CLIMATE CHANGE AND ROOT CROP PRODUCTION IN GHANA

A REPORT PREPARED FOR ENVIRONMENTAL PROTECTION AGENCY (EPA), ACCRA-GHANA

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EXECUTIVE SUMMARY

The root and tuber crops cassava, yam and cocoyam are important source of energy in our daily diets and constitute a major part of the rural Ghanaian staple diet. With an estimated per capita consumption of 151.4 kg of cassava, 43.3 kg of yam and 56 kg of cocoyam, they account for 58% of the per capita food consumption; making them a major source of food and government savings on revenue. Root and tuber crops as part of the agriculture exports generate about 75% of government earnings and employs 70% of the population. Experimental research has shown that root crop yield response to climate change vary widely, depending on the species or cultivar, soil properties, pest and pathogens. The need to assess the effects of climate change on root crop demand, farm incomes, and prices can not be overemphasized.

This report is a scientific assessment of the consequences of, and adaptation responses to climate change. This report;

- Evaluates evidence that observed changes in climate have on root crop production.
- Studies the vulnerability of root crop yields and human population to future climate change.
- Identifies and discusses how adaptation options may lessen adverse effects.
- Identifies and analyzed linkages with other aspects of the economy and describes adaptation strategies available for mitigation.

Climate change scenarios generated indicated an increase in both the minimum and maximum temperatures for Ghana; these were the same for all ecological zones. The mean base year temperature range from 26.4^{o}C (Forest) to 28.6^{o}C (Sudan) and the scenarios gave a possible mean temperature change from 0.6, 2.0 and 4.0 for 2020, 2050 and 2080 respectively. A positive correlation exist between temperature and root crop yield, this relationship gave a correlation less than 40%. Scenarios for rainfall amounts in the various ecological zones differed; the rate of change in total rainfall will increase from -1.1% to -20.5% for 2020 to 2080. This means that less amount of rainfall should be expected in future. Rainfall in the rain forest zones had the highest percent reduction of rainfall amount for all 3 rainfall scenarios created. The least was in the Guinea Savanna Zone. The number of rainy days and total rainfall was found to be highly correlated for some ecological zones, years with high number of rain days have higher total amount of rainfall. The least number of days of rainfall is in the coastal savanna eco-zone. With the exception of the Sudan Savanna and Rain Forest eco-zones that gave coefficient of correlations below 50% all the others gave valves above 80%, indicating a high positive correlation between rainfall amount and number of rain days within a year.

The current state and trends in root crop production was assessed; yields were found to be positively correlated to total rainfall with a correlation factor R of 89 – 92% and mean daily temperature with R <50%. Climate factors identified and perceived to be stressors within the limits of the study includes the following;

- Rain fall within the community was unreliable, irregular and unpredictable. Duration of rain has been shortened and it is either too much (flooding) or too little (drought) as phrased by the community.

- Daily temperature was perceived as hot or high when the sun shines too much, thus scorching crops. They attributed this condition to indiscriminate deforestation.
- Poor or degraded soils as a result of intensive and bad cultivation practices, erosion and deforestation subsequently reduce yields.
- Prolonged drought increases the population of variegated grasshoppers which destroy cassava.

Cassava, yam and cocoyam exported were classified under the non traditional horticultural products. Cocoyam and yam exports contribute from about 3% to 10% of the total horticultural export commodity; whilst cassava and its other products contribute from 0.1% to 1.2% of the total horticultural exports from 1990 to 2002. The number of persons exporting yam and cocoyam products was more than cassava exporters and this increase with time at a correlation coefficient of 97%; increase in quantities exported will increase the number of exporters. It was observed that increase in the number of cassava exporters does not necessary mean an increase in amount of cassava products exported or vice versa. Cassava export market was found to be in consistent and gives an indication of a not too organized export market or drive as compared with yams and cocoyam export market which seems to be increasing with time in terms of quantities exported and persons involved with export. The export drive or the well organized export market for cocoyams and yams would be the reason for the relatively higher wholesale price for the commodity even with increases in production. A fall in the production levels will definitely increase wholesale price as a result of increased demand and a decline in person who export these commodities.

Using the projected climate scenarios and the crop model CROPSIM-cassava and CROPGRO (ARGRO980)-tanier; yields of cassava and cocoyam is expected to reduce with the rate of reduction increasing with time or rise in temperature and solar radiation. Cassava productivity or yields are expected to reduce by 3%, 13.5% and 53% in 2020, 2050 and 2080 respectively. Percent reductions in cocoyam productivity are 11.8%, 29.6% and 68% in 2020, 2050 and 2050 respectively.

Farmers on their own do have options that help them bear and share loses or modifies threats. Appropriate technologies and improved varieties also exist to prevent or help share losses that may occur when climate changes. The study identified the following as adaptation options for climate change:

- Improved farming technologies which includes planting more than 2 types of varieties of root crops on the same piece of land, planting improved varieties that are nutrient efficient and drought tolerant, adjustments to planting dates, fertilizer applications and irrigation applications.
- Post harvest technologies – This option provides insurance against local supply changes through storage which tends to store the crop for a longer period and also guarantees a good price for the commodity.

- Alternate livelihood development especially those that give fast income.

- Marketing policies that encourage root crop production.

The vulnerable groups most likely to benefit from these adaptation strategies are the farmers and rural folks, fisher folks, women and the urban poor in a decreasing order of severity. And to achieve the above mentioned strategies the following researchable topics needs to be studied;

- Drought tolerant and early maturing root crops need to be identified and made available to farmers.
- Tree planting as part of the root crops production systems – yam and cocoyam need to be introduced.
- Identification of fast growing trees that cope with root crops production
- Identification of potential processing techniques and adapt to our local conditions.
- A detail household survey to identify alternate livelihood which is economically feasible and acceptable to the rural folks or farmers.
- A socio-economic survey in a community (Volta region) where their main source of income is processing cassava.
- Identifying and designing appropriate irrigation system that is cost effective.
- Identification and implementation of policies that address marketing issues in relation to root crop production needs to be done.

