger Delta, tax officials noted that cassava was a minor crop compared to the dominant staple, namely yams. But by 1954, cassava had become a joint staple with yams, and from 1959 to 1964, the Federal Office of Statistics agricultural census revealed that cassava had become the main food in the area (Martin 1988). In about 1930, the cassava mosaic disease reached West Africa. Farmers believed that yield was affected minimally unless the infection was extraordinarily severe (Jones 1959).

In the early to mid twentieth century when cassava was at the rural food staple stage in Nigeria, farmers relied on farmer-to-farmer transfer of varieties. Until 1940 in Nigeria, the number of cassava varieties (cultivars) introduced in the 65 COSCA study villages was low, one or two per ten year interval (Figure 3.1). The varieties were not improved because the farmers obtained them from other villages and towns and in some cases from other countries through migrant farmers, development agencies, and churches groups.

[13] Yam is grown in heap seed bed.

[14] In a war situation, cassava has several advantages over yam production. For examples, the establishment cost of cassava production for home consumption is generally low because stem cuttings and family labor are the main inputs. Cassava generates a high yield of carbohydrate per ha and it requires labor only at planting and harvesting. Since the roots can be stored in the ground for several months and even up to four years without deterioration, there is a possibility that a displaced population can find their cassava fields unharvested upon their return home.

Figure 3.1--Nigeria: Number of cassava varieties introduced in the COSCA villages from 1901 to 1980



Source: COSCA data analysis

In the early to mid twentieth century in Nigeria, cassava varieties planted by the farmers were mostly the sweet type that could be eaten without processing but gave low yield and were susceptible to pests and diseases. But as the cassava transformation progressed from the famine-reserve through the rural food staple to a cash crop for rural and urban consumption stages in Nigeria, farmers replaced several of the sweet cassava varieties with the bitter varieties (Nweke et al. 1994). In 1952 in Nigeria, the national average cassava yield was about 10 tons of fresh root per ha and 40 years later in 1992 in the COSCA villages, about 15 tons per ha (FAOSTAT).

During the first half of the twentieth century in Nigeria, cassava area remained small because of labor bottlenecks at the cassava processing stage which constrained expansion of planted area. Cassava processing was labor intensive because it was carried out by hand especially by the women. In 1946 to 1949, the Federal Government set up five Pioneer mills for processing palm oil. In the Ngwa area of the Lower Niger Delta, the introduction of the Pioneer oil mills released female labor from palm oil processing for cassava production, processing, and marketing (Martin 1988). Cassava area in Nigeria increased from 382,000 ha per year from 1946 to 1949 to 635,000 ha per year from 1956 to 1958 (FAOSTAT).

Cash Crop for Rural and Urban Consumption

In 1914, the world price of palm oil began to collapse and cassava became an attractive alternative source of cash income to oil palm producers in Eastern Nigeria. In 1916, the NDP (Niger Delta Pastorate) brought Christianity to Ngwa land in Eastern Nigeria. The pastors of the NDP were mostly emancipated slaves from Sierra Leone and Yorubaland in Western Nigeria. Along with Christianity, the NDP pastors brought *gari* processing technology. This new processing technology proved vital to the development of cassava as a cash crop for urban consumption.

A trade in *gari* began growing in urban centers such as Aba and Umuahia (Martin 1988). By the eve of the World War II (1939 to 1945), the people of Eastern Nigeria were exchanging *gari* for cattle produced in northern Nigeria. The emerging *gari* trade initially transited via growing road networks, particularly following the opening of the Benue River bridge in 1931. By 1944, the railway had also become an important means of transporting *gari* from Eastern Nigeria to Northern Nigeria. Throughout the 1940s and 1950s, Nigerian cassava production expanded because of growing urban demand for *gari*.

From 1941 to 1950, the number of cassava varieties introduced in the COSCA study villages began to accelerate (Figure 3.1). Production nearly doubled within a decade. In 1946 to 1948 in Nigeria, cassava area was 382,000 ha per year compared with 635,000 ha per year 10 years later in 1956 to 1958 (FAOSTAT). The accelerated pace of the farmer-to-farmer transfer of cassava varieties from the 1940's onward testifies to growing interest in cassava as a cash crop.

Strong and growing urban demand over many decades has eroded the common perception of cassava as an inferior food. In Nigeria, consumption data reveal that the income elasticity of demand for cassava products among rural households are all greater than zero and in some cases they were greater than one (Table 3.1)[15]. Surprisingly, the cassava estimates were

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[15] The income elasticity of demand provides an insight into the level of market demand for a commodity. The income elasticity of demand measures the percent of change in the quantity of a commodity purchased (consumed) by consumers in response to one percent change in their incomes. A negative income elasticity of demand means that the quantity of the commodity purchased by consumers will decline with rising incomes. A zero income elasticity of demand means that the amount of the commodity demanded will be unchanged with rising incomes. An income elasticity of demand between zero and one implies that a one percent increase in incomes will cause consumers to increase the amount of the commodity they are willing to purchase, although by less than one percent. Finally, an income elasticity of demand of more than one implies that market demand is very high for the commodity. Scholars and policy makers who dismiss cassava as an inferior good assume that the income elasticity of demand for cassava is negative or zero.

about the same as estimates for maize. The estimate for *gari* was significantly higher than that of maize, even among high income rural households.

In Ghana, the income elasticity of demand estimates based on the World Bank Living Standards Surveys data are equally surprising: the estimate for cassava was significantly greater among the urban households (1.46) than among rural households (0.73). Among the urban households, the estimate for cassava was about the same as the estimate for rice (1.50) but significantly greater than the estimate for maize (0.83) (Alderman 1990)[16]. These estimates show that cassava has as much market demand potential as maize and provide convincing evidence that demand for cassava will continue to rise as income increases.

Table 3.1--Nigeria and Ghana: Income elasticity of demand for cassava and other food staples

STAPLE	NIGERIA			GHANA	
	All Sample House-holds	Low Income House-holds	High Income Households	Rural Households	Urban Households
All Cassava	0.78	0.84	0.76	0.73	1.46
Fresh Roots	1.24	1.28	1.21	--	--
Gari	0.85	0.85	0.77	--	--
Dried Roots	0.55	0.57	0.53	--	--
Maize	0.71	0.74	0.65	0.84	0.83
Rice	1.12	1.13	1.13	1.00	1.50
Pulses	1.02	1.01	1.02	--	--
Plantain	2.06	1.97	1.69	1.13	1.10
Yam	0.91	0.90	0.92	--	--

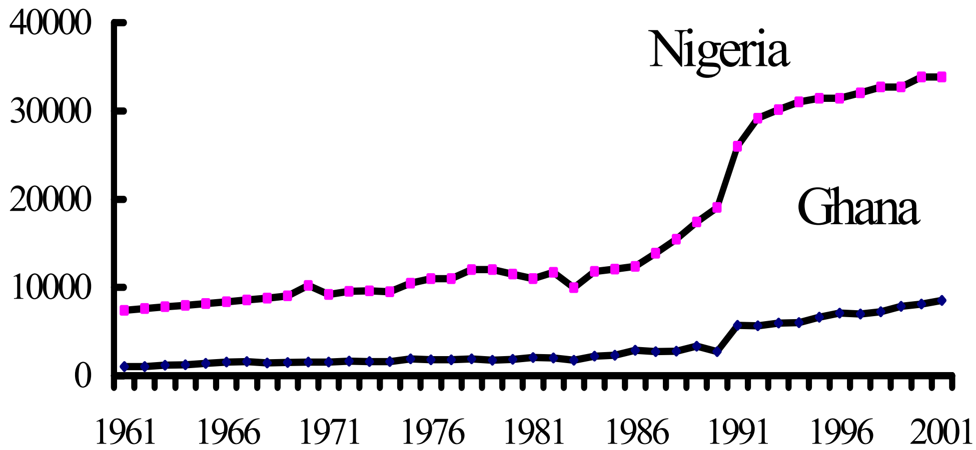
Source: Nweke et al. (2002).

MOTORS OF THE CASSAVA TRANSFORMATION

From 1961 to 2001, growth in Nigerian cassava production can be divided into four distinct periods (Figure 3.2). Turning points and trends within each period can be explained by several driving forces -- the introduction and diffusion of the cassava mechanized grater, the development and diffusion of the new high-yielding TMS cassava varieties, the biological control of the cassava mealybug, and favorable government agricultural development policies (Table 3.2).

[16] The COSCA study did not measure the cassava consumption among the urban households in Nigeria.

Figure 3.2--Nigeria and Ghana: Cassava production, 1961 to 2001 in 000 tons



Source: FAOSTAT

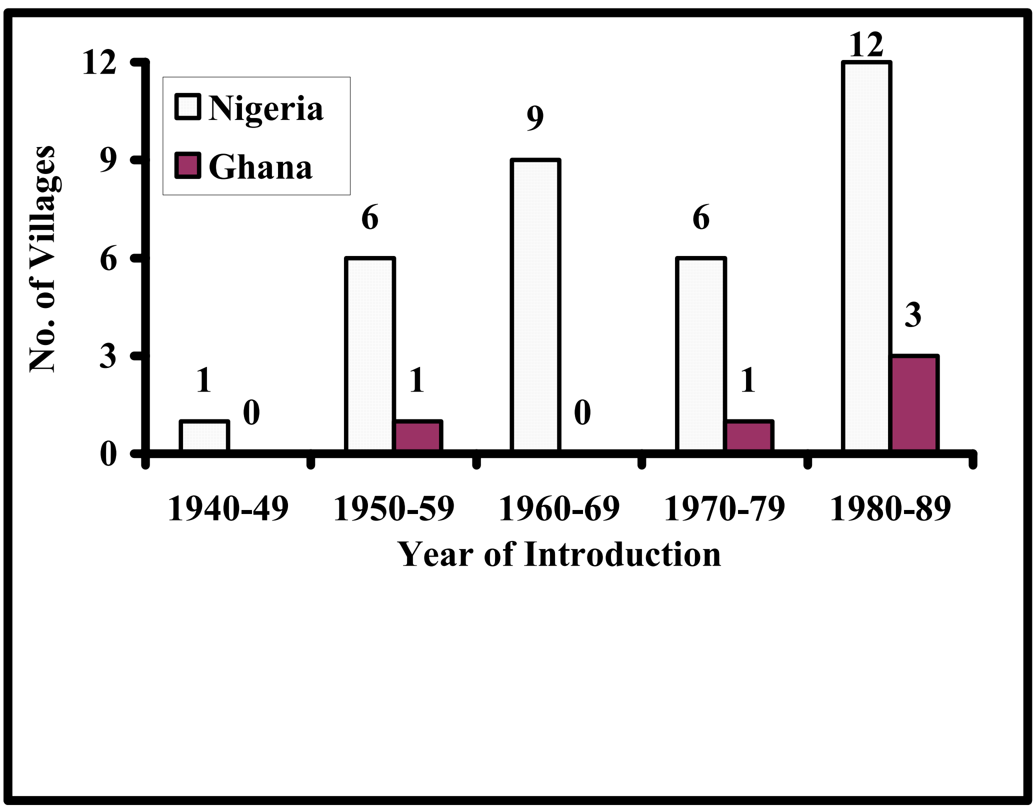
Table 3.2--Nigeria: Technologies and policies in place during the cassava transformation from 1961 to 2001

Year	Technology	Agricultural Development Policy and Macro-Economic Environment
1961 to 1971	Mechanization of the cassava grater	-emphasis on industrial crop production for export -ethnic tension, secession of Biafra, and civil War (1967 to 1970)
1972 to 1983	Development and release of the TMS varieties	-subsidization of food grains importation -exclusion of cassava in major government funded agricultural extension programs
1984 to 1992	Diffusion of the TMS varieties	- ban of the subsidization of food grains importation -inclusion of cassava in major government funded agricultural extension programs -government invested in measures to diffuse the new TMS varieties
1993 to 2001	Hand harvesting of the high-yielding TMS varieties	-ethnic tension following the annulment of 1993 Presidential election -government secured IFAD loan for root and tuber crops expansion

Grater Mechanization

Traditionally, cassava was pounded in a mortar with a pestle to make *gari*. Later, artisans developed a manual grater in the form of a sheet of perforated metal mounted on a flat piece of wood. But the efficiency of the hand grater was low because of its high labor input. In the 1930s, the French introduced mechanical graters in the Republic of Benin (formally Dahomey) to teach farmers how to prepare *gari* and tapioca for export markets (Jones 1959, p. 209). During that same decade in Nigeria, local artisans introduced and modified the mechanized grater (Adegboye and Akinwumi 1990 and Adjebeng-Asem 1990). Initially, the mechanized grater spread slowly. By 1969, for example, the mechanized grater was available in 16 of the 65 COSCA villages (Figure 3.3).

Figure 3.3--Nigeria and Ghana: Number of the COSCA study villages with mechanical grater



Source: COSCA data analysis.

From 1961 to 1971 in Nigeria, government agricultural development policy focused on industrial crop (cocoa, cotton, ground nut, oil palm, and rubber) production for export as a source of government revenue and foreign exchange. Consequently, they did not invest in the R and D (Research and Development) necessary to adapt, fabricate, and diffuse the mechanical grater. Regional governments in Nigeria established farm settlements to promote export crop production--in the Eastern Region, oil palm; in the Northern Region, ground nut and cotton; and in the Western Region, cocoa and rubber and grains for the subsistence of the settler families (Table 3.2). Between 1961 and 1971, serious political tension led to the secession of the Eastern Nigeria as the state of Biafra in 1967 culminating in the Nigerian Civil (Biafra) War from 1967 to 1970. The political tension and the civil war created a situation of insecurity that prevented farmers from investing in private R and D to adapt, fabricate, and diffuse the mechanical graters.

Since the early 1970s in Nigeria, village smiths, welders, and mechanics have over time refined the mechanized grater originally introduced via the Benin Republic. They make these mechanized graters with old engines and scrap metals at costs ranging from US$200 to US$500. Most of the graters are owned by village entrepreneurs and operated by young men who provide grating services to smallholders for a fee based on the quantity grated. The quantity processed for a customer can be as small as one kilogram or as large as several tons. The processors remain at the beck and call of farmers at any hour of the day. In some villages, the graters are located in the market. In other villages, a grater is mounted on wheels and moved to the fields or the homes of farmers who request the services. Roadside mechanics and welders provide maintenance services for the graters at any hour of the day.

Likewise, in the 1970s in Nigeria, several government R and D agencies were established to undertake research into the chemical, biochemical, and engineering/processing of crops including cassava. The agencies include the Fabrication Engineering and Production Company (FABRICO), established in 1971; the Products Development Agency (PRODA), 1971; the Federal Institute of Industrial Research, Oshodi (FIIRO), 1975[17]; the Rural Agro Industrial Development Scheme (RAIDS), 1981; and the African Regional Centre for Engineering Designs and Manufacturing (ARCEDEM), 1983 (Idachaba 1998 and Idowu 1998). The cassava graters developed by government agencies achieved limited adoption because they were more expensive

[17] In 1955, the Nigerian colonial government established the Institute of Applied Industrial Research to institute was re-designated as the Federal Institute of Technical Research in 1958 and the name was changed to the Federal Institute of Industrial Research, Oshodi (FIIRO), 1975 (Idachaba 1998).

and not as efficient, reliable, or convenient as graters developed by the village artisans. Also, the graters developed by engineers in the government agencies have capacities far in excess of the processing needs of the smallholders. As a result, many entrepreneurs who bought the government machines have either had them modified by local artisans or abandoned them (Adegboye and Akinwumi 1990).

Development of the High-Yielding TMS Varieties

In 1891, Warburg reported that the mosaic (cassava mosaic virus) disease was prevalent in East Africa and adjacent islands. Soon after, the mosaic disease was reported in most countries in Central and West Africa (Storey and Nichols 1938). The widespread occurrence of the mosaic disease motivated the British colonial government to launch a cassava breeding program at the Amani research station in Tanzania in the mid-1930s. The goal of research was to develop varieties that were tolerant to the mosaic disease.

Research on varieties resistant to the mosaic disease was also carried out by the British colonial government researchers in the Coast Experiment Station Kibarani in Kenya, the Morogoro Experiment Station in Tanzania, the Agricultural Department in Zanzibar, and the Serere Experiment Station in Uganda (Nichols 1947). Similar research was also carried out in the Kumasi research station in Ghana, at Njala in Sierra Leone, and at the Moor Plantation research station in Ibadan, Nigeria (Jones 1959).

The French colonial research on cassava was carried out by scientists at IRAT (Institut De Recherches Agronomiques Tropicales) (Fresco 1986). In 1913, the French established a research station at Bambey in Senegal for peanuts primarily for export. In 1950, the scope of research at the station was expanded to include food crops and the research designed cassava variety selection programs with the goal of finding varieties that were high yielding and suitable for processing as *gari* (Jones 1959).

In 1933, the Belgian Government established INEAC (the Institut National pour l'Etude Agronomique du Congo Belge) at Yangambi in the Congo to pursue research on agricultural development, including the genetic improvement of cassava in Central Africa. Nearly 40 research stations were established by INEAC in Central Africa (Fresco 1986). Initially, the cassava genetic improvement objective of INEAC was to select local varieties that were best suited for small-scale processing for home consumption. But since 1950, as the urban demand increased for cassava products such as *chickwangue* and dried root flour, the goal of research

was extended to include selection of varieties suitable for intensive mechanized production (Drachoussoff et al. 1993).

Among these disparate research efforts, the program at the Amani research station ultimately proved to be the most successful colonial cassava breeding program in Africa. In 1935, H. H. Storey conducted a worldwide search for cassava varieties that were resistant to the mosaic disease. Yet he failed to find varieties with sufficient resistance to the mosaic disease. Continuing the search, Storey and his assistant, R. F. W. Nichols, discovered that sugar cane varieties immune to sugar cane mosaic disease were developed by crossing the sugar cane plant with its wild non-sugar producing relative. So Storey and Nichols crossed cassava with tree species which are related to cassava genetically, namely Ceara rubber, Manicoba rubber, and "tree" cassava[18] (Nichols 1947). These species conferred mosaic virus resistance to their hybrids, namely Ceara rubber x cassava, Manicoba rubber x cassava, and "tree" cassava x cassava hybrids (Jennings 1976). Although the various rubber species x cassava hybrids proved resistant to the mosaic disease, they produced a low root yield of poor food quality and they had poor agronomic characteristics such as lodging.

During World War II (1939 to 1945), the breeding work at the Amani research station was scaled back (Nichols 1947). In 1951, Nichols died in an automobile accident and was replaced by D. L. Jennings. Jennings intercrossed the Storey/Nichol' s various mosaic- and brown streak-resistant rubber species x cassava hybrids to release recessive genes for resistance and to combine genes that had been dispersed during the process of backcrossing by Storey and Nichols. This led to segregates, e.g. 5318/34, that showed higher and more stable resistance over a wide area than the hybrids created by Storey and Nichols. Jennings distributed pollinated seeds of these segregates to several African countries in 1956, one year before the Amani research station program was terminated in 1957[19] (Jennings 1976).

In 1958, at Moor Plantation research station, in Ibadan Nigeria, B. D. A. Beck and M. J. Ekandem selected the Ceara rubber x cassava hybrid, 58308, from the seed derived from the Jennings' series 5318/34. The Ceara rubber x cassava hybrid, 58308, though resistant to the mosaic disease gave low yield and poor root quality. So Beck and Ekandem crossed the Ceara

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[18] Tree cassava is believed to be a natural hybrid of Ceara rubber and cassava (Jennings 1976).

[19] Cours et al. (1997) reported that a parallel research activity in the 1930s following the same approach was carried out independently by the French at Alatroa agricultural research station in Madagascar and achieved similar results as at the Amani research station.

rubber x cassava hybrid, 58308, with high-yielding West Africa selections to combine the mosaic disease-resistance genes of the Ceara rubber x cassava hybrid, 58308, with the genes for high yield from West African varieties (Jennings 1976).

At Nigeria's independence in 1960 the cassava breeding program at the Moor Plantation research station, Ibadan was moved to the Federal Root Crops Research (now National Root Crops Research) Institute, Umudike in Eastern Nigeria and breeding work was continued by Ekandem. Unfortunately, almost all the progenies developed from the Ceara rubber x cassava hybrid, 58308, and the records of the research program at Umudike along with records transferred from the Moor Plantation research station in 1960 were lost during the Nigerian Civil (Biafran) War (1967-1970). The original Ceara rubber x cassava hybrid, 58308, however remained at the Moor Plantation research station (Beck 1980).

Cassava breeding at the IITA' s Ibadan headquarters commenced in 1971 when S. K. Hahn was appointed as the leader of the Institute's root and tuber program. Hahn's strategy for developing the TMS varieties was a collaborative undertaking involving national cassava research programs, training national scientists, developing partnerships with private companies, and investing in germ plasm exploration and conservation. The IITA's cassava breeding program was carried out by a multi-disciplinary team including a plant pathologist, entomologist, nematologist, virologist, agronomist, tissue culture specialist, biochemist, and food technologist (Dixon et al. 1992). Hahn invited two of Storey' s former colleagues to join his research team at IITA: A. K. Howland, 1972 to 1976 and D. L. Jennings 1975[20].

Hahn and his team members set about developing new cassava varieties with two key characteristics: mosaic resistance and high yield. Drawing on the earlier work of Storey, Hahn and his team members combined the mosaic-resistance genes of the Ceara rubber x cassava hybrid, 58308, with genes for high yield, good root quality, low cyanogens, and resistance to lodging. Hahn utilized the Ceara rubber x cassava hybrid, 58308, as a source of resistance to the mosaic virus and bacterial blight[21].

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[20] Hahn (2000) reported that Ms Howland was especially helpful in providing information on Storey's research program on the mosaic disease.

[21] At the time of the commencement of the IITA's cassava breeding program, a new and serious disease of cassava, the bacterial blight, was reported in Nigeria in 1972. The disease spread to the Congo, Cameroon, Togo, Benin, Ghana, Uganda, Kenya, Burundi, Rwanda, and the Central African Republic.

Over a two year period (1971 to 1973), Hahn and his team members drew on the genes from the Ceara rubber x cassava hybrid, 58308, and developed varieties which were resistant to the mosaic virus[22]. Hahn then set about developing mosaic-resistant, high-yielding varieties by crossing mosaic-resistant varieties with many other high-yielding varieties from West Africa and Brazil and selecting and testing clones at the farm level in different agro-ecological zones (Hahn et al. 1980; Otoo et al. 1994; Mba and Dixon 1998).

From 1973 to 1977, the IITA cassava program established a partnership with the Shell BP Petroleum Development Company of Nigeria Limited (Shell-BP) in a high rainforest village in the delta area in Nigeria where the Shell-BP was producing oil. Shell-BP hired an agronomist and launched a development program to assist cassava farmers in the area. In 1974, IITA scientists conducted a diagnostic survey and found that severe bacterial blight infection and low yield were the main cassava production problems in the area. In collaboration with the Shell-BP, IITA conducted on-farm testing of the IITA's clones to select varieties for the mosaic disease and bacterial blight resistance, high yield, and root quality.

After six years (1971 to 1977) of research, Hahn and his staff achieved the goal of developing high-yielding, mosaic-resistant TMS (Tropical Manioc Selection) varieties. These new high-yielding-mosaic-resistant varieties included TMS 50395, 63397, 30555, 4(2)1425, and 30572 (hereafter cited as TMS varieties). The COSCA researchers discovered that the farm-level yield of the TMS varieties in Nigeria was 40 percent higher than that of the local varieties, even when grown without fertilizer. The IITA released these new varieties to farmers in Nigeria in 1977.

Control of the Cassava Mealybug

The mealybug is an exotic pest introduced into Africa from South America in the early 1970s. First reported in 1973 in the Congo (formally Zaire), the mealybug spread rapidly throughout the cassava growing areas of Africa. In some areas, it destroyed so much of cassava fields and local sources of the planting materials that production practically came to a halt (IITA 1992). It spreads by wind and the exchange of infested planting materials. The mealybug feeds

[22] The Ceara rubber x cassava hybrids were not real cassava because they did not stand erect and they produced low root yields that were of poor food quality. Hahn crossed the Ceara rubber x cassava hybrid, 58308, with West African and South American cassava varieties that were susceptible to mosaic but stood erect and gave high root yields that were of good food quality. The result was the mosaic-resistant and high-yielding TMS varieties.

on the cassava stem, petiole, and leaf near the growing point of the cassava plant. During feeding, the mealybug injects a toxin that causes leaf curling, slowing of shoot growth, and eventual leaf withering. Yield loss in infested plants is estimated to be up to 60 percent of root and 100 percent of the leaves (Herren 1981).[23] The mealybug epidemic contributed to the unstable growth in cassava production in Nigeria in 1971 to 1986.

Starting in 1979, the IITA led a large scale biological control campaign in collaboration with numerous national and international organizations to attack the mealybug. The team identified a natural predator wasp that feeds on the mealybug in its home habitat in South America, then transferred specimens to the IITA and reared them at an IITA research station. But in order to decentralize and speed up the multiplication of the wasp, IITA scientists developed a new and simpler system that was employed by most national programs in Africa (IITA 1992). The wasp was first released by airplanes over cassava growing areas in Nigeria in 1981 and later in other countries (Herren et al. 1987). The control of the mealybug contributed to the high rate of growth in cassava production in Nigeria from 1987 to 2001. Without question, the biological control of the mealybug with the aid of the wasp is one of the important scientific success stories of the past two decades in Africa.

The mealybug remains present in Nigeria and sometimes damages cassava fields even where the wasp has been well established (IITA 1992). In 1991, the presence of the mealybug was reported in Nigeria in 57 percent of the COSCA villages. However, because of the new lower-level equilibrium established by the presence of its natural predator, the percentages of plants per field infested remain low and the mealybug does not seriously affect cassava yields. Even so, the persistence of the mealybug suggests a continued need to monitor the impact of the biological control program.

Government Policies

The dramatic expansion of Nigeria's oil exports in the 1970s increased the real rate of growth of per capita GNP by 5.3 percent and sparked massive rural to urban migration together with high urban demand for food (Akande 2000). During the 1970s, government used foreign

[23] The yield losses presented here for the pests and diseases are guesstimates. The interactions among the various pests and diseases, the influences of soil fertility, seasonal factors, the cassava varietal factors, and cropping practices complicate the assessment of yield loss due to specific pests and diseases (Thresh 1997).

exchange earnings from petroleum exports to help pay for food imports (Table 3.2). From 1976 to 1985, the annual per capita rice imports increased by more than 1,500 percent of its 1961 to 1965 level. The substantially overvalued Naira effectively subsidized the consumer price of imported rice. In addition, the Nigerian National Supply Company Limited, a money-losing government agency, further subsidized rice consumers by selling rice at a uniform price nationwide and absorbing transportation costs.[24] The resulting quantum jump in subsidized rice and wheat imports artificially depressed the price of *gari* and acted as a constraint on the spread of the TMS varieties from the late 1970s to 1985. Without doubt, the Nigerian government's policy of subsidized grain imports contributed to unstable growth in cassava production from 1971 to 1986.

Likewise during the early 1980's, government subsidy on fertilizer ranged from 72 percent to 85 percent of the farm delivered price. Not surprisingly, use quintupled, increasing from 100,000 tons in 1980 to 518,120 tons in 1990 (Akande 2000, p.5). Cassava, however, did not benefit from the fertilizer subsidy. In Nigeria, the COSCA study found that chemical fertilizer was used in only 15 percent of cassava fields compared to 52 percent of maize fields.[25]

By the early 1980s, rapid petroleum-led economic growth had slowed down significantly. The declining petroleum revenue in the mid 1980s spurred renewed interest in cassava by the Nigerian government. Owing to declining petroleum revenue, the Nigerian government was no longer able to finance large-scale subsidized grain imports to feed the country's large urban population.

In 1985, the Nigerian government banned the import of wheat, rice, and maize and the export of yam and cassava products. The following year, the government adopted a SAP (structural adjustment program) which consisted of a number of policy reforms, including the devaluation of the Naira (Akande 2000, p.11).[26] The ban on food import, the SAP, and the currency devaluation contributed immensely to the rapid diffusion of the TMS varieties.

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[24] During the foreign exchange bidding in September 1986, the value of the Naira dropped from US$1.12 to about $0.30.

[25] Cassava has been widely reported to display a selective yield response to chemical fertilizer application (Ndibaza 1994 and IITA 1989).

[26] From 1.0 Naira per US$1.0 in 1986 to 4.0 Naira per US$1.0 in 1987. The Naira has continued to slide. In February 2001, the value was 124 Naira per US$1.0.

Diffusion of TMS Varieties

In the 1970s and early 1980s, the petroleum revenue enabled the Nigerian government to experiment with alternative extension programs. But these extension programs did not include cassava. For example, the NAFPP (National Accelerated Food Production Program) was set up in 1972 to design, test, and transfer technological packages for five crops: rice, maize, sorghum, millet, and wheat. It was after two years, in 1974, that cassava was added to the list. In 1974, the World Bank financed the establishment of three ADPs (Agricultural Development Projects) in Funtua, Gombe, and Guzau--all in northern Nigeria outside the major cassava producing zone. Thus, in the 1970s, cassava did not benefit from the large-scale public investment in the ADPs (Table 3.2).

Following the radical reorientation of agricultural policy during the SAP years, beginning in the mid-1980's, cassava emerged as an important crop in the national effort to replace imported foods with domestic production. In 1984, the NCRCP (National Coordinated Research on Cassava Project) was set up to coordinate the on-farm adaptive research on cassava by the NAFPP, ADPs, research institutes, and universities. In 1985, the ADPs were established in cassava producing states to carry out on-farm evaluation of new technologies including the TMS varieties, construct roads for input delivery and output evacuation, provide extension service to farmers, and multiply and distribute the TMS stem cuttings and seeds of other crops. In 1986, for example, the Oyo State ADP distributed the planting cuttings of the TMS 30572 varieties to 55,000 farmers in the state. The ADPs in the other cassava producing states also distributed the planting cuttings to farmers in their states. Thus, the ADP played a significant role in the diffusion of the TMS varieties in Nigeria[27] (Table 3.2).

By 1985, the NAFPP was working with 704,000 farmers in the 12 major cassava producing states of Nigeria[28]. Under the NAFPP, extension agents helped farmers prepare 7 x 39 square meter-demonstration plots planted with the TMS varieties side by side with local varieties. At harvest time, a panel of local farmers compared the plots and if TMS varieties were found to be superior, the TMS demonstration advanced to a second phase which involved fewer plots of a larger size. Farmers are expected to adopt the package of the TMS varieties if they

[27] The World Bank admits that the ADP (Agricultural Development Project) was a big failure in Nigeria (World Bank 1993).

[28] Nigeria was divided into 19 states at the time.

continued to be superior to the local varieties in the second phase of the demonstration. The NAFPP introduced the TMS varieties to all the cassava producing areas of Nigeria, making it easy for further diffusion by the farmer-to-farmer method of technology transfer.

In 1986, the cassava program of the National Seed Service was established with a US$120 million grant from the IFAD (International Fund for Agricultural Development) to multiply and distribute the stem cuttings of the TMS varieties free to farmers. The free distribution of TMS stem cuttings was critical to the rapid diffusion of the TMS varieties because the multiplication rate is low, about 5 cuttings from a plant, compared with maize, about 100 seeds from a plant. The cassava planting cuttings are bulky and perishable. They dry up within a few days after harvest. But farmers who plant the IITA’s high-yielding TMS varieties do not need to collect new planting materials each season from research or specialized seed companies in order to maintain planting material quality. The COSCA study found that the farmers' most common source of cassava planting material is their own fields. Each cassava plant represents its own clone because cassava is vegetatively propagated. Hybrid vigor is easier to fix and lasts longer in cassava than in other crops such as maize that are propagated by seed. In addition, cassava is a genetically complex crop since it is an allotetraploid, that is, each trait -- such as pest resistance -- is determined by more than one gene. These attributes mean that a pest-resistant cassava variety does not easily succumb to a pressure of new races of pests and disease.

The rapid diffusion of the TMS varieties in Nigeria was facilitated by the collaboration of NRCRI (National Root Crops Research Institute), the World Bank, IFAD, churches, the Nigerian Cassava Growers’ Association; by government revenue from the oil sector; and by availability of low cost gasoline. From 1988 to 1991, Texagric, a private agro-business organization jointly owned by a Nigerian businessman and Texaco Oil Company, distributed free planting materials to local farmers. The Nigerian Agip Oil Company also multiplied and supplied TMS planting materials to a large number of farmers, cooperative societies, women's associations, and schools. Other non-governmental organizations involved in the production, promotion, and distribution of planting materials of the improved varieties included church groups, schools, universities, Nigeria Cassava Growers Association, and the mass media.

Dr S. K. Hahn, the head of the IITA’s cassava research program, encouraged cassava farmers to launch the Nigerian Cassava Growers’ Association with membership drawn from all the cassava producing states of Nigeria. Hahn also prepared news releases about the TMS

varieties and distributed them to Nigerian newspapers and radio and television stations. Hahn distributed the planting materials of improved varieties through churches and schools (Hahn 1998). Hahn, a Catholic, went to different churches each Sunday dressed in his Yoruba tribal chieftaincy regalia.[29] At the end of the mass, he stood at the church's main door with small bundles of the cuttings of the improved varieties, encouraging members of the congregation, especially women, to take the cuttings and test-plant in their fields. Hahn also visited numerous schools and encouraged children to take the materials to their parents to plant along side local varieties.

What are the lessons from the story of the rapid diffusion of the TMS varieties in Nigeria? First, government policy was an important factor in the rapid diffusion of the TMS varieties. The TMS varieties were released to farmers in 1977 but diffusion did not take place until government invested in measures to multiply and distribute the TMS varieties to farmers.

The second lesson is that Dr Hahn, the scientist responsible for the development of the TMS varieties at the IITA, played a critical role in eliciting the collaboration of the national programs, the private sector, the donors, and the media in the diffusion program. Hahn himself directly distributed the TMS varieties to farmers throughout Nigeria. In my opinion, the mandate of the IARCs (International Agricultural Research Centers) should be broadened to include extension so that cassava breeders can play a leading role in the diffusion of their varieties. Dr Hahn spent six years (1971 to 1977) on the development of the TMS varieties and 17 years (1977 to 1994) on the diffusion of the TMS varieties. In an innovative discussion of the role of policy analysts in agricultural policy process in Africa, Professor Francis Idachaba (2000) advocated that agricultural scientists should lead in the diffusion effort for their technologies.

The third lesson is that the rapid diffusion was possible because the mechanized grater was available in most of the cassava producing villages in Nigeria. The replacement of hand grating with the mechanized grater has reduced the cost of making *gari* and dramatically increased the profitability of *gari* production with the TMS varieties.

By the late 1980s, the TMS diffusion in Nigeria had become an African success story *par excellence*! In 1989, COSCA researchers found that the TMS varieties were grown by many farmers in 60 percent of the surveyed villages in the cassava growing areas of Nigeria (Table

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[29] Hahn was honored with the chieftaincy title of Ba-ale Agbe (King of Farmers) by the members of a town in Western Nigeria in recognition of his work in developing the TMS varieties.

3.3). The TMS varieties were grown in both the forest and the savanna zones of Nigeria. The TMS 30572 variety was the most popular, especially among farmers who process it as *gari* for sale in urban markets. In Nigeria, the TMS varieties have contributed to the rapid expansion in cassava production that has occurred from 1987 to 1993.

Table 3.3--COSCA countries: Percentage of villages by relative number of farmers who planted the TMS varieties in 1989

RELATIVE NO. OF FARMERS	CONGO	COTE d'IVOIRE	GHANA	NIGERIA	TANZANIA	UGANDA
No Farmers	97	100	100	11	50	85
Few Farmers	3	0	0	30	50	5
Many Farmers	0	0	0	36	0	5
Most Farmers	0	0	0	23	0	5
TOTAL	100	100	100	100	100	100

Source: Nweke et al. (2002)

EMERGING HARVESTING AND PROCESSING LABOR BOTTLENECKS

Cassava production, which expanded at an increasing rate from 1987 to 1993 in Nigeria, saw momentum fall as production continued to grow but at a decreasing rate from 1994 to 2001 (Figure 3.2). In the 1980s in Nigeria, the cassava transformation as a cash crop for urban consumption was speeded up by the use of the mechanized grater for preparing *gari* after the Nigerian government invested in measures to promote the cassava transformation.[30] In 1990, the mechanical grater was available in 52 percent of the COSCA villages in Nigeria. Since the grating task is mechanized, peeling is now the most labor-intensive task followed by the toasting stage in *gari* preparation. Yet during the 1990s, progressive farmers who achieve high yields by growing the TMS varieties face new labor bottlenecks at the harvesting and processing stages. They are no longer able to secure sufficient seasonal hired labor because of rising wages. This second-generation labor constraint increasingly hampers cassava expansion in Nigeria.

The high yields obtained using the TMS varieties created labor bottlenecks that are dampening cassava production growth in Nigeria. Table 3.4 shows that harvesting cassava is the most labor-intensive field task in Nigeria where the TMS varieties have boosted yields by 40 percent and shifted labor constraint from cassava weeding to cassava harvesting. Labor is the

[30] See "Government policies and Diffusion of the TMS Varieties in Nigeria" below.

main item in the cost of cassava production. Conventional wisdom holds that cassava requires relatively low labor inputs for production (Hendershott 1972). However, COSCA research confirms that this conventional wisdom is valid only where cassava is produced as a famine-reserve crop or as a rural food staple. The conventional wisdom is not valid where cassava is produced as a cash crop for urban consumption such as in Nigeria.

Table 3.4--COSCA countries: Cassava production labor by task

TASK	CONGO	COTE D'IVOIRE	GHANA	NIGERIA	TANZANIA	UGANDA
			DAYS PER HA			
Land Clearing	66	53	44	409	54	45
Seed Bed Prep.	21	29	31	41	27	31
Field Planting	39	22	28	32	27	28
Weeding	27	28	34	38	28	32
Harvesting	48	44	53	62	46	52
TOTAL DAYS	201	173	191	222	182	187

Source: Nweke et al. (2002).