Costs will be involved in coping with climate-induced yield losses; the need for a well laid down policy on root crop production is being encouraged. This is because most communities visited claim there are no policies for root crop production and marketing in Ghana.

The adaptation options identified were reviewed in relation to other sectors of the national economy as affected by climate change. Changes in one sector as a result of climate impact were found to affect another. The water, coastal and forest resources are possible productive sectors that can affect agriculture production particularly root crop production. The promotion of inland fish farming under the fisheries sector would make water available for irrigating food crops if they are integrated into our farming system.

Socio-economic drivers such as poor human health, poor nutrition and population growth or out migration would also affect root crop production reducing labor availability and quality and / or high labor cost. A better marketing policy and an increase in yields or productivity would increase household income.

Adaptation options strongly support policies that will prevent poverty as outlined in the Ghana Poverty Reduction Strategy.

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SECTION ONE

1.1 INTRODUCTION

In an intensively human-managed system, climate change causes responses in many human and natural systems. This influences human health, agricultural yields, pest outbreaks, crop timing, flooding and biological distribution and extinction. Climate change effect may either be buffered or confounded with other factors that make it impossible to detect. Understanding climate variability is important for agricultural decision making at the farm, marketing or policy level. Further, options for responding to climate change are few and therefore makes the poor more vulnerable to the change especially in Ghana where the populace depend on farming, fishing and/or forestry as their main livelihood. Effective or sound policies would therefore minimize the climate impact on food security.

1.2 BACKGROUND AND TERMS OF REFERENCE

Developing countries like Ghana has an obligation under the United Nations Framework Convention on Climate Change (UNFCC) to produce National Communications and action plans for implementation to buffer climate change. The Netherlands Climate Change Studies Assistance Program (NCCSAP2) was created among its numerous tasks to assist developing countries to prepare, formulate, implement and evaluate their policies in relation to climate change. And raise awareness of the problem of climate change through an increased involvement of policy makers, scientist and all stakeholders of the populace in climate change debate. It is in light of this, that the Team was tasked with a main goal of assessing the vulnerability of Root and Tuber Crops to climate change with the following terms of reference:

1. Develop and submit a methodology for the vulnerability and adaptation assessment of root and tuber crops production.
2. Investigate the impacts of climate change on root and tuber crops – yam, cassava and cocoyam.
3. Assess the socio-economic implications of climate change on the crop yields and their implication for National food security and income.
4. Formulate and prioritize appropriate adaptation options giving cost indications of such options.
5. Participate in the development of a National Adaptation Policy Framework through an integrated assessment process.
6. Formulate concrete project proposals for funding (GEF Assistance) to address Adaptation options.

1.3 OBJECTIVES

The world's poorest people are at risk of increased hunger, particularly those in the tropical and sub tropical areas in the face of climatic change effect on Agriculture IPCC (1996). Root and tuber crops are vulnerable to the damaging effects of climate change, however if the changes take place gradually, it may be able to adapt. Sudden changes such as water shortages, increases in crop damage as a result of new unpredictable changes in interaction among crops, weeds, insects and diseases or pathogens could have drastic effect. With the varying changes in root crop yields in Ghana and these crops being the main staple food in low income households, makes it more vulnerable to the change. This study sought to assess the vulnerability of root and tuber crops - cassava, cocoyam and yam production to climatic change in Ghana.

With the following specific objectives;

1. To define clearly the ranges of possible climatic impacts
2. To determine which locations and farming systems may be most vulnerable.
3. To identify critical thresholds and economic implication.
4. And to explore adaptation strategies.

It is expected that at the end of the study, the public and policy makers will be well informed and their knowledge improved about the effect of climate change on root crops production. Management or adaptation options for these crops will be identified.

1.4 REPORT OUTLINE

The report is structured to include the following;

An executive summary which basically summaries the whole report and captures the background, purpose and findings.

Section one provides a general introduction to the study. It gives an indication of the background, purpose and expected output of the study.

Section 2 describes the mode of study and defines the scope of the study, identifying the regions and farming systems most vulnerable to climate change.

Section 3 discusses trends in climate change and defines the range of climate change impact and evaluates the impact analysis in relation to yields. The current trends of natural yield variability in relation to climate variables are discussed.

Section 4 assesses the vulnerability of the various root ant tuber crops and evaluates its implication to the socio-economic well being of the populace.

Section 5 identifies and analyzed linkages with other aspects of the economy and describes adaptation strategies available for mitigation.

Section 6 concludes the report with findings, challenges and strategic directions for its achievement.

SECTION TWO

2.1 INTRODUCTION

Agriculture production is Ghana's main source of employment with over 70% of the population earning its livelihood from this sector. It generates about 75% of the export earnings of the country and a major source of food and government savings on revenues. An overall economic progress will therefore depend to a large extent on the agriculture sector.

Root and tuber crops occupy an important position in Ghana's agriculture, contributing 40% of the country's agricultural gross domestic product (AGDP); with cassava accounting for 22% of the AGDP. The main root and tuber crops grown in Ghana are cassava, yam and cocoyam. They are mostly grown by smallholders for household food security, as is the case of cassava and cocoyam or they may be as in the case of yam and recently cassava, be produced for sale.

The root and tuber crops cassava, yam and cocoyam are important source of energy in our daily diets and constitute a major part of the rural Ghanaian staple diet. And