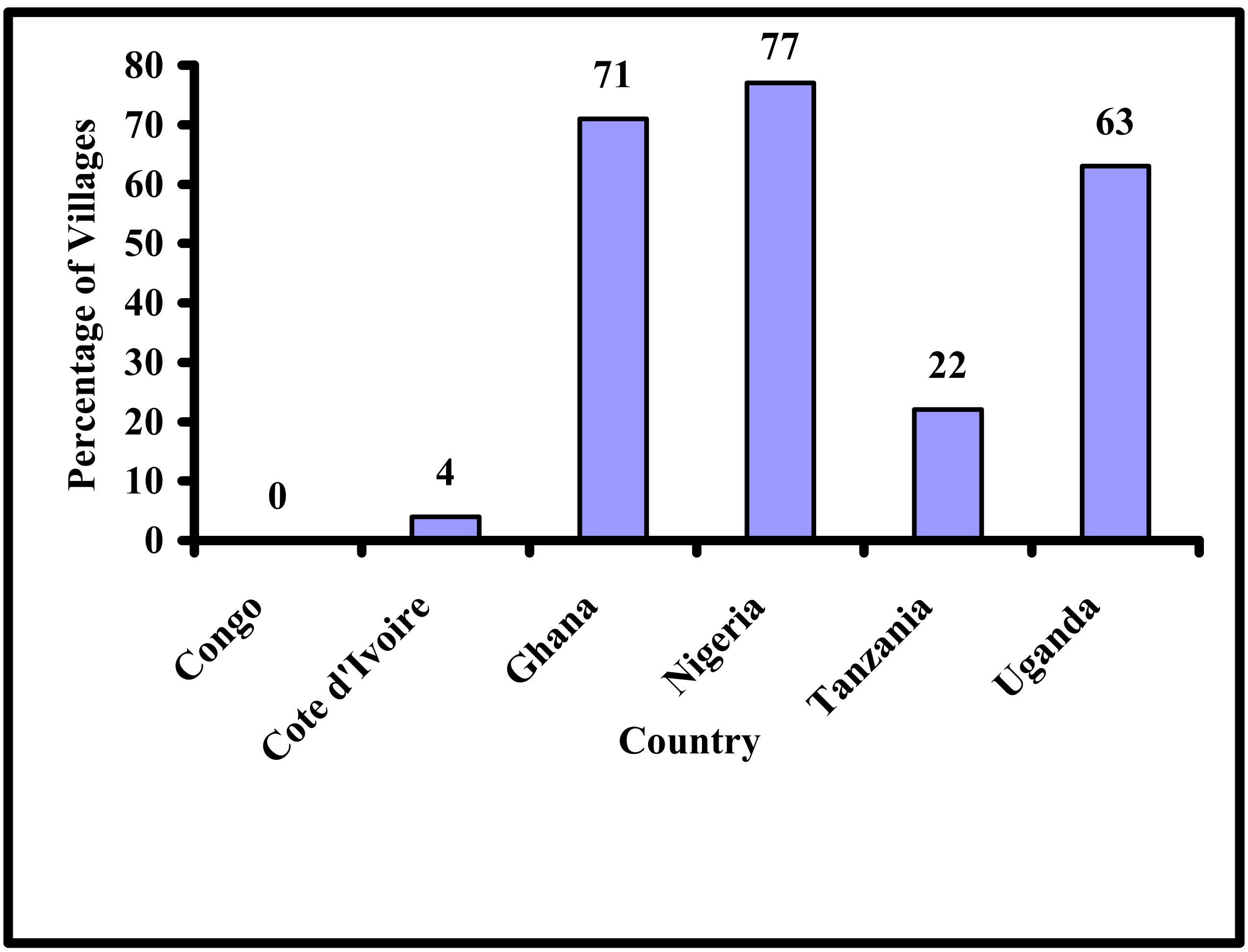
The COSCA study reveals that farmers in Nigeria use more labor in cassava production and processing than any other country because farmers must harvest and process such large volumes of increasingly high yielding cassava. Harvesting and processing labor is now proving to be a serious constraint to the expansion of cassava production in Nigeria because labor for cassava harvesting and processing increases in direct proportion to yield. It is not surprising that farmers who plant TMS varieties in Nigeria have sometimes had to suspend planting because they were unable to hire sufficient labor to harvest previously planted cassava fields. Addressing the problem of labor constraints will improve the productivity of the cassava system, raise farm incomes, and reduce cassava prices to consumers.

In Nigeria, the harvesting constraint for cassava is reminiscent of the state of grain harvesting in the United States at the beginning of the nineteenth century when grain was still harvested by hand, by the same method that had been used since the fourteenth century (Johnson 2000, p.6). The invention of the reaper in America in the second quarter of the nineteenth century sharply reduced labor inputs in grain harvesting. The combine then replaced the reaper and the direct labor inputs used to produce a ton of grain declined by 70 percent in the nineteenth

century (Johnson 2000). Without question, a mechanical revolution is now needed to break the labor bottleneck in cassava harvesting among farmers in Nigeria who are planting the TMS varieties.

In Nigeria, progressive farmers who produce cassava as a cash crop for urban consumption secure labor in two ways. First, they use hired labor for cassava production and harvesting in most of their cassava fields because cassava is grown mostly as a cash crop for urban consumption (Figure 3.4).

Figure 3.4—COSCA countries: Cassava fields using hired labor



Source: Nweke et al. (2002)

However, as wage rates increase in Nigeria, it is becoming difficult for farmers to continue to produce and harvest cassava at prices competitive with grain. In Nigeria, the COSCA study found that within an interval of 10 years (1991 to 2001), the real farm wage rate more than doubled. In 1991, the COSCA farmers in Nigeria who planted the TMS varieties and sold *gari* to urban consumers paid on the average, the equivalent of US$1.24 per man day. Ten years later, in 2001, they paid the equivalent of US$3.50 per man day. Over the same period, the price of *gari* increased by less than 40 percent, from an average of US$185 per ton in 1991 to an equivalent of US$255 per ton in 1998.[31]

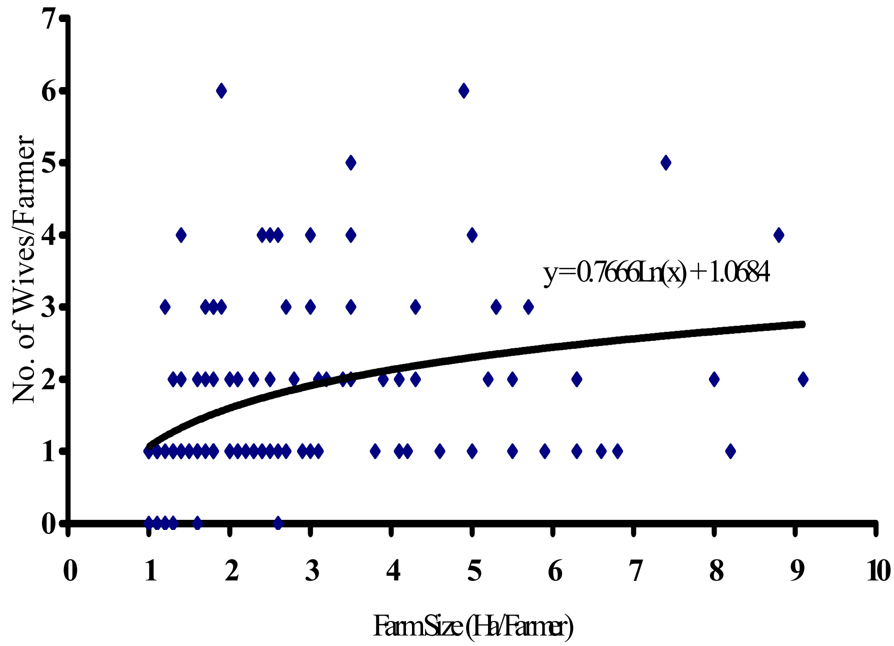
But the wage rates were not high enough to attract sufficient labor for hire on the farm during the peak farm labor demand period. At the same time, the farmers found the wage rates too high to pay because of the low productivity in the cassava sector and because the wage rate was increasing faster than the price of *gari*. Farmers who planted the TMS varieties as a cash crop for urban consumption sometimes suspended cassava planting because they could not find sufficient hired labor to harvest and process earlier planted fields (Nweke et al. 2002).

Second, progressive farmers in Nigeria marry many wives to secure labor supply for their cassava production. In Nigeria, the COSCA researchers found a positive and significant correlation between cassava farm size and number of wives per farmer (Figures 3.5).

But the practice of marrying wives for farm power is not cost effective in the long run because wives bear children. The children go to school and do not contribute to farm work. Instead, farm income is used to pay school expenses for the children. The practice of marrying wives for farm power instead of buying tractors or oxen proves costly to human life and welfare. The COSCA researchers found that most of the women married as a source of farm power do not live long because of hard labor, especially in cassava processing.

[31] Source: Ministry of Finance and Economic Development, Benin City, Nigeria.

Figure 3.5--Nigeria: Number of surviving wives per farmer by farm size.



Source: COSCA study

For example, by 2002 Mr Onoriemu Akpozobo (Onoriemu for short) 59, the most progressive of the COSCA study farmers in Nigeria in terms of farm size, had married a total of 10 wives who bore 46 children. By 2002, only four of the wives, including a young one he married in 2001, and 21 of the children were still alive. In 1955, W. Arthur Lewis described women in under-developed countries as beasts of burden because they were used to execute tasks which in more advanced societies are done by mechanical power (Lewis 1955, p. 422). There is urgent need to develop labor-saving technologies for cassava production, harvesting, and processing to replace the practice of using women as beasts of burden.

New mechanical technologies for cassava harvesting and processing are required to generate the rate of growth in cassava production realized in Nigeria from 1987 to 1992. Further improvement in yield-increasing technologies alone will not generate the same level of cassava production growth because genetic technologies which increase yield will only add to the existing labor bottlenecks at the harvesting and processing stages. Yield-increasing genetic

technologies are important but insufficient engine of growth of the cassava sector. The challenge is to augment the yield-increasing genetic technologies with mechanical technologies in order to break the new labor bottlenecks at the harvesting and processing stages and transform cassava to play an additional role as a livestock feed and industrial raw material.

IMPACT ON PRODUCTION AND PRICES

What is the impact of the mechanical grater, the new TMS varieties, and radically altered government policies on cassava output, prices, and poverty in Nigeria? The analysis of the impact of the cassava transformation on output is based on per capita output. The impact of the cassava transformation on food prices is assessed by comparing the price of *gari*, the most common form in which cassava is marketed in Nigeria, with the prices of alternative staples, namely yam and rice.[32] During the past 40 years the impact of the cassava transformation on output per capita and prices in Nigeria is mixed depending on the technologies and government policies at play during different time periods.

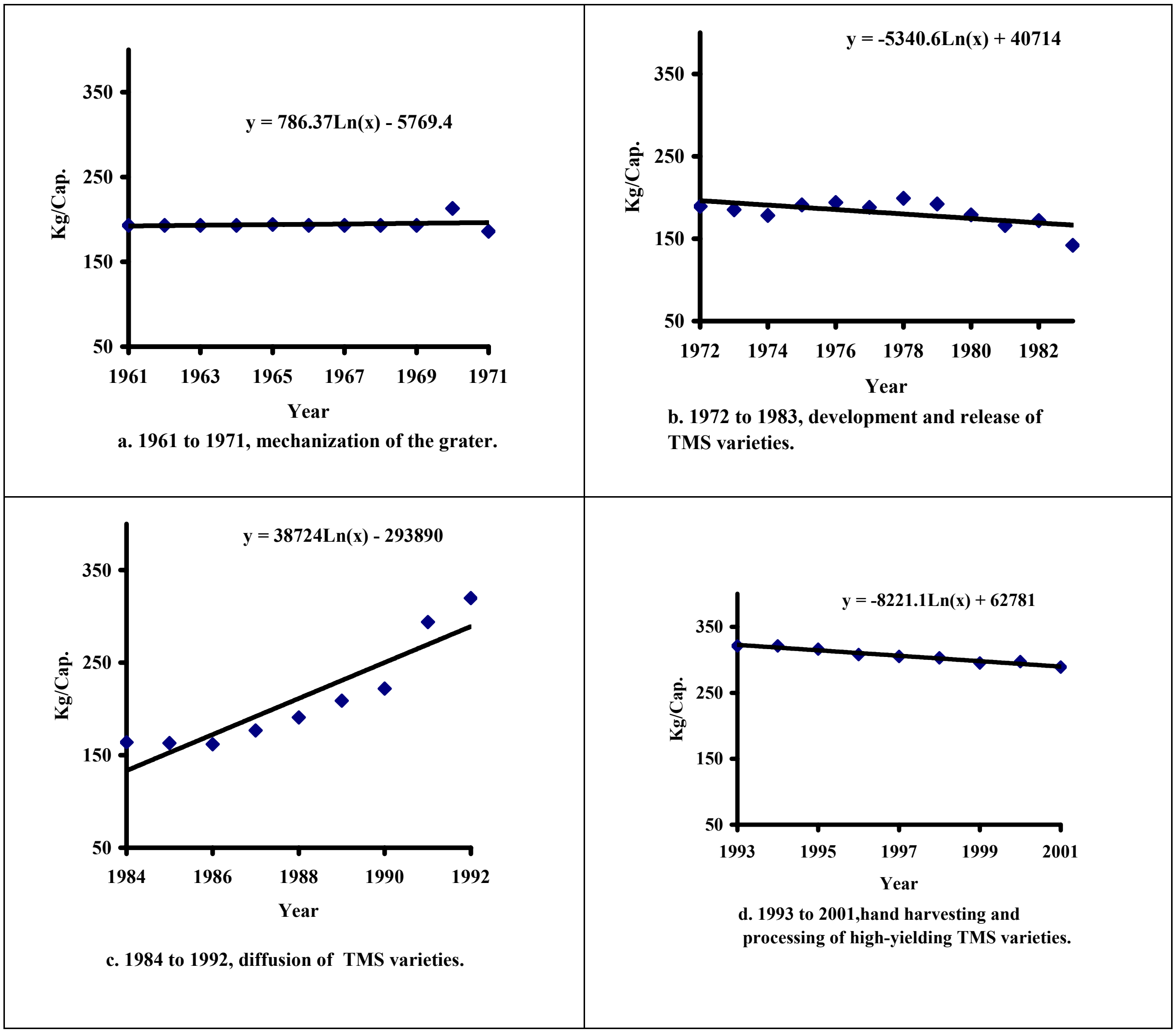
Impact of the Mechanized Grater

From 1961 to 1971in Nigeria, the mechanized grater was the major cassava technology available. But from 1961 to 1971 in Nigeria, the cassava transformation did not produce a significant impact on cassava output per capita or on driving down the price of cassava to consumers. From 1961 to 1971 in Nigeria, national cassava output per capita declined and the price of *gari* increased relative to yam and to rice (Figures 3.6a, 3.7a, and 3.8a).[33] From 1961 to 1971, the Nigerian government did not invest in extension to diffuse the mechanical grater which would have released labor from processing for production of cassava. In the 1960s, the Nigerian government's agricultural policy emphasis was focused on export crops such as cocoa, cotton, oil palm, and rubber as the main sources of government revenue and foreign exchange.

[32] In Nigeria, yam and rice are the second and third mot important staples after cassava in terms of calories consumed in the cassava producing areas. In Ghana, maize and yam are the second and third most important staples after cassava in terms of calories consumed.

[33] In Nigeria, price data was available from 1966 to 1998.

Figure 3.6--Nigeria: The impact of the cassava transformation on per capita output, 1961 to 2001



a. 1961 to 1971, mechanization of the grater.

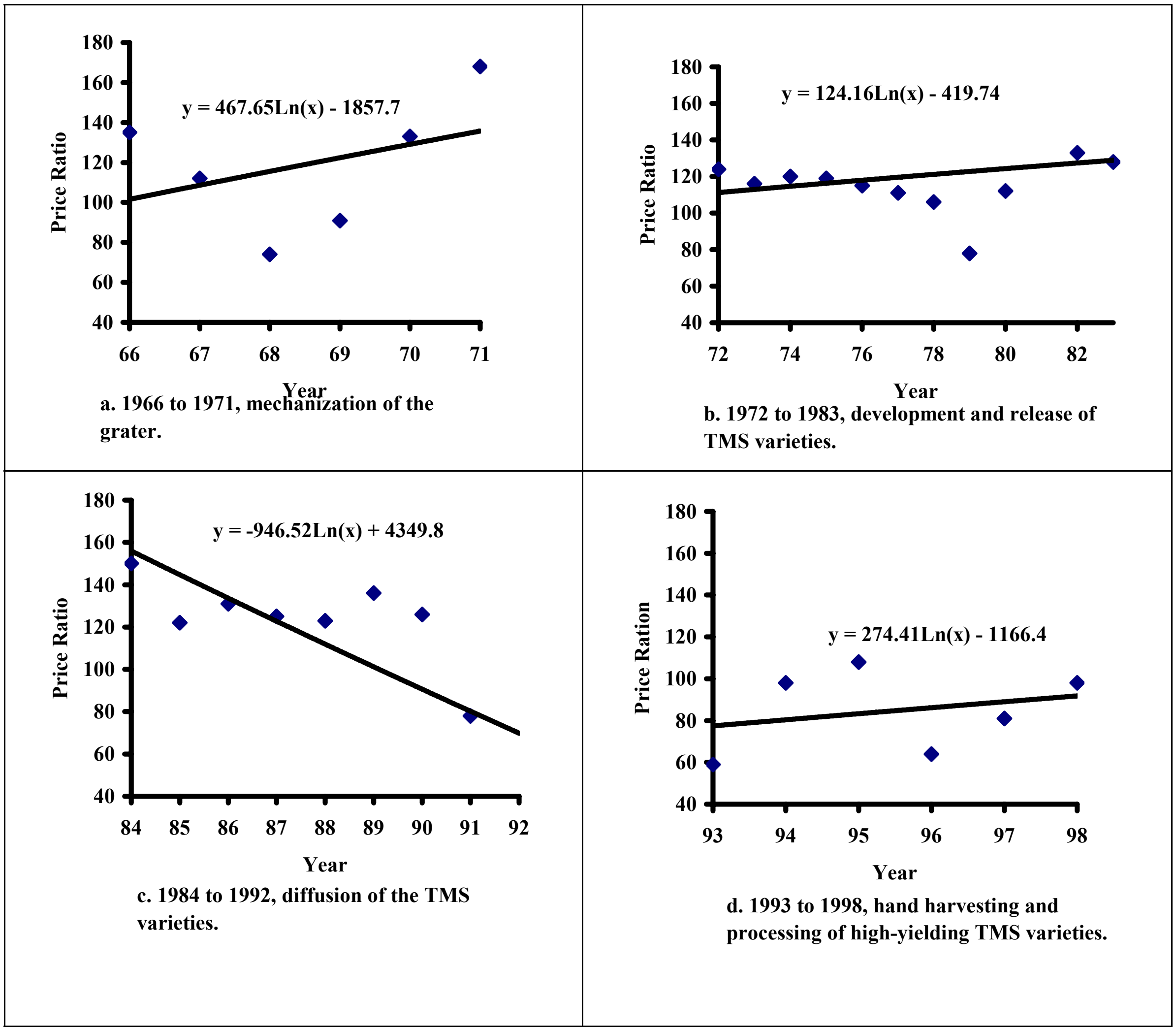
b. 1972 to 1983, development and release of TMS varieties.

c. 1984 to 1992, diffusion of TMS varieties.

d. 1993 to 2001,hand harvesting and processing of high-yielding TMS varieties.

Source: FAOSTAT.

Figure 3.7--Nigeria: The impact of the cassava transformation on the *gari* –to-yam price ratio, 1966-1998



a. 1966 to 1971, mechanization of the grater.

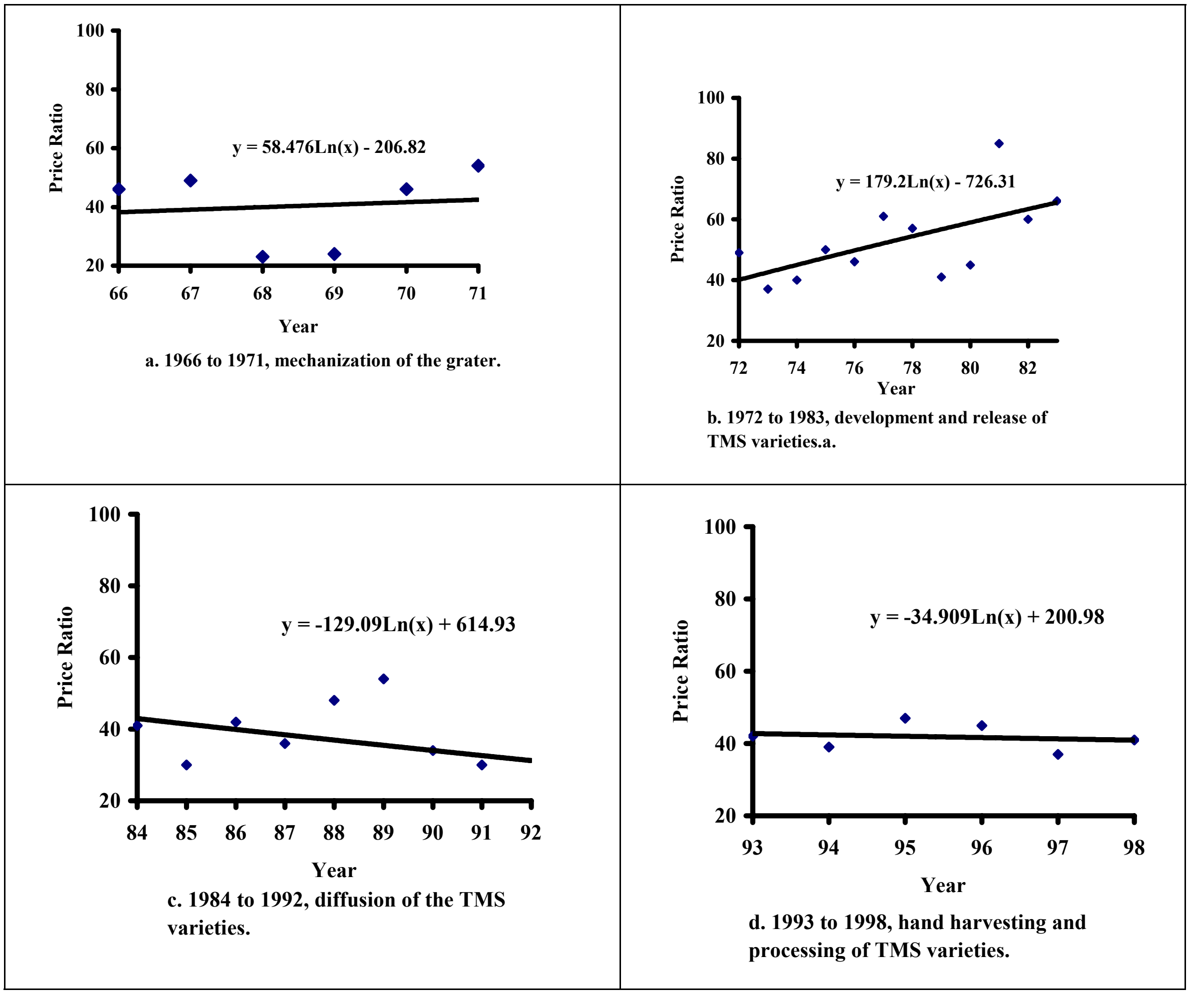
b. 1972 to 1983, development and release of TMS varieties.

c. 1984 to 1992, diffusion of the TMS varieties.

d. 1993 to 1998, hand harvesting and processing of high-yielding TMS varieties.

Source: Ministry of Finance and Economic Development, Benin City.

Figure 3.8--Nigeria: The impact of the cassava transformation on the *gari*-to-rice price ratio, 1966 to 1998



Source: Ministry of Finance and Economic Development, Benin City.

Impact of TMS Varieties

From 1972 to 1977 in Nigeria, the TMS varieties were developed and released to farmers. But the diffusion of the TMS varieties was slow because the government through grain import subsidy policy and exclusion of cassava from major government extension programs discouraged cassava production. Meanwhile, government subsidized fertilizer for cereals and expanded investments in the ADPs (Agricultural Development Projects) for grain production outside the cassava producing zones. From 1972 to 1983, cassava output per capita declined in Nigeria and the *gari* price increased relative to the prices of yam and maize (Figures 3.6b, 3.7b, and 3.8b).

Combined Impact of TMS Varieties, Mechanical Graters and a Favorable Policy Environment

Production. From 1984 to 1992, the Nigerian government banned the import of grain, removed subsidies on fertilizer and cereals, established the ADPs in the cassava producing states, and invested in diffusing the high-yielding TMS varieties, including free distribution of the TMS varieties to farmers. As a result, the planting of TMS varieties spread rapidly and cassava production soared (Figures 3.6c).

The dramatic increase in the cassava output per capita from 1984 to 1992 arose from a combination of increased yield and area expansion. The farm-level yield of the TMS varieties in Nigeria was 40 percent higher than that of the local varieties, even when grown without fertilizer.[34] The yield performance of the TMS varieties is comparable to that of the green revolution wheat and rice varieties in Asia in the 1960s and 1970s (Ruttan 2001). The IITA has used data from the COSCA study (1989 to 1992) to calculate that the TMS varieties have contributed an extra 1.4 million tons of *gari* per year than would have been available from local varieties. The incremental output of 1.4 million tons is enough to feed 29 million people (CGIAR 1996).

[34] The farm-level yield of the high-yielding TMS varieties was not significantly different from the yield in researcher-managed on-farm trials conducted by Hahn. For example, the yields of the TMS varieties in researcher-managed on-farm trials were 21.0 tons per ha in 1983, 23.5 tons per ha in 1984, and 16.0 tons per ha in 1985 in different locations in the forest zone of Nigeria (IITA 1986).

Farm income. The profitability of the TMS varieties critically depends on the type of available cassava grating technology.[35] By reducing the cassava processing labor by as much as 50 percent, from 51 to 24 person-days in the preparation of *gari*, the mechanized grater has released labor, especially female labor, from cassava processing for cassava production. The replacement of hand grating with the mechanized grater has reduced the cost of making *gari* and dramatically increased the profitability of *gari* production with the TMS varieties.

Drawing on COSCA data and the classification by Camara (2000) and Johnson and Masters (2002), COSCA farmers in Nigeria can be divided into four categories based on the variety (local or TMS) planted and the grating method (manual versus mechanized grating). Table 3.5 presents a financial analysis of four combinations of cassava production and *gari* preparation technology. This financial analysis shows that farmers who plant local varieties and grate manually earn a modest net profit of 42 Naira (about US$2.50) per ton of *gari*. Farmers who plant local varieties and use mechanized grating earn 478 Naira (about US$28.00) net profit per ton of *gari* as compared with a net profit of 339 Naira (about US20.00) per ton of *gari* by farmers using TMS varieties and manual grating. Cassava farmers benefit more from using labor-saving grating technology than planting TMS varieties. TMS varieties are significantly more profitable when grating is mechanized. For example, farmers planting the TMS varieties and using mechanized grating earned a net profit of 776 Naira (about US$46.00) per ton of *gari*.

In summary, the net profit per ton of *gari* is as follows:

	US$
-local varieties with manual grating---------------	2.50
-local varieties with mechanized grating--------	28.00
-TMS varieties with manual grating-------------	20.00
-TMS varieties with mechanized grating-------	46.00

[35] *Gari* preparation is divided into three main steps: (1) peeling and washing; (2) grating, pressing, and sieving; and (3) toasting. Only the grating, pressing, and sieving step is mechanized.

Table 3.5--Nigeria: Financial budget for gari preparation by alternative cassava production and processing technologies, 1991

BUDGET ITEM	PRODUCTION AND PROCESSING TECHNOLOGIES			
	local varieties manual processing	local varieties mechanized processing	tms varieties manual processing	tms varieties mechanized processing
INPUTS/LABOR				
Production (man-days/ha)				
Bush clearing	49	49	49	49
Tillage	41	41	41	41
Planting	28	28	28	28
Weeding	34	34	34	34
Subtotal	152	152	152	152
Harvesting (man-days/ha)	56	56	82	82
Total male labor (man-days/ha)	208	208	234	234
Processing (woman-days/ha)				
Peeling (3.6 woman-days/ton of root)	39	39	56	56
Grating (9.9 woman-days/ton of root)	106	0	154	0
Toasting (3.3 woman-days/ton of root)	35	35	51	51
Total female labor (woman-days/ha)	180	74	61	107
OUTPUTS				
Root yield (tons/ha)	13.41	13.41	19.44	19.44
Usable root yield (80%of root yield	10.73	10.73	15.55	15.55
Root-to-*gari* conversion ratio	0.33	0.33	0.33	0.33
Gari yield (tons/ha)	3.54	3.54	5.13	5.13
Village market price of *gari* (Naira/ton of gari)	3140	3140	3140	3140
COSTS (Naira/ha)				
Male labor (21 Naira/man-day)	4368	4368	4914	4914
Female labor (10 Naira/woman day)	2700	1110	3916	1605
Farm transportation (92 Naira/ton of root)	123	1233	1790	1790
Grating fee (15 Naira/ton of root)	0	161	0	233
Bagging (82 Naira/ton of *gari*)	290	290	420	420
Fire wood (207 Naira/ton of *gari*)	733	733	1062	1062
Transportation to market (235Naira/ton of *gari*)	832	832	1205	1205
Sub total	10156	8727	13306	11229
Interest on capital (8% of subtotal)	812	698	1064	898
PERFORMANCE MEASURES (Naira)				
Total cost/ha	10968	9426	14370	12127
Cost/ton of gari	3098	2662	2801	2364
Total revenue/ha	11116	11116	16108	16108
Revenue/ton of *gari*	140	3140	3140	3140
Net profit/ha	148	1690	1738	3981
Net profit/ton of *gari*	42	478	339	776

Source: Nweke et al. (2002).

The financial analysis shows that the use of a labor-saving grating technology is essential for the rapid adoption of TMS varieties. But the growing availability of the mechanized grater has shifted the cassava labor bottleneck to harvesting, peeling, and toasting. The COSCA study found that several farmers in Nigeria who were growing the TMS varieties frequently reduced the area planted because, owing to labor shortage, they are not able to harvest and process the crop from the previous season's plantings.

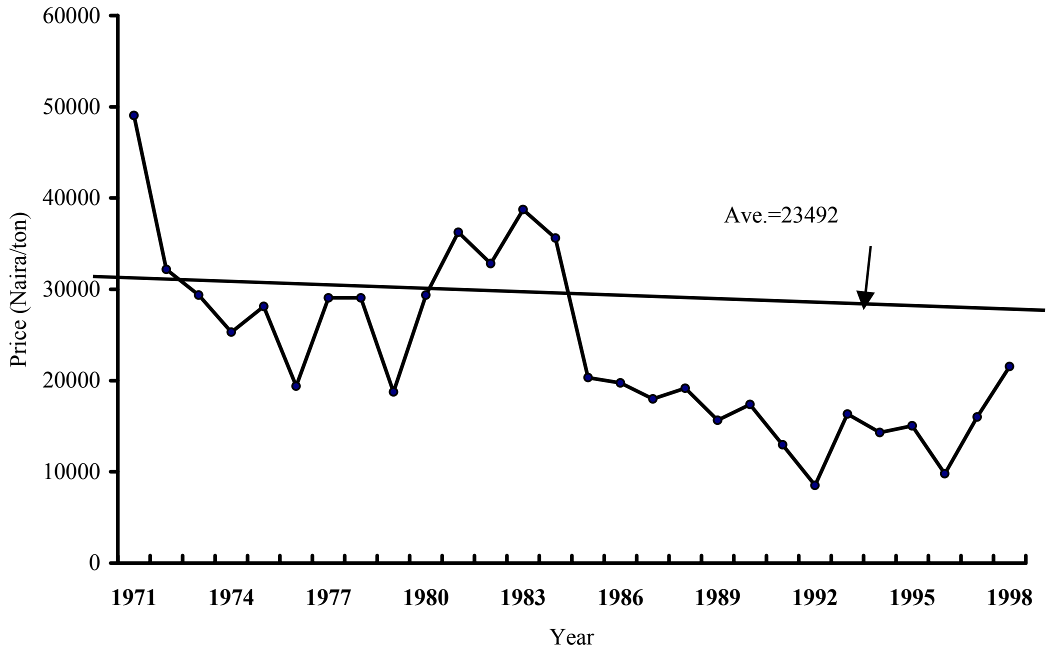
The mechanization of any of the harvesting, peeling, and toasting operations will reduce processing cost and raise cassava income to farmers and drive down the price of cassava to consumers. The mechanization of any of the harvesting, peeling, and toasting operations will encourage diffusion of the TMS varieties and encourage farmers who are already planting them to expand the area under cassava cultivation. There is urgent need to develop labor-saving technologies for cassava production, harvesting, and processing to replace the costly practice of marrying many wives to supply farm power.

Prices. During the rapid diffusion of the TMS varieties in Nigeria, from 1984 to 1992, cassava prices fell sharply as did *gari*-to-yam and *gari*-to-rice price ratios (Figures 3.7c and 3.8c). The average inflation-adjusted *gari* price (18,000 Naira per ton) was 40 percent lower than from 1971 to 1983 before the diffusion (29,000 Naira per ton) (Figure 3.9). This dramatic reduction in cassava price represents a significant increase in the real income of the millions of the rural and urban households who consume cassava as their most important staple food.

In Nigeria, the impact of the cassava transformation on driving down cassava prices is less dramatically reflected in terms of *gari*-rice than *gari*-yam price ratio (Figure 3.10)[36]. But in Nigeria, the price of rice is often influenced by the government rice import policy which changed dramatically during the structural adjustment period. Prior to 1984, the artificially low price of rice discouraged private investment in cassava production and delayed the cassava transformation.

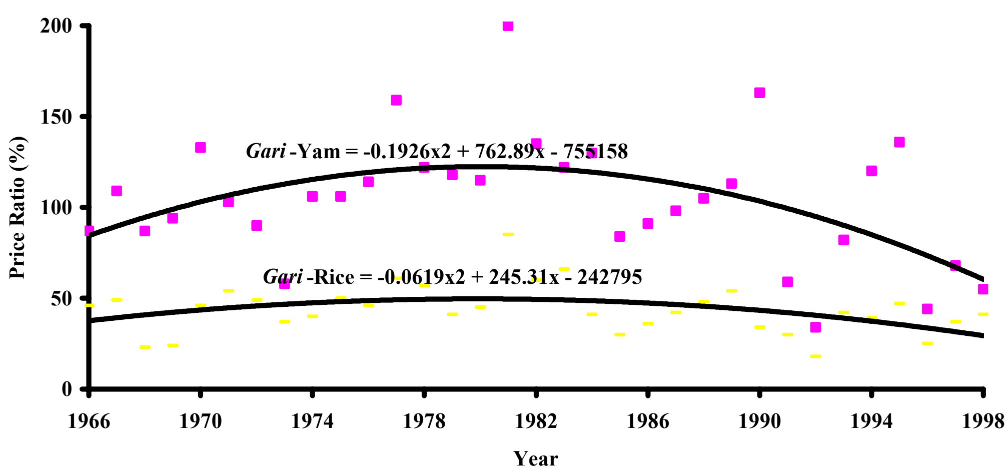
[36] More research that has been carried out on rice than on yam means that production cost has been reduced more for rice than for yam (IITA 1992).

Figure 3.9--Nigeria: Inflation adjusted (1995 level) price of *gari* in Edo state, 1971 to 1998



Source: Ministry of Finance and Economic Development, Benin City.

Figure 3.10--Nigeria: *Gari*-to-yam and to-rice price ratios, 1966 to 1998.



Source: Ministry of Finance and Economic Development, Benin City.

From 1993 to 2001, after the diffusion of the TMS varieties decelerated in Nigeria, the production gains softened, stemming the downward fall in cassava prices. From 1993 to 2001 in Nigeria, cassava output per capita decreased (Figure 3.6d). As a result, consumer cassava prices increased as did *gari*-to-yam and *gari*-to-rice price ratios (Figures 3.7d and 3.8d).

Equity. In Nigeria, cassava is the main source of cash income for the COSCA households producing cassava and other crops. For example, during the rapid diffusion of the TMS varieties in 1992, the mean cash income at current prices was 33,980 Naira per study household in Nigeria.[37] Food crops contributed 55 percent of the COSCA study household cash income; industrial crops, 20 percent; livestock, 7 percent; and non-farm activities, 18 percent. Therefore, in Nigeria, food crop production was the main source of cash income in the COSCA study households and cassava generated 11.6 percent of the total cash income per farm household; yam, 8.3 percent; maize, 7.7 percent; rice, 6.1 percent; etc. (Table 3.6).

Table 3.6--Nigeria and Ghana: Percentage of cash income by source

Staple	Ghana	Nigeria
Cassava	12.6	11.6
Yam	5.5	8.5
Maize	12.6	7.7
Rice	3.3	6.6
Sweet potato	--	0.6
Banana	3.9	0.6
Other food crops	17.1	19.4
Industrial crops	21.0	20.0
Livestock	3.0	7.0
Non-farm activities	21.0	18.0
Total	100.0	100.0

Source: Nweke et al. (2002).

[37] At the average monthly exchange rate of 17 Naira to US$1.00 and the average of 11 persons per COSCA household, the mean cash income per person in the COSCA households was equivalent to US$177 which amounted to 120 percent of agricultural GDP per capita in the same year. That the cash income of the COSCA households is greater than the agricultural GDP per capita can be a paradox. But the chaos that exists in Nigeria's agricultural production statistics is exceptional (Berry 1993).

In Nigeria, cassava production was more egalitarian, in terms of cash income distribution, than the production of the alternative staples such as yam and maize. Cassava cash income accrued to more households than that of these other major staple: 40 percent of the COSCA households earned cash income from cassava; maize, 35 percent; and yam, 24 percent. Unlike the other staples, cassava income does not accrue primarily to the better off farm households. The COSCA studies indicate that 50 percent of cassava cash income; 60 percent of yam; and 70 percent of maize accrued to the top 10 percent (in terms of cash income earning) of households (Nweke et al. 2002).

In Nigeria, the cassava cash income was more evenly distributed in COSCA villages where farmers used the mechanical grater to prepare *gari* than where they processed dried cassava roots. For example, in COSCA villages where farmers used the mechanical grater to prepare *gari*, 45 percent of the cassava cash income accrued to 10 percent of the households and 55 percent of the cash income accrued to 90 percent of the households. But where farmers prepared dried cassava roots, 65 percent of the cassava cash income accrued to 10 percent of the households and only 35 percent of the cash income accrued to 90 percent of the households.

Cassava can be a powerful poverty fighter in Africa! The cash income from cassava proves more egalitarian than the other major staples because of cassava's low cash input cost. Compared with other major staples, cassava performs well across a wide ecological spectrum. It therefore benefits farmers across broader swath of ecological zones. Cassava is likewise less expensive to produce. It tolerates poor soil, adverse weather and pests and diseases more than other major staples. Carbohydrate yield from cassava per unit of resource is higher than from other major staples. Measures that will drive down cassava production cost and transform cassava to play additional roles as a livestock feed and industrial raw material will generate income for millions of farmers and industrialists. At the same time, low and falling cassava prices benefit poor and urban consumers by driving down food prices, a critical determinant of real incomes in urban areas.

4. CONTRASTING EXPERIENCES IN GHANA

In Ghana, the cassava transformation has lagged behind Nigeria by about a decade. This is a puzzle because cassava is an important food crop in both countries which also have similar political history. Nigeria and Ghana are the two largest cassava producers in West Africa and in both countries, cassava is the most important food in terms of calories consumed (FAOSTAT). Both countries were British colonies and they regained independence at about the same time, Ghana in 1957 and Nigeria three years later in 1960. Since the independence, the two countries have gone through many years of military rule.

But for many years, the government of Ghana maintained a socialist policy and aimed at rapid industrialization. They favored grain production by public farms as a food import substitution crop. In the early 1980s in Ghana, a severe drought occurred during which cassava emerged as the crop that helped Ghana feed its population. That experience caused the government to review its policy emphasis on grain production and to invest in measures to accelerate the cassava transformation. They began to import TMS varieties from Nigeria and initiate on-farm testing.

This section explains the role of the government socialist policy in delaying the cassava transformation from independence in 1957 to the early 1980s in Ghana. The section also explains how, from the early 1980s in Ghana, the cassava transformation accelerated during government investments in R and D to develop the cassava sector following the important role of cassava in maintaining food supply during the drought of the early 1980s. Finally, the section assesses the impact of the cassava transformation on cassava production and prices and poverty in Ghana.

KEY PHASES AND MOTORS OF CHANGE

Introduction and Early Diffusion

In the mid 18th century in Ghana, cassava was the most widely grown crop of the people of the coastal plains (Adams 1957). But the spread of cassava from the coast into the hinterland was very slow. The forest people had plantain and cocoyam and the people of the north had sorghum and millet. Cassava reached Ashanti and Tamale in 1930 (Ofori et al. 1997). In 1935 in

Ghana, cassava area was less than 500 ha and twenty years later in 1955, cassava area was still only 66,000 ha (FAOSTAT).

Socialist Policy and Cassava Marginalization

After independence from the British in 1957, the government of Ghana adopted a socialist policy that recognized that "the need for the most rapid growth of the public and cooperative sectors in productive enterprise (agriculture and industry) must be kept in the fore front of government policy" (Planning Commission 1964, p.2). In 1962, the government established the SFC (State Farms Corporation) "to do those things which, in the opinion of government officials, the private farmers could not be relied upon to do, namely to use modern methods to expand the production of food crops and raw materials on commercial scales" (Agricultural Committee of the National Liberation Council 1966a, p.203). The SFC absorbed proportionately more resources than it farmed land. Employment opportunities offered by the SFC with government-set minimum wages attracted many farm workers off private farms (Nweke 1978).

At the same time, in 1962, the Scientific Services Division of the MOA (Ministry of Agriculture), which was responsible for agricultural research, was closed. The SFC converted the MOA research stations into production units. The SFC declared agricultural research as a waste of time and money, an irrelevant and unproductive activity (La-Anyane 1971p.29).

For nearly the first 25 years of independence (1957 to 1980) in Ghana, agricultural policy for food crops marginalized root crops in favor of grains (Table 4.1). Government encouraged production of grains with a price support program through the Grains Marketing Board and the Food Distribution Corporation and subsidized irrigation water, farm mechanization, and agricultural credit. From 1960 to 1966, 20 percent of total government capital expenditure on agriculture was invested on farm mechanization. From 1963 to 1975, 29 percent of government agricultural capital expenditure was used for irrigation development (Nweke 1979 and Nweke 1978a). Cassava is not produced under irrigation and available tractor mechanization technology is not suitable for cassava production.[38] Most agricultural bank credit for food crops was for

[38] Available mechanical technologies for seedbed preparation are designed for plowing, harrowing and ridging. They are not relevant for no-till seedbeds and are not designed for mound making. The COSCA study found that the frequency of no-till seedbed was higher in cassava fields than any other staple. In Africa, in well drained soils cassava is grown on flat no-till seedbed; in poorly drained soils, cassava is grown on ridges and mounds (Hahn

maize and rice, each of which received three times as much loan as all root crops combined (Nweke 1978b).

For nearly 20 years, from 1962 to 1975 in Ghana, the development strategy had no role for cassava (Ofori et al. 1997). From 1960 to 1975 in Ghana, the rate of growth for grains production was 5.4 percent, compared with the root crops, 1.2 percent which was well below the population growth rate of approximately 3.0 percent (Nweke 1979a).

In Ghana, the first government expression of interest in cassava is found in the First Five-Year Development Plan (1975 to 1980). The plan's primary goal was to reduce food and raw material imports, unemployment, and high inflation. The plan made agriculture the priority sector. In 1975 in Ghana, cassava area was 285,000 ha. The First Five-Year Development Plan provided for an increase of 93,600 ha to be attained in 1980. The increase would come through small farmer expansion, but the state farms would contribute 2,400 ha.

Table 4.1--Ghana: Technologies and policies in place from 1961 to 2001

Year	Technology	Agricultural Development Policy and Macro-Economic Environment
1961 to 1989	Mechanization of the grater Development of the TMS varieties	-state production of agricultural-based industrial raw material with the aim of rapid industrialization -policy emphases on grains production as import substitution crop
1990 to 2001	Release and diffusion of the TMS varieties	-government invested in measures to on-farm test of the TMS varieties official release of the TMS varieties to farmers

1984). In Africa, available technologies for seedbed preparation would not normally be relevant for cassava production because in poor drainage soils where cassava needs ridges, mechanical tillage is not efficient (Pingali et al. 1987). In well drained soils mechanical tillage is efficient, but cassava does not need ridges. Available mechanical technologies for seedbed preparation are designed for plowing, harrowing and ridging. They are not relevant for no-till seedbeds and are not designed for mound making. The COSCA study found that the frequency of no-till seedbed was higher in cassava fields than any other staple. In Africa, in well drained soils cassava is grown on flat no-till seedbed; in poorly drained soils, cassava is grown on ridges and mounds (Hahn 1984). In Africa, available technologies for seedbed preparation would not normally be relevant for cassava production because in poor drainage soils where cassava needs ridges, mechanical tillage is not efficient (Pingali et al. 1987). In well drained soils mechanical tillage is efficient, but cassava does not need ridges.

In spite of the expression of policy interest in cassava in the form of allocation of additional area to be cultivated by the private and public sectors, "policy still favored the cereals, namely rice and maize, the long time favorites" (Ofori et al. 1997, p. 22). For example, the government of Ghana did not display an interest in the TMS varieties released in Nigeria in 1977. Therefore, Dr. Hahn hired a Ghanaian agronomist to help introduce the TMS varieties in Ghana. Hahn reports that the Ghanaian agronomist, the Ghana River Basin Development Authority funded by the World Bank, and Texaco of Nigeria informally moved truckloads of the planting materials of the TMS varieties to farmers in Ghana during the early 1980s[39]. But the government lacked interest in multiplying and distributing the TMS cuttings to farmers.

Government Investment in the Development of the Cassava Sector

The severe drought that occurred in 1982 to 1983 acted as a wake up call to the Ghanaian agricultural policy makers highlighting the important role of cassava in the Ghana's food security agenda. The drought brought severe consequences to the economy: crop failure, sky-rocketing food prices, and mass exodus of Ghanaians to escape famine in other countries of West Africa (Figure 4.1). Cassava, the only crop that did not fail, helped Ghana survive the drought. The drought experience and the key role played by cassava in preventing famine led Ghanaian agricultural policy circles to question the wisdom of reliance on maize for food security. It awakened government interest in development of the cassava sector.

In 1983, the government initiated the ERP (Economic Recovery Program) under which they liberalized trade and lifted foreign exchange controls. Around 1984, Ghana's Commissioner (Minister) for Agriculture visited the IITA in Ibadan and met with Hahn. During their discussion, the Commissioner used the expression "Monkey de work Baboon de chop" to describe the emphasis given to cassava and maize in food policy circles in Ghana. The expression means "cassava is feeding Ghana but maize is consuming the research resources in Ghana."[40] In 1985, Ghana hosted the Central and Western African Root Crops Network

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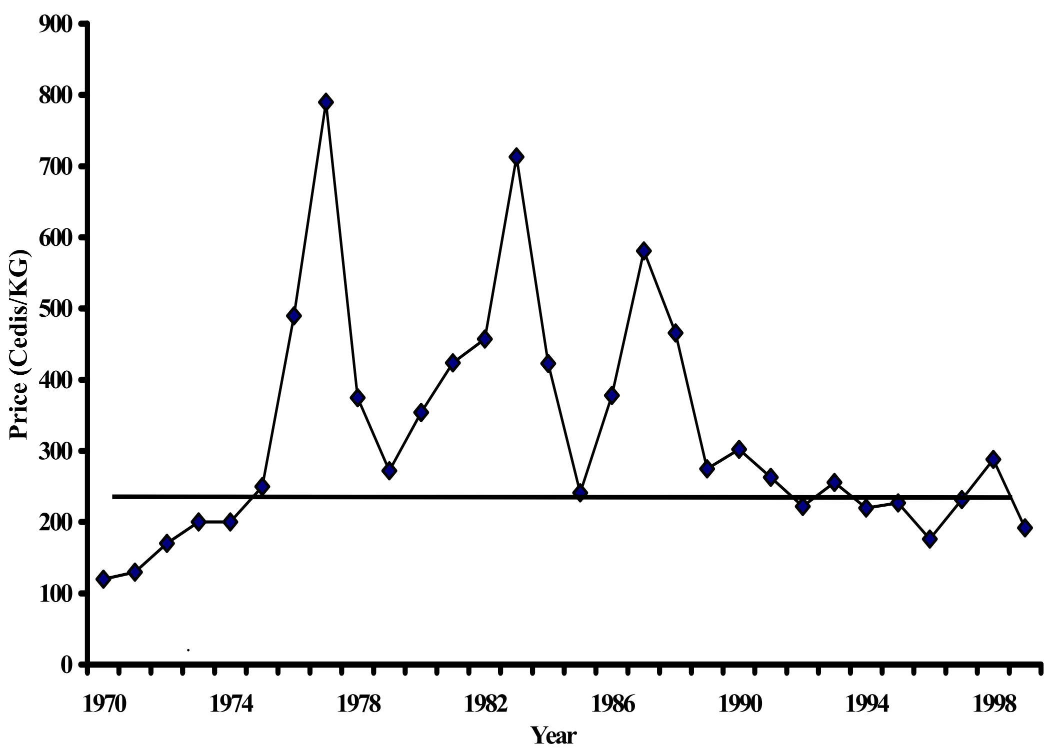
[39] Personal telephone conversation with Dr S. K. Hahn, March 20, 2001.

[40] The literal translation of "Monkey de work Baboon de chop" means "monkey works for baboon to eat" This is in West African pigeon English saying.

workshop in Accra. The workshop helped government officials to grasp the importance of cassava in Ghana.

In 1988, eleven years after the TMS varieties were released to farmers in Nigeria in 1977, the Government of Ghana finally displayed interest in the TMS varieties by importing the stem cuttings from the IITA and turning them over to Ghanaian researchers for field testing. Dr S. K. Hahn then helped the government of Ghana to obtain IFAD funding for on-farm testing and evaluation of the TMS varieties in Ghana. From 1988 to 1992, the Ghanaian researchers, with backstopping of an IITA cassava breeder, Dr O. O. Okoli, evaluated the TMS varieties in farmers' fields.[41]

Figure 4.1--Ghana: Inflation adjusted price of *gari* (1995 price level), 1970 to 1999



Source: Statistics and Information Directorate, Ministry of Food and Agriculture, Accra, Ghana

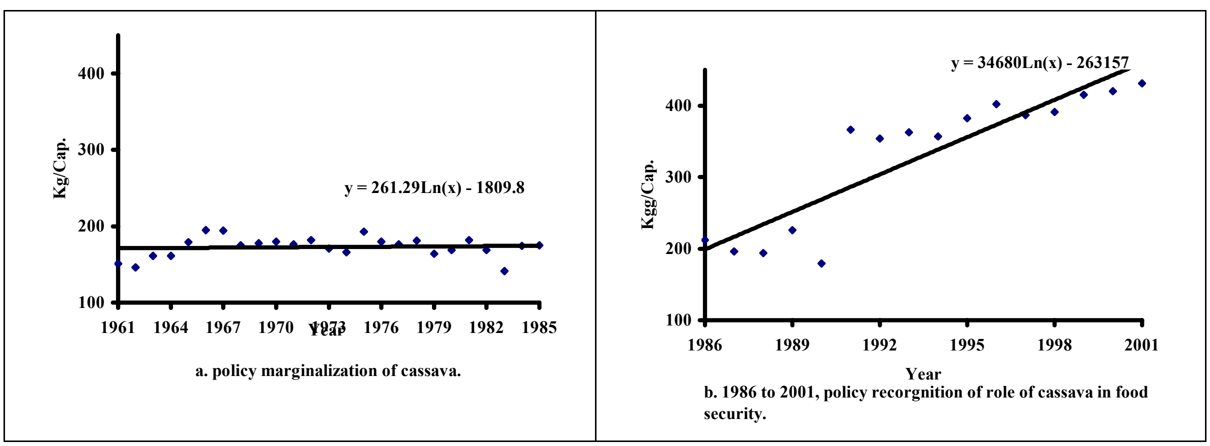
[41] Dr O. O. Okoli helped introduce the IITA's high-yielding TMS varieties in Ghana under the IITA's technical assistance program to the cassava project of the Ghana's Small-Holder Rehabilitation and Development Program (SRDP).

IMPACT ON PRODUCTION AND PRICES

From 1961 to 2001 in Ghana, the cassava transformation proceeded in fits and starts. Performance varied, as in Nigeria, depending on the technologies and government policies at play in different periods. In Ghana, the big production surge was delayed because for the first 28 years after independence, from 1957 to 1985, the government of Ghana neglected cassava in the national agricultural development programs. In a second phase, from 1986 onwards, performance improved dramatically as government recognized the importance of cassava and began to support basic research, technology transfer and testing.

During the first phase, from 1961 to 1985 in Ghana, the complete omission of cassava in and the national agricultural development programs led to a declining cassava production per capita and as a result, *gari*-to-maize price ratio increased (Figures 4.2 and 4.3a).[42]

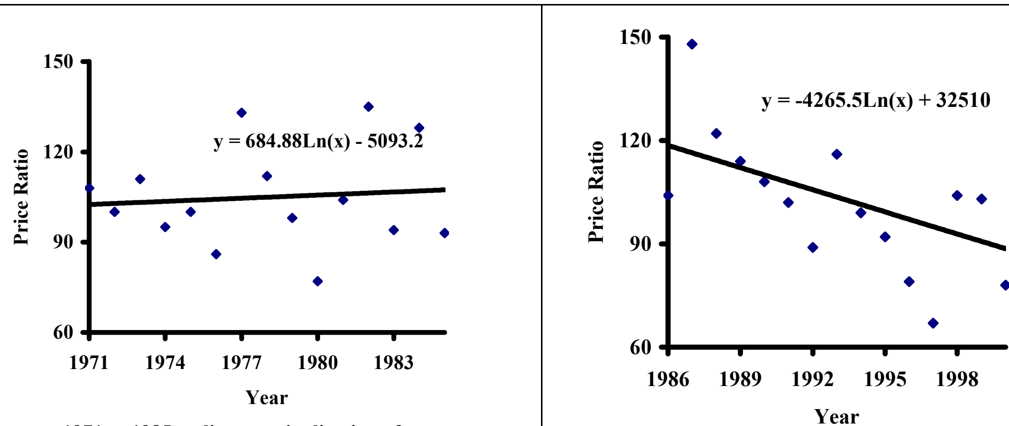
Figure 4.2--Ghana: The impact of the cassava transformation on per capita output, 1961 to 2001



Source: FAOSTAT

[42] In Ghana, price data was available for 1970 to 2001.

Figure 4.3--Ghana: The impact of the cassava transformation on *gari*-to-maize price ratio, 1971 to 2000



a. 1971 to 1985, policy marginalization of cassava (note: data not available for 1961 to 1970).

b. 1986 to to 2000, Government investment in R and D to diffuse the TMS varieties.

Source: Ministry of Food and Agriculture, Accra.

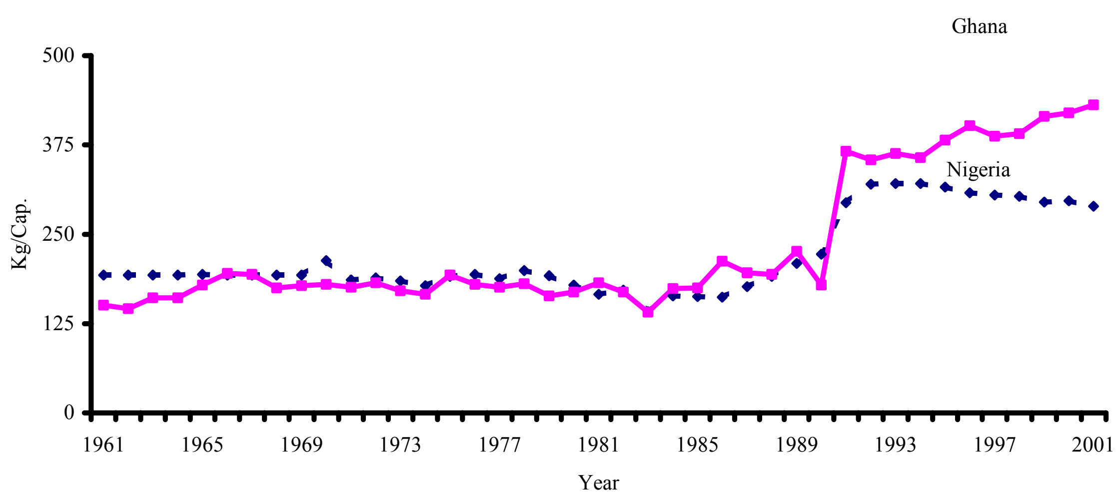
During the second phase, from 1986 to 2001, the spread of the mechanized grater, the TMS varieties and the mealybug control had a significant impact on increasing cassava production. During this period, output per capita increased significantly (Figure 4.2b). In fact, in an interval of one year (1990 to 1991) Ghana moved from being the sixth largest cassava producer in Africa to the fourth largest producer. In 1990, Ghana produced 2.88 million tons of cassava and it was the sixth largest producer in Africa after Nigeria, 19.04 million; the Congo, 18.72; Tanzania, 7.79 million tons; Mozambique, 4.59 million tons; and Uganda, 3.42 million tons. But in 1991, Ghana produced 5.99 million tons and became the fourth largest producer in Africa after Nigeria, 29.55 million tons; the Congo, 18.80 million tons; and Tanzania, 6.92 million tons displacing Mozambique and Uganda (FAOSTAT).

From 1991 to 2001 in Ghana, per capita cassava output exceeded Nigeria because the impact of the TMS varieties in terms of per capita output decreased in Nigeria owing to the harvesting and processing labor bottlenecks created by the planting of the high-yielding TMS varieties in Nigeria (Figure 4.4). In Ghana, the diffusion of the TMS varieties is now well under

way. After the TMS diffusion in Ghana, one will expect a decline of the impact of the cassava transformation in terms of per capita output unless laborsaving mechanical technologies for cassava harvesting and processing are developed and diffused to farmers.

During the rapid growth phase, from 1986 to 2001 in Ghana, the spread of grater mechanization, TMS varieties and mealybug control had a significant impact on driving down cassava prices to consumers. During these years, the *gari*-to-maize price ratio declined dramatically in Ghana (Figure 4.3b).

Figure 4.4--Nigeria and Ghana: Per capita cassava production, 1961 to 2001.

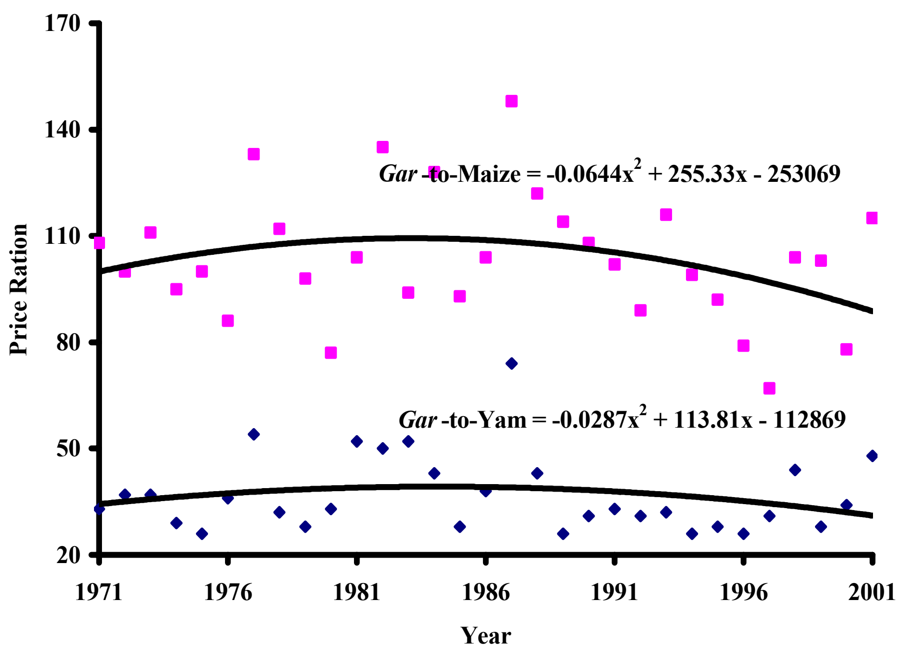


The impact of the cassava surge on driving down the price of cassava was more dramatic in the case of *gari*-to-maize than *gari*-to-yam price ratio (Figure 4.5). This difference emerged because, in the first 23 years of independence from 1957 to 1980 in Ghana, government food policy favored grains namely, maize and rice, and marginalized all root crops including cassava, yam, and cocoyam. As a result, in 1971 to 1985 in Ghana when the price of cassava increased, the price of yam also rose. Similarly, from 1986 to 2001 in Ghana, the new policy emphasis on cassava was extended to all root crops because many development projects were funded for root

crops as a group as they are produced in the same moist agro-ecologies. As a result of these general promotion efforts, from 1986 to 2001 when the price of cassava declined, the price of yam also declined.

The important lesson emerging from this analysis of the *gari*-to-maize price ratio in Ghana is that cassava can compete with maize as an urban food staple once the bias in government support in favor of maize is removed, thus providing a level playing field. Cassava is a cheaper source of calorie than maize and *gari* is an urban convenience food. In Ghana, the income elasticity of demand for cassava is significantly greater than one among urban households (1.46). Among the urban households, the income elasticity of demand for cassava is about the same as that of rice (1.50) but significantly greater than that of maize (0.83) (Alderman 1990). The challenge is to sustain policy interest so that government will finance R and D projects to drive down the cassava production and processing costs still further and transform the cassava to play an expanded role as livestock feed and industrial raw material.

Figure 4.5--Ghana: The impact of the cassava transformation on *gari*-to-maize and *gari*-to-yam price ratios, 1971 to 2001

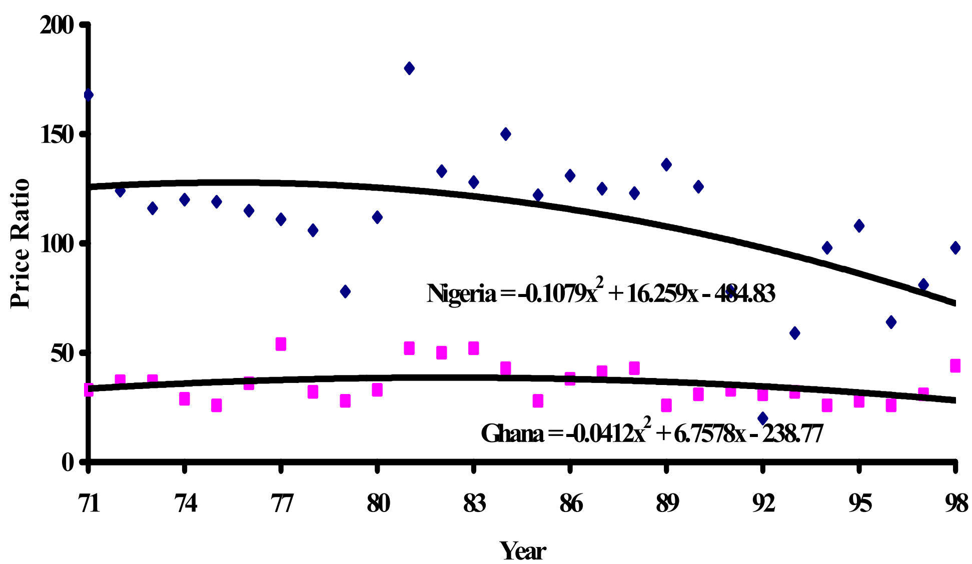


Source: Ministry of Food and Agriculture, Accra.

In Ghana, the real *gari* price declined by 20 percent from an average of 366 Cedis per ton during 1971 to 1985 period to 290 Cedis per ton during 1986 to 2000 period (Figure 4.1). This reduction in cassava price represents a significant increase in the income of the millions of the rural and urban households who consume cassava as the most important staple, in terms of calories consumed.

But in Ghana, the fall in the price of cassava was not as dramatic as in Nigeria. During the period of the rapid diffusion of the TMS varieties, the average inflation-adjusted *gari* price was 40 percent lower than before the diffusion in Nigeria compared with 20 percent in Ghana. The graph of the *gari*-to-yam price ratio was less steep in Ghana than Nigeria because in Ghana, the price of *gari* did not decline relative to yam as fast as in Nigeria (Figure 4.6). [43] In Ghana, the cassava transformation has exerted less downward pressure on cassava prices than in Nigeria because of the lag in production surge. In Ghana, the challenge is to promote the diffusion of TMS varieties and grater mechanization so that Ghana can catch up with Nigeria in the cassava transformation as a cash crop for urban consumption.

Figure 4.6--Nigeria and Ghana: The impact of the cassava transformation on the *gari*-to-yam price ratio, 1971 to 1998



Sources: Ministry of Finance and Economic Development, Benin City and Ministry of Food and Agriculture, Accra

[43] Yam is a common staple to both Nigeria and Ghana.

In Ghana, as in Nigeria, cassava is the main source of cash income for the COSCA households producing cassava and other crops (Table 3.6). In 1992 in Ghana, the mean cash income was 400,000 Cedis per COSCA study household.[44] Food crops contributed 55 percent, industrial crops, 21 percent; livestock, 3 percent; and non-farm activities, 21 percent. Therefore, in Ghana, food crop production was the main source of cash income in the COSCA study households and cassava was tied with maize as the most important food crops in terms of cash income

In Ghana, cassava is widely consumed in various forms and in many parts of Ghana, even outside the producing areas. Compared with other major staples, cassava thrives across a wider range of ecological zones. Cassava tolerates poor soil, adverse weather and pests and diseases more than other major staples. The carbohydrate yield from cassava per unit of land is higher than from other major staples. Measures that will drive down cassava production cost and transform cassava from a cash crop produced for urban consumptionto one produced to play additional roles as a livestock feed and industrial raw material will generate income for farmers and industrialists.

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[44] At the average monthly exchange rate of 430 Cedis to US$1.00 and the average of 9 persons per COSCA household, the mean cash income per person in the COSCA households was equivalent to US$108 which amounted to 25 percent of agricultural GDP per capita in the same year.

5. ACCELERATING THE CASSAVA TRANSFORMATION: A RESEARCH AGENDA

This section highlights the need for investments in R and D on the genetic, mechanical, and industrial technologies necessary to enhance the impact of the cassava transformation. This section emphasizes needed investment in R and D measures to drive down the cost of cassava production and develop new uses for cassava in food, non-food, and livestock feed industries.

GENETIC IMPROVEMENT

Restructuring the Cassava Plant Canopy and Roots for Mechanized Harvesting and Processing

The improvement of cassava genetic resource pool represents an unfinished agenda. The TMS varieties attain their peak yield around 13 to 15 months after planting as compared with 22 to 24 months for local varieties. But the COSCA researchers discovered that Nigerian farmers desired TMS varieties that could be harvested in less than 12 months after planting without yield loss in order to be able to plant cassava on the same field every year because of growing market demand for *gari* and population pressure on land. The fact that the TMS varieties attain maximum yield from 15 months after planting means that farmers wait for 15 months to respond to increased demand for cassava.

In 2001, the manager of the Nigerian Starch Mill (NSM), Ihiala revealed to the COSCA researchers that the most critical constraint in his industry was irregular supply of cassava. The irregular supply of cassava for industrial uses in Nigeria and Ghana is explained by two factors, namely the cassava bulking period and the high production cost. In Nigeria and Ghana, cassava production for import substitution as an industrial raw material requires the development of early bulking varieties which will allow the farmers to respond to industrial demand in a timely fashion.

The dramatic increases in cassava production from 1984 to 1992 in Nigeria and from 1990 to 2001 in Ghana was driven by the yield-increasing genetic and agronomic technologies alone. Other than the mechanical grater, the cassava producers relied on human power for cassava production, harvesting, and processing. Very little research has focused on developing machines to harvest cassava. Mechanized machines have not been developed for cassava harvesting and peeling because cassava roots vary in size and shape. In the mid 1970s to early

1980s, attempts were made at IITA to adapt mechanized potato harvesters for cassava harvesting. But the variable cassava plant canopy and root shapes and sizes hampered the research. This suggests that breeding to restructure the cassava plant to standardize its canopy and root sizes and shapes is a prerequisite to a successful development of mechanical harvesters and peelers for the cassava. The mechanization research at the IITA was also thwarted by the premature termination in the early 1980s (Garman and Navasero 1982). Mechanization of the harvesting operation is more urgent than mechanization of any of the pre-harvesting tasks because it will facilitate the adoption of genetic and agronomic technologies that can raise cassava yields.

Section 3 above explained the R and D that culminated in the development and release to farmers of the TMS varieties in Nigeria in 1977. The section therefore provides an insight into the R and D measures required to develop early bulking TMS varieties restructured with regular canopy and root shapes and sizes that can be harvested and peeled mechanically. For example, S. K. Hahn's strategy for developing the TMS varieties was a collaborative undertaking involving a multi-disciplinary team of scientists and training of national scientists. The IITA's cassava breeding program was carried out by a critical mass of multi-disciplinary team members including a plant pathologist, entomologist, nematologist, virologist, agronomist, tissue culture specialist, biochemist, and food technologist (Dixon et al. 1992). Hahn realized that IITA needed to help develop strong national cassava research programs in cassava producing countries in Africa in order for IITA's cassava varieties and agronomic practices to be evaluated over a wide range of African agro-ecologies.

The long time period required to develop scientific capacity within Africa is one of the major lessons that emerges from the analyses of the development and release of the TMS varieties. It took more than 40 years (1935 to 1977) of hard work by different research teams to develop the TMS varieties. The evolution of cassava breeding in Africa can be described as a human ladder. Starting in the 1930s, one generation of breeders climbed on the shoulders of the past generations until they hit the jackpot with the release of the TMS varieties in the mid 1970s.

The long term growth cycle of the cassava plant relative to maize, for example, introduces another element of risk. Some cassava plants are ready for crossing in at least five months after planting, but several varieties do not flower regularly because they are sensitive to

weather. This means that a conventional breeding program can lose a year or more when a breeding stock fails to flower in a particular year because of unfavorable weather conditions.

The lesson of the multi-disciplinary team of scientists and long time period required in cassava breeding is a need for commitment to sustained long term investment in R and D to restructure the cassava plant and develop mechanical harvesters and processors. Unfortunately many policy makers expect breeders to develop new varieties in an unrealistically short period of time.

Pest and Disease Control

Since the control of the mealybug, attention has shifted to the cassava green mite. The green mite was first observed in Africa in 1971 in a suburb of Kampala, the Ugandan capital. The Ugandan researchers hypothesized that the green mite attached itself to cassava cuttings that Uganda imported from Colombia. After it became established in Uganda, the green mite spread by wind throughout the Africa's cassava belt, reaching West Africa in 1979 (IITA 1992). The green mite attacks cassava leaves, sucking out the fluid content of individual cells on the leaves and the leaves become mottled and deformed. Eventually, the leaves dry out and die, although the plant usually survives. But with less leaf area for photosynthesis, plant growth is retarded and energy from the stems and edible storage roots is consumed, resulting in drastically reduced yields (IITA 1996).

In 1983, research began at IITA on the biological control of the green mite by selecting the insects that feed on the green mite in their original environments in Colombia. This approach duplicates the model that the IITA used to gain control of the mealybug. In 1991, the IITA scientists imported three predator mites from South America and multiplied them at the IITA's Biological Control Center for Africa in the Republic of Benin in 1992. The predator mites were released in farmers' fields in the Republic of Benin in 1993. In 1994, they were reported to have spread over an area totaling 1,500 square kms in the Republic of Benin and later to eight cassava producing countries (IITA 1994). However, the degree to which the predator mites have controlled the green mite has not been determined.

In 1991, COSCA researchers found the incidence of the mosaic disease in a large percentage of villages: in Ghana, 100 percent, and in Nigeria, 89 percent. The numbers of

infected cassava plants per field and the severity of the disease were also high.[45] The mosaic disease is transmitted by a white fly, *Bemisia tabaci*, and by the planting of cuttings derived from the mosaic disease-infected plants. In a resistant cassava variety, the mosaic disease is usually confined to a few branches only. Shoots derived from cuttings obtained from symptomless branches segregate in varying proportions of incidence of the mosaic disease (Rossel et al. 1994). The mosaic disease causes chlorotic blotches and distortion of the leaves and a reduction of the leaf area. Infected plants are estimated to sustain yield losses of 30 to 40 percent (Thresh et al.1997).

The latest effort to control the mosaic disease was through the Cassava Biotechnology Network (CBN) that was established jointly by CIAT and the IITA in 1988 and sponsored by the Dutch Government beginning from 1992. The network involved scientists from national and international organizations in several developed and developing countries (Thro 1998). Unfortunately, the CBN in Africa was terminated in 1998 when the Dutch government funding was withdrawn. IITA planned to coordinate the African CBN, but donor financing was not available (Bokanga 2000 and Mba 2000). However, the South American CBN continues to be funded by the Dutch and it is coordinated by the CIAT. Dr Martin Fregene and Dr Chikelu Mba at CIAT are using biotechnology breeding tools to address the problem of cassava yield loss due to the pest and diseases. The future control of the mosaic disease will also depend on extension efforts to diffuse the IITA's resistant varieties in several cassava producing countries and on the development of private sector supply market for healthy cassava planting materials.

New forms of the mosaic disease have been reported. For example, in Uganda, an unusually high incidence and severity of a rare form of the mosaic disease was reported in 1988 (Harrison et al. 1997). In September 2002 in Nigeria, the IITA warned farmers that the one time destructive cassava mosaic disease which almost wiped out cassava plant in Nigeria in the early 1970s is back in a more devastating form. The new cassava mosaic disease has been identified by the IITA as a novel type and a recombinant of the African Cassava Mosaic Virus (ACMV) and the East African Cassava Mosaic Virus, more devastating to cassava than the old form of the African Cassava Mosaic Virus known to Nigeria (This Day 2002).

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[45] In the early 1990s, an epidemic of an extremely severe form of the mosaic disease spread through most of Uganda. Researchers discovered that the virus epidemic was caused by a new form of cassava *gemini* virus. The Uganda variant of the *Gemini* virus is now widely distributed in Uganda (Harrison et al. 1997).

In 2003, the IITA secured funding to fight this new form of the cassava mosaic disease in Nigeria. Beginning in early 2004, the IITA cassava team began work to control the mosaic disease by diffusing new varieties of cassava which are reported to be resistant to the new form of the mosaic disease and which were developed by the IITA cassava team under the leadership of Dr. Alfred Dixon. The high-yielding TMS varieties which were developed by the IITA in the 1970s under the leadership of S.K. Hahn and diffused to the farmers in Nigeria in the mid 1980s are resistant to the old form of the mosaic disease.

What is the lesson from the experience of the control of cassava pests and diseases in Africa? The control effort against the mosaic disease beginning with the work of H.H. Storey in the mid 1930s and the international campaign against the cassava mealybug beginning in the late 1970s in Africa point to the fact that the pests and disease control efforts must remain a continuous process because the mosaic disease and the mealybug problems have not been solved with definitive finality. Besides, in Africa new pests have emerged and the mosaic disease has mutated. The important implication of this lesson is that long term genetic research to develop cassava varieties that can be harvested and processed mechanically must go on at the same time with the effort to control the new form of the mosaic disease in Nigeria.

The Role of Biotechnology Research

Breeding research to develop pest-resistant and early cassava varieties that have uniform canopy and root shapes and sizes that can be mechanically harvested and processed is critical for cassava to play the expanded roles as a livestock feed and industrial raw material in Africa. Conventional breeding programs are bulky and lengthy, requiring screening of 20,000 to 100,000 seedlings in the first sexual generation and eight to ten years for an improved variety to reach the farmer. Biotechnology technique offers tools that circumvent many limitations of the conventional breeding to cassava improvement (Mba 2002 and Fregene 2002). Similarly, biotechnology research has an important role to play in the development of cassava food products, use of dried cassava roots in making beer malt, soft drink syrup concentrate for soft drink, alcohol/ethanol, and in improving the quality of cassava starch to make it as attractive as imported corn starch.

Rebuilding Africa's National Cassava Research Programs

The implication of these insights for the genetic, pest and disease control, and mechanical research agenda is a need for long-term core research funding to promote the cassava transformation in Nigeria and Ghana. In 1986, during the hey-days of the development and diffusion of the TMS varieties in Nigeria, IITA's cassava program had 15 core scientists (IITA 1987). In 2000, the IITA's cassava program had just one full time core scientist, a breeder (IITA 2001).

What is the likelihood that the Nigerian and the Ghanaian national cassava research programs will pick up and continue the aggressive cassava research which was going on at the IITA? The research, which culminated in the development and diffusion of the high-yielding TMS varieties in Nigeria, was achieved with an annual budget between US$0.5 million and US$4.6 million from 1972 to 1993. The annual economic rate of return from that investment in cassava research in Nigeria was 55 percent over a 31-year period (Afolami and Falusi 1999). The research was paid for mostly by international donor organizations. Until recently, several donors have funded cassava research in Africa to increase food security. But donor funding to help Nigerian or Ghanaian cassava starch to compete with European and North American corn in the global market is unlikely to be a priority of the European and the North American governments. Therefore, Nigerian and Ghanaian governments should make the affordable investment in cassava research to accelerate the cassava transformation.

Based on the past experience and funding levels in the development and diffusion of the TMS varieties, with an annual budget between US$0.5 million and US$4.6 million from 1972 to 1993, Nigerian and Ghanaian governments can fund cassava research by providing the core funding of about US$5 million per year for the next 10 to 15 years for the IITA to work in collaboration with the Nigerian and Ghanaian cassava scientists. Guaranteed core funding over a 10 to 15-year period is necessary because genetic research on cassava is a long-tem effort and it requires endurance in terms of donor and researcher efforts.

Funding cassava research by the Nigerian and the Ghanaian governments through a regional center such as IITA offers many advantages at this time because of the economies of scale and scope in regional research and because the Nigerian and the Ghanaian national cassava research programs are plagued by an array of problems. For example, the Nigerian and the

Ghanaian national research programs do not have a critical mass of scientists, such as Dr Hahn had at the IITA, to constitute effective cassava breeding programs. In Ghana in the year 2000, there was only three full-time and a few part-time scientists in the cassava research program of the Crops Research Institute, Kumasi, the national institute responsible for cassava research (Otoo 2000).

The issue of incentives poses another vexing problem. Scientists in most national programs in Africa are poorly motivated to engage in scientific research. In fact, they are often treated like second class clerks. In 2001, Dr John Otoo, the leader of Ghana's cassava program reported that the salaries of his staff were "too low to quote" (Otoo 2000).[46] Ghana's Crop Research Institute had only four computers with sporadic connections to the Internet. In 2001, it took an average of two weeks to get an email response from John Otoo because he did not have regular access to a functional email facility. By contrast, in 2001, every scientist at Brazil's Embarapa Cassava and Fruit Crop Research Institute had a computer on his/her desk and connected to the Internet.

Another implication of the past four decades of experience is that the new cassava research agenda for Nigeria and Ghana should give a serious consideration to the application of the biotechnology research tool. The conventional breeding program that has been in place at the IITA since 1971 has resulted in the development and release to the farmers of the high-yielding TMS varieties with elevated resistance to some major pests and diseases. But cassava's irregular flowering habit and wide segregation of desired characteristics when intercrossed make conventional cassava breeding programs elaborate and time consuming (Mba 2002 and Fregene 2002).

LIVESTOCK FEED AND INDUSTRIAL RESEARCH

Expanding the Use of Cassava in Livestock Feed

In 2000, 10 percent of Nigeria's cassava production and 4 percent of Ghana's were used as livestock feed. Both are significantly lower than Brazil where 56 percent of cassava is used as livestock feed. The poultry industry in Nigeria only has 125 million birds and in Ghana, only 21

[46] In 2000, the monthly salary of a Nigerian University Professor was equivalent of US$100. Even then, the monthly salary was usually paid three months late.

million compared with 867 million in Brazil (FAOSTAT).[47] The global outlook for Nigerian and Ghanaian cassava exports to Europe for livestock feed is pessimistic because of the high cassava production cost in Nigeria and Ghana and the declining world market price of cassava pellets. Thailand has dominated the export of cassava pellets for livestock feed for more than three decades. In Thailand, only 3 percent of national cassava production is consumed as food, the most important uses for cassava are for livestock feed and starch (Ratanawaraha et al. 1999).

Beginning in 1960s, the government of Thailand encouraged private firms to set up private pellet factories and produce cassava pellets for export to the EU (European Union). The private sector responded and pellet exports literally 'took off'. In fact, exports increased from 100,000 tons in 1966 to a peak of nine million tons in 1989. But because of competition with U. S. grain exports to the EU market, the price of cassava pellets has declined, making it unattractive for Thailand to produce cassava for export. In fact, Thai pellet exports have declined from nine million tons in 1989 to three million in 1998 (Ratanawaraha et al. 1999, p. 18). In 1999, there were 200 palletizing factories in Thailand with a total capacity of 10 million tons per year. But because of depressed prices, they were operating at less than 50 percent of capacity.

What is the outlook for Nigerian and Ghanaian pellet exports? Faced with over-capacity in pellet factories in Thailand and depressed world prices of cassava pellets, the answer is clear: Nigeria and Ghana should concentrate on expanding the use of cassava in livestock feed at home rather than trying to break into the EU market at this time. What can be done to increase the use of cassava in livestock feed in Nigeria and Ghana? A poultry feed trial has shown that if cassava roots and leaves were combined in a ratio of four to one, the mixture could replace maize in poultry feed and reduce feed cost without a loss in weight gain or egg production (Tewe and Bokanga 2001). This type of research needs to be expanded to identify other technologies that can lead to expanded use of cassava in livestock feed in Nigeria and Ghana.

Food Manufacturing Industry

The potential use of cassava as an industrial raw material is highest in the food industry because cassava is primarily a food crop in Nigeria and Ghana. Investment in measures that will

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[47] In 1996 to 1998, there were 19.3 million cattle and 4.5 million pigs in Nigeria compared with 156 million cattle and 28 million pigs in Brazil (FAOSTAT). In Nigeria, nomadic herdsmen move their cattle to wherever grass is available and tsetse is not a problem. The nomads neither respect boundaries not do they pay for grazing rights. Frequently, they are halted by crop farmers, including cassava farmers, when cattle graze on fields with crops.

increase the use of dried cassava roots and cassava starch in food industries will accelerate the cassava transformation by extending the demand for cassava thereby increase farm income of cassava producing households.

Technologies exist for the use of cassava as a partial substitute for wheat in bread-making (Satin 1988; Eggleston and Omoaka 1994; Defloor 1995; Onabolu et al. 1998). But in Nigeria and Ghana, the amount of cassava used for food manufacture by the food industries is insignificant. For example, in Nigeria in the late 1990s, only three tons of cassava was used per year for food manufacture compared with 133,000 tons of maize (FAOSTAT). Use of cassava as a partial substitute for wheat in food manufacture will increase if the practice can result in a reduction in the prices of the manufactured composite cassava and wheat flour food products compared with the prices of the same products made with 100 percent wheat flour.

But in Nigeria and Ghana, because of an array of reasons, the composite cassava and wheat flour food products are more expensive than all wheat flour food products. For example, a partial substitution of cassava for wheat in bread flour requires expensive supplementary viscosity enhancers such as eggs, milk, and gums to compensate for the lack of gluten in cassava (Eggleston and Omoaka 1994, Defloor 1995, and Onabolu et al. 1998). Other important factors such as the cassava variety, age of the cassava root, and the cassava growing environment also influence the quality of the food products in which cassava flour substitutes partially for wheat flour (Eggleston and Omoaka 1994; Defloor 1995). Measures to standardize cassava varieties, age of cassava roots, and the cassava growing environments will further increase the costs of the food products in which the cassava flour is used to substitute partially for wheat flour.

In Nigeria and Ghana, an increase in the use of cassava in food manufacturing industries critically depends on the development of technologies for industrial manufacture and packaging of traditional African cassava food products that have a snack value such as *gari, attieke,* and *chickwangue*. In the 1970s in Nigeria, the increasing demand for food spurred the investment in cassava food manufacturing industrial schemes by Texagric, a private sector and the Root Crop Production Company a public sector organization.[48] The schemes ceased operation because they faced the problem of an irregular supply of cassava roots and they lacked the technology to prepare cassava products that meet the color, taste, and texture requirements of consumers. For

[48] The company engaged in production and industrial processing of cassava as food.

example, the schemes had difficulty producing fermented cassava with a uniform taste (Bokanga 1992). The schemes also failed because of the difficulty of hiring and managing a large number of women to hand-peel cassava.

But in Brazil, recent development in the use of cassava in food industries shows that sustained investment in R and D can make industrial manufacture of 100 percent cassava starch traditional food products profitable. For example, the main cassava-based fast food in Brazil is *pao de queijo*, a type of bread made with sour cassava starch, which has been fermented and dried (Vilpoux and Ospina 1999). In Brazil, industrial preparation of *pao de queijo* by traditional methods has similar problems as industrial preparation of *gari, attieke,* and *chickwangue* in Africa (Vilpoux and Ospina 1999). But through sustained investment in research and development, *pao de queijo* was transformed from a small-scale home-made product to a large-scale factory-manufactured product.

In Brazil, the R and D in the improvement of *pao de queijo* were carried out mostly by the private sector. But the expansion in the consumption of the *pao de queijo* was facilitated by political support. For example, the consumption was endorsed by a former Brazilian president, Itamar Franco. He required that *pao de queijo* be present at all official government meetings. Since the mid-1990s, Brazilian consumption of *pao de queijo* has increased dramatically, changing from a regional to a nation-wide fast food. It is also possible to find *pao de queijo* in other South American countries such as Argentina and Peru (Vilpoux and Ospina 1999).

In Nigeria and Ghana, high potential exists for use of cassava in biscuit manufacture. Changes in cassava production are not required to make dried cassava root flour suitable for biscuit baking since the rising property required in bread is not essential in biscuits. But in Nigeria and Ghana, biscuits, particularly a brand labeled “Cabin Biscuit”, is as popular as bread, in terms of snack value. The feasibility study of industrial manufacture of “Cassava Cabin Biscuit” with dried cassava root flour needs to be undertaken. In April 2002 in Ghana, the COSCA survey revealed that home made “Cassava Cabin Biscuit” with 100 percent dried cassava root flour is sold to travelers by women at the Aflao boarder with Togo. The home made “Cassava Cabin Biscuit” displays the density of the wheat flour “Cabin Biscuit”. But the acid taste of fermented dried cassava root flour differentiates the “Cassava Cabin Biscuit” from the wheat flour “Cabin Biscuit”. The acid taste of fermented cassava food products is appreciated by

consumers in Nigeria and Ghana who are accustomed to eating dried cassava root flour, pasty cassava, and *gari* which are fermented food products.

The challenge is to carry out R and D for industrial manufacture of indigenous cassava food products which cannot be manufactured with wheat or maize. This challenge calls for identification of local cassava food products such as the home-made 100 percent "Cassava Cabin Biscuit" and for conducting studies to ascertain the technical, economic, and social feasibility of industrial production by the small-scale African industrialists.

Non-Food Industries

Turning to non-food industries, in Nigeria in the early 2000s, only about 700 tons of cassava starch were produced per year. In 2001 in Nigeria, the COSCA survey revealed that cassava starch was only 3 percent of total starch used as industrial raw material. FAOSTAT show that the use of dried cassava roots as industrial raw material is insignificant in Nigeria because of the high cost of cassava production, harvesting, and processing. The reason also includes lack of R and D to improve the quality of Nigerian cassava starch. Nigerian cassava starch is not a good substitute for imported corn starch in the textile, pharmaceutical, petroleum drilling, soft drink, alcohol, and other industries because of low quality.

Nigerian cassava starch is considered to be of low quality by Nigerian industries and none is exported. In Nigeria, the textile mills use mostly imported corn starch. In 2001, the director of the NCM (Nigerian Cotton Mill) in Onitsha reported that the NCM discontinued the use of Nigerian cassava starch because it was of low quality.[49] In January 2001, the director of the Nigerian Starch Mill (NSM) reported that he did not consider improving the quality of his product necessary because if he invested in R and D necessary to improve starch production technology, he would not have any patent protection.

In 2001, the COSCA study found that in Nigeria, imported starch was being used in water-based drilling mud for petroleum but other types of starch could be used if they gelatinize in cold water. The director of the NSM reported to the COSCA researchers that he was reluctant to invest in research to make cassava starch gelatinize in cold water because of the lack of patent protection.[50] Since the oil sector supplies 95 percent of Nigeria's foreign exchange earnings,

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[49] Personal interview, Onitsha, January 13, 2001.
[50] Personal interview, Port Harcourt, January 11, 2001.

investment in research to make cassava starch acceptable to the petroleum drilling industry could lead to a large increase in the demand for cassava. Nigeria has oil reserves of 22.5 billion barrels and it is currently producing two million barrels a day (MBendi 2000, pp. 1 and 2).

But Nigeria has a policy of not enforcing the intellectual property law. In fact, Nigeria has a government agency, NOTAP (National Organization for Technology Acquisition and Promotion), which was set up by the Federal Government to, as the name implies, acquire technologies from anywhere in the world and promote their adoption in Nigeria without respect for intellectual property rights. In March 2002 in Abuja, the director of NOTAP explained to the COSCA researchers that Nigeria adopted the policy of not enforcing the intellectual property rights because the country did not have the resources to police intellectual property laws since the Nigerian judiciary and police force are weak.

The potential for use of cassava starch in preparing syrup concentrate for the manufacture of soft drinks is high in Nigeria and Ghana. For example, in Nigeria in the late 1990s, 174,000 tons of syrup concentrates were used in the soft drink industry to produce 33 million hectoliters of soft drinks per year (RMRD.C. 2000, p.23). The soft drink industry is dominated by Coca Cola which imports the syrup concentrates and keeps them as a trade secret. Nigeria's soft drink industry imports all of its syrup concentrate because cassava starch is not currently hydrolyzed into syrup in Nigeria. But in the early 1990s, the IITA post-harvest technologists made syrup concentrate from cassava starch by treating it with sorghum enzyme. A pilot project is needed to test the suitability of cassava starch syrup concentrate in the preparation of soft drinks. If locally produced cassava starch could be converted into syrup concentrate and replace imported syrup, it would open up a market for almost one million turns of cassava per year.

The potential for use of dried cassava roots in preparing beer malt is also high in Nigeria. Beer has been brewed in Nigeria with imported barley malt for many decades. However, in 1985/86, Nigeria banned grain imports and the brewery industry began to produce beer malt with sorghum produced in northern Nigeria. The initial concern that sorghum beer would not be acceptable to consumers proved to be without basis as beer consumption did not decline after sorghum malt was used to replace barley malt. In the late 1990s, around 11 million hectoliters of beer was being produced per year in Nigeria (RMRD.C. 2000, p. 23).

Although cassava is produced in southern Nigeria where all of the beer breweries are located, no attempt has been made to produce beer malt with dried cassava roots even though

dried roots are cheaper (US$79 per ton) than sorghum (US$139 per ton) (Ogazi et al. 1997, pp. 31 and 77).[51] A biochemist of the NRCRI (National Root Crops Research Institute) at Umudike reported in early 2001 that beer malt can be made with any starch provided the right type of enzymes are available.[52] But research is needed to determine the type and quantity of enzymes suitable for making beer malt from dried cassava roots. However, the NRCRI is unable to carry out the needed research because the operational budget for its research unit is only a few hundred dollars per year.

In 2001 in Nigeria, the manager of the Golden Guinea Brewery, Umuahia, near Umudike explained that consumers would accept cassava malt beer judging from their ready acceptance of sorghum beer in the mid 1980s.[53] However, the manager reported that the Golden Guinea Brewery would be reluctant to invest in research on making beer malt from cassava roots because patent law is not enforced in Nigeria.

In 2001 in Nigeria, the manager of the Life Beer Brewery in Onitsha reported that the Life Beer is made directly from sorghum without malting at the rate of nine tons of sorghum per 500 hectoliters of beer.[54] Using this ratio, the beer industry in Nigeria consumed about 200,000 tons of sorghum per year in the late 1990s. If dried cassava roots had replaced sorghum, the beer industry would have consumed 220,000 tons of dried cassava roots which is more than two percent of current annual cassava production. Research is needed on how to make beer malt from dried cassava roots because, even a partial substitution of dried cassava roots for sorghum in the beer malt will expand market for cassava and raise the income of cassava farmers.

In 1963, the Nigerian government set up a sugar plant, the Nigerian Sugar Company (NISUCO) to produce sugar from sugar cane. Ten years later, the government set up the Nigerian Yeast and Alcohol Manufacturing Company (NIYAMCO) as an annex to NISUCO with a goal of producing ethanol with molasses. Although NIYAMCO had an installed capacity for four million liters of ethanol per year, the supply of molasses began to decline in the early 1990s because of the collapse of the government-owned sugar plantation that supplied sugar cane to NISUCO. In 1994, NIYAMCO began looking for an alternative source of raw material.

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[51] Northern Nigerians are mostly Moslems and forbid alcohol consumption.
[52] Personal interview, Umudike, January 12, 2001.
[53] Personal interview, Umuahia, January 12, 2001.
[54] Personal interview, Onitsha, January 12, 2001.

With IITA's technical support, dried cassava root was selected as a raw material for the manufacture of ethanol by the NIYAMCO because cassava is abundant in Nigeria, has a high starch content, and low gelatinization temperature (Bamikole and Bokanga 2000). NIYAMCO requires only about 30 tons of dried cassava roots per day but because of problems in organizing the collection of dried cassava roots from scattered smallholders, NIYAMCO closed its ethanol plant (Bamikole and Bokanga 2000). If the 88 million liters of alcohol currently imported each year for the liquor industry were produced with cassava roots in Nigeria, it would open up a market for about 600,000 tons of cassava roots, or about two percent of national cassava production during this period.[55]

DATA REQUIREMENTS

Until the COSCA study was implemented in Africa in the late 1980s and early 1990s, basic information was lacking on cassava's growing conditions and on the economics of production, processing, and marketing. There was also a dearth of information on market opportunities for expanding the use of cassava in industrial markets and for livestock feed in Africa and in Europe. The COSCA information has been used to guide the development of improved food policies and research and extension programs to accelerate the cassava transformation and ultimately increase food security and incomes of the people of Africa. But the COSCA information is now about fifteen years old and it needs to be updated to provide current information on cassava production and processing methods and constraints and consumption patterns.

The COSCA field studies in Ghana were completed in 1992 before the TMS varieties were released to farmers in 1993. There is need in Ghana to determine the level of adoption of the TMS varieties and their performance in terms of yield, pest resistance, and food quality attributes. There is need in Nigeria and Ghana to assess the potential for use of cassava as an industrial raw material by conducting a survey of industries that use (and can use) dried cassava roots, cassava starch, and cassava starch derivatives as raw materials. This information is critical for research and policy interventions aimed at accelerating the cassava transformation in both Nigeria and Ghana.

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[55] One ton of fresh cassava roots yields 150 liters of alcohol (Balagopalan et al. 1988, p.182)

6. SYNTHESIS: LESSONS FOR AFRICAN POLITICAL LEADERS, POLICY MAKERS, AND DONORS

Over a period of 35 years from the early 1960s to the late 1990s in Africa, per capita cassava production increased by about 5 percent. This increase was due to dramatic increases in cassava production in Nigeria and Ghana where production gains outstripped population growth and where cassava is now produced primarily as a cash crop for urban consumption. The dramatic increase in cassava production in both Nigeria and Ghana was achieved through an increase in both area and yield. The availability of cassava graters to farmers in both countries released labor, especially female labor, from cassava processing to plant more cassava. The widespread adoption of improved agronomic practices and the new high-yielding TMS varieties were responsible for increased cassava yields in Nigeria and Ghana.

In Nigeria and Ghana, cassava is primarily a food crop. In the year 2000, 90 percent of total production in Nigeria and 96 percent in Ghana were used as food and the balance as livestock feed (FAOSTAT). This section provides a synthesis of this discussion paper. The aim of the synthesis is to highlight the measures that can be implemented to accelerate the cassava transformation.

THE CASSAVA TRANSFORMATION

A dramatic cassava transformation is underway in Nigeria and Ghana. Driving this transformation have been the use the mechanized grater to prepare *gari*, the planting of the new high-yielding TMS varieties to raise yield, and the use of a predator wasp to control the otherwise devastating cassava mealybug. With the aid of mechanical graters to prepare *gari*, cassava is increasingly being produced and processed as a cash crop for urban consumption in Nigeria and Ghana. The use of the new TMS varieties transformed cassava from a low-yielding famine-reserve crop to a high-yielding cash crop that is prepared and consumed as a dry cereal (*gari*). The use of the wasp to control the cassava mealybug in the 1980s throughout the cassava producing areas of Africa reduced cassava yield loss due to the bug which were estimated as 60 percent for roots and 100 percent for leaves.

The cassava transformation encompasses four stages: Famine Reserve, Rural Food Staple, Urban Food Staple, and Industrial and Livestock Feed Uses. In Nigeria and Ghana, cassava remains primarily a food crop. Consequently, the first three stages account for 90 percent of total production in Nigeria and 96 percent in Ghana.

Looking ahead, the challenge is to implement measures that can accelerate the cassava transformation by reducing the cost of production, harvesting, and processing in order to drive down cassava prices to rural and urban consumers and increase the industrial and livestock feed uses. In Nigeria and Ghana, cassava can be a powerful poverty fighter by driving down the price to rural and urban consumers and increasing the uses in the industry and livestock feed.

IMPACT ON CASSAVA OUTPUT AND PRICES

In Nigeria and Ghana, cassava is the most important food staple in terms of calories consumed and it offers consumers their cheapest source of calories. New technologies that can drive down cassava prices to consumers by reducing the production, harvesting, and processing costs will increase the incomes and reduce the poverty among cassava consuming households.

From 1984 to 1992 in Nigeria and 1986 to 2001 in Ghana, cassava output per capita increased and *gari* price declined because the governments in Nigeria and Ghana invested in R and D to diffuse the TMS varieties. In the late 1980s, the TMS diffusion in Nigeria had become an African success story *par excellence*! Dr S. K. Hahn, the head of the IITA's cassava program, played a critical role in the diffusion program by personally eliciting the collaboration of the national researchers, the private sector, the donors, and the media. Hahn himself directly distributed the TMS varieties to farmers throughout Nigeria.

Without doubt, the decline in cassava price from 1984 to 1992 in Nigeria and 1986 to 2001 in Ghana has increased the real income of the cassava consuming households. In fact, during the period of the rapid diffusion of the TMS varieties from 1984 to 1992 in Nigeria, the average inflation-adjusted *gari* price (18,000 Naira per ton) was 40 percent lower than from 1971 to 1983 before the diffusion (29,000 Naira per ton). This dramatic reduction in cassava price represents a significant increase in the income of the millions of cassava consuming households because cassava is primarily a food crop and it is the most important staple in terms of calories consumed.

From 1993 to 2001 in Nigeria, the impact of the TMS varieties on output per capita and consumer price of cassava declined as the TMS varieties and improved agronomic practices created labor bottlenecks which slowed cassava production growth. Harvesting cassava is the most labor-intensive field task in Nigeria where the TMS varieties and improved agronomic practices have boosted yields by 40 percent and shifted the labor constraint from weeding to cassava harvesting. Harvesting is now proving to be a serious constraint on the expansion of cassava production in Nigeria because labor for harvesting increases in direct proportion to yield.

Without question, new mechanical technology is required to supplement yield-increasing genetic and agronomic technologies. Yield-increasing genetic and agronomic technologies are important but insufficient as engines of growth in the cassava sector. The challenge is to augment the yield-increasing genetic and agronomic technologies with labor-saving mechanical technologies in order to break the new labor bottlenecks at the harvesting and processing stages and reduce production cost, drive down the price of cassava to consumers and reduce rural and urban poverty.

LESSONS AND CHALLENGES

In Nigeria and Ghana, the high income elasticity of demand for *gari* in rural and urban centers means that there is a strong market demand for *gari*. The first lesson is that continued strong market demand for *gari* depends on driving down the cost of production to keep the *gari* produced in Nigeria and Ghana competitive should a low-cost cassava producing country such as Benin Republic decides to produce *gari* for the Nigerian market. A recent occurrence in *gari* trade illustrates that foreign *gari* can easily undercut Nigerian *gari*. During the first quarter of 2001, the price of *gari* rose sharply as a result of the increased demand for dried cassava roots for livestock feed in Europe following the outbreak of mad cow disease and the subsequent need to reconstitute herds.[56] In May 2002, the bulk of *gari* consumed in the Lagos area of Nigeria was imported from the neighboring Benin Republic. The same quantity of *gari* was selling at 1,900 Naira in Nigeria but only at the equivalent of 1,700 Naira across the boarder in Benin Republic

[56] The COSCA survey reveals that civil disturbances that displaced farmers in important producing states such as Nasarawa and Benue are additional factors.

(Guardian 2002). The Guardian also reported that the imported *gari* was not only cheaper, it was also of superior quality and more readily available[57].

In Nigeria, this story of *gari* imports illustrates how vulnerable the Nigerian *gari* market is to foreign *gari.* A strong market demand for Nigerian *gari* depends on driving down the production and processing costs to make Nigerian *gari* competitive with other food staples in Nigeria and other countries. The vulnerability of the Nigerian *gari* market to foreign competition is a new challenge in the cassava transformation.

Presently, in both Nigeria and Ghana, there is an expressed political interest in cassava. For example, in 2000, Nigerian government signed a loan agreement with the IFAD (International Fund for Agricultural Development) for the root and tuber crops expansion for US$16 million (Federal Republic of Nigeria 2000). On August 8, 2002 in Nigeria, President Obasanjo, inspired by *The Cassava Transformation: Africa's Best Kept Secret,* constituted a National Committee on Cassava Production and Export "to address issues relating to an increase in yield and production, post harvest management, promotion of local and industrial utilization of cassava products, promotion of exports as well as market to industries. President Obasanjo wants to increase food security and also export US$1 billion worth of cassava products in the next three years" (Bello 2002). On August 16, 2001 in Ghana, President Kufuor launched the President's Special Initiative to promote an aggressive export of garments, textile, and cassava starch to earn Ghana US$4.4 billion over a four-year period (Daily Graphic 2001). The second lesson is that Presidents Obasanjo and Kufuor's goals of exporting billions of US dollars worth of cassava in the next three to four years is not attainable because of high cost of cassava production in Nigeria and Ghana and declining price of cassava products in the global market owing to low cost of American corn.

In Nigeria and Ghana, more than 90 percent of cassava production is consumed as food. The past experience in Nigeria and Ghana is that when dried cassava roots were exported to Europe, the local price of *gari* skyrocketed because of the shortage that was created at home. Ghana's recent attempt to export dried cassava roots to Europe illustrates this point. The EU

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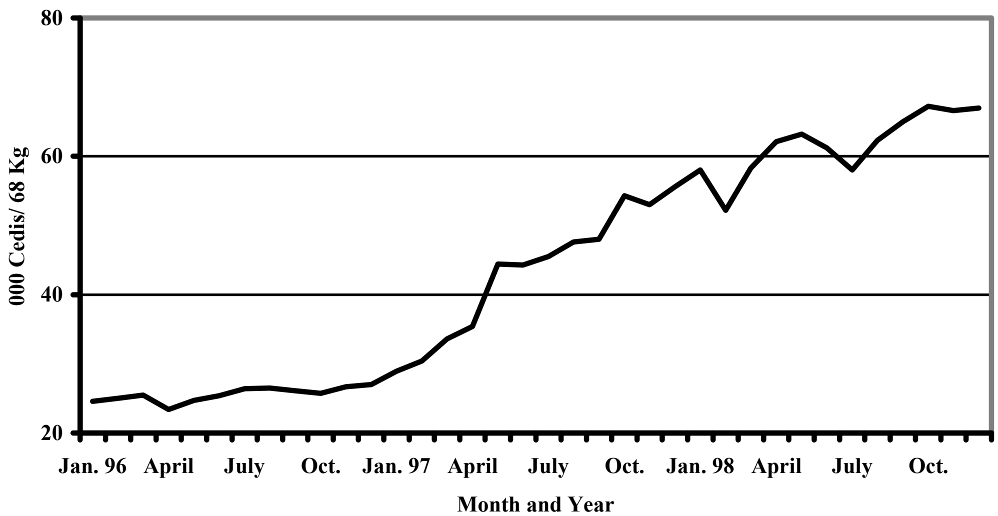
[57] The Guardian reported that the invasion of Nigerian market by imported *gari* was an embarrassing development for the Nigerian government because only a year earlier in April 2001, President Obasanjo announced that his government committed 19.7 billion Naira to the agricultural sector since May 1999. The embarrassment was serious enough because on July 18, 2002 the Guardian reported that on July 17, 2002, President Obasanjo ordered a strict implementation of a ban on importation of cassava and cassava products (Guardian 2002a).

(European Union) has allocated a quota of 145,000 tons of cassava pellets to the WTO (World Trade Organization) member countries excluding Thailand, Indonesia, and China. In Ghana, the private entrepreneurs sought to exploit the opportunity offered by the WTO quota by exporting dried cassava roots to Europe. In Ghana, 18,322 tons was exported in 1996 and 17,449 tons in 1997. In 1997, the price of *gari* skyrocketed and in 1998, the export of dried cassava roots dropped significantly (Figure 6.1 and Table 6.1).

Figure 6.1--Ghana: Price of *gari* from January 1996 to December 1998.



Source: Ministry of Food and Agriculture, Accra.

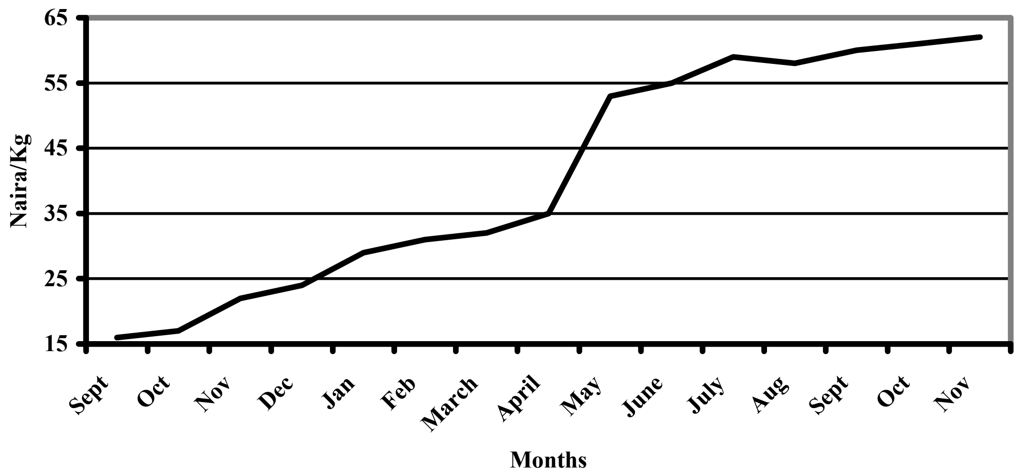
Table 6.1--Ghana: Dried cassava roots export for livestock feed in Europe, 1996 to 2001

YEAR	Tons	VALUE (US $)
1996	18,322	1,832,079
1997	17,449	1,357,545
1998	--	--
1999	7,230	630,020
2000	35	10,495
2001	15	3,558

Source: Francis Ofori.

Nigeria has witnessed similar price movements. In January 2001, Mr O. A. Edache, the Director of the Federal Department of Agriculture, lamented that cassava producers were losing money because of cassava glut in the market and declining cassava prices.[58] Later in 2001, after Mr Edache's comment, the price of cassava rose sharply in Nigeria because of the increased demand for dried cassava roots for livestock feed in Europe following the herd rebuilding required after the outbreak of the mad cow disease (Figure 6.2).

Figure 6.2--Nigeria: Price of *gari* from September 2000 to December 2001.



Source: Ministry of Agriculture, Abuja.

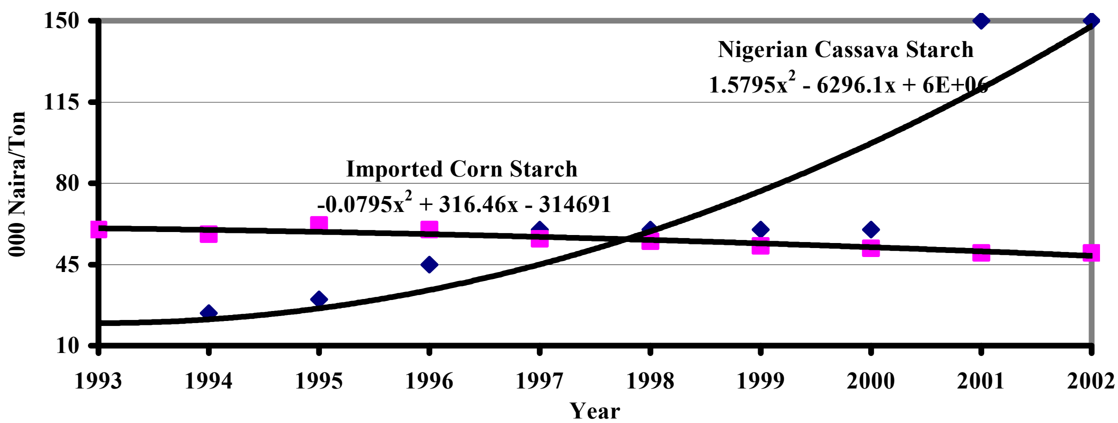
There are two explanations for the skyrocketing of price of *gari* following attempts to export dried cassava roots as livestock feed to Europe from Nigeria and Ghana. The first explanation is that cassava is a long term crop. The fact that the TMS varieties attain maximum yield from 15 months and local varieties from 24 months after planting means that farmers wait for 15 to 24 months to respond to an export demand during which time period the demand has shifted to alternative sources of supply such as maize. The second explanation is that farmers find difficulties in recruiting sufficient migrant hired labor to plant more cassava because of high labor required to harvest and process cassava and because of the increasing wage rates.

In Nigeria, the story of a high level of use of imported corn starch as raw material by industry illustrates the point that Nigerian cassava starch is not competitive with European corn

58 Personal interview, Abuja, January 17, 2001.

starch because of the high production cost. In 2002 in Lagos, the price of corn starch imported from Europe was significantly lower than the price of Nigerian cassava starch. Moreover, the price of the imported corn starch was declining while the price of the Nigerian cassava starch was increasing (Figure 6.3).

Figure 6.3--Nigeria: Prices of Nigerian cassava starch and imported corn starch in Lagos, 1993 to 2002.



Sources: Nigerian Starch Mill, Ihiala (NSM) and Uche Iwuamadi, a Lagos-based corn starch importer.

The third lesson is that in Nigeria and Ghana the scope for increasing the use of dried cassava roots and starch as industrial raw material is highest in food manufacturing industries. But the potential is also high in the non-food industries such as the soft drink, beer malt, and ethanol/alcohol industries. Syrup concentrate has been successfully made from cassava starch by the IITA post-harvest technologists. A pilot project is needed to determine its acceptability and potential profitability in making soft drinks. No attempt has yet been made to prepare beer malt from dried cassava roots. However, biochemists at the National Root Crops Research Institute (NRCRI) believe that given the right enzyme, it is possible to prepare beer malt from dried cassava roots. Research is needed to develop the technology for making beer malt from dried cassava roots.

Turning to use of cassava to prepare alcohol/ethanol, Nigeria and Ghana may be able to produce ethanol or alcohol with small-scale cassava-based production units. Nigeria could theoretically benefit by using cassava to produce alcohol and replace alcohol imports for alcoholic beverages. Public enterprises such as the NIYAMCO and NISUCO have floundered in

Nigeria because of mismanagement of public resources and the inability of the government to provide R and D support to assist new industrial enterprises. However, a cost-benefit study of ethanol production should be completed in petroleum importing Ghana because a cassava-based ethanol industry could reduce the country's petroleum import bill.

In Nigeria and Ghana, a successful transformation of cassava to play the additional roles as a raw material for the food and non-food industries poses two critical challenges to the political leaders, policy makers, scientists, and donors. The first challenge is to invest in measures to drive down the cost of cassava in order that cassava products will become competitive with American corn products in the global market. In Nigeria and Ghana, driving down the cost of cassava can be done by restructuring the cassava plant to standardize the canopy and root shapes and sizes and developing labor-saving mechanical technologies for production, harvesting, and processing. Another critical challenge is to provide incentives, especially patent protection, to private entrepreneurs to invest in developing technologies for using cassava as a raw material for the preparation of snack foods, soft drink, beer malt, and ethanol/alcohol.

APPENDIX 1—CASSAVA YIELD MEASUREMENT IN THE COSCA STUDY

METHOD OF THE YIELD MEASUREMENT

Cassava yield measurement poses unique problems because it depends on a wide range of factors which are peculiar to cassava such as variable root sizes, flexible age for harvesting, and piecemeal harvesting by some farmers (Fresco 1986). Most cassava varieties form edible roots at six months after planting and they may be harvested at that age. But if not harvested, the roots continue to grow for up to four years after which they begin to deteriorate (Jones 1959). Therefore, cassava yield varies with age, increasing up to a point, after which it declines. Yield measurement was taken from all cassava fields of each COSCA study farmer which were nine months or older.

Most farmers spread the harvesting of a cassava field over a period of months and they often target the harvesting to specific cassava plants depending on size, variety, or location in the field. Also, some farmers who plant cassava as a famine-reserve crop milk their cassava plants, i.e. the farmers harvest some roots of a plant at a time. Cassava fields where harvesting was targeted to specific plants or where cassava plants were milked were excluded from the COSCA yield samples.

Inter-cropping also affects the cassava yield because in the COSCA study mono-cropped cassava fields produced higher yields than inter-cropped fields. Yield measurements were taken from all cassava fields, mono-cropped and inter-cropped, of each COSCA study farmer. But cassava yield is not prone to year to year variation due to weather because cassava has more than one year growth period.

Size of the root can affect processing cost because smaller roots are more difficult to peel by hand. Therefore some farmers discard small roots and discount them from yield. But the size of a cassava root a farmer will discard depends on processing method, peeling before or after soaking in water; the farmer's food needs; and alternative uses for cassava which the farmer has, such as livestock feed. The COSCA study counted all edible cassava roots irrespective of size.

Since cassava has a flexible harvesting schedule, a farmer usually has cassava fields at different stages of maturity. Therefore, it was possible to obtain a representative cassava yield sample at any time of the year. In the COSCA (Collaborative Study of Cassava in Africa)

studies, yield measurement was based on one or two representative sample plots of 40 m^2 or 20 m^2 per field depending on the size, variability in the soil, and toposequence of the field.

YIELD MEASUREMENT RESULTS

In 1991 and 1992, the COSCA studies revealed that the average cassava yield in the Congo was 9.9 tons per ha; Cote d'Ivoire, 10.8 tons per ha; Ghana, 12.4 tons per ha; Nigeria, 14.7 tons per ha; Tanzania, 10.5 tons per ha; and Uganda, 10.6 tons per ha. In the same years, 1991 and 1992, the FAO (Food and Agriculture Organization of the United Nations) reported national average cassava yields for the Congo, 8.00 tons per ha; Cote d'Ivoire, 5.1 tons per ha; Ghana, 10.5 tons per ha; Nigeria, 10.4 tons per ha; Tanzania, 11.4 tons per ha; and Uganda, 8.2 tons per ha. which are significantly lower than those of the COSCA studies (FAOSTAT).

The FAO cassava yield data for each country was based on the national agricultural census. But the COSCA information was based on a sample representing major cassava producing areas which was at least 90 percent of the cassava producing areas of each of the countries (Carter and Jones 1989). The FAO derives its yield data from detailed area and production reports prepared by the various national governments and does not state the method of measurement used (FAOSTAT). But official production data on cassava in Africa are inconsistent and unreliable because cassava yield is difficult to measure and most African governments do not have sufficient resources to conduct agricultural census efficiently (Fresco 1986 and Berry 1993).

In Africa, few farm surveys have included cassava yield measurement because it poses several problems. In Nigeria, Ezedinma (1989) reported cassava yield at 15 months after planting, 12.0 tons per ha and at 18 months, 13.1 tons per ha. In Zambia, Bangwe (1990) found average yield at 30 months or less after planting, 10.4 tons per ha; 31 to 36 months, 11.3 tons per ha; and above 36 months, 16.8 tons per ha. In the Cameroon, Almy and Besong (1988) reported average yield 11.6 tons at 12 months and 14.8 tons, 18 months. These farm survey yield measurements are similar to those obtained by the COSCA studies in other African countries.

Given variable methods used by national reporting systems and subsequently compiled by the FAO, the inconsistencies in these official data make cross-country comparisons tenuous at

best. Therefore, where available, this report has cited COSCA yield data, since these offer a consistent methodology for measurement and comparison across countries.

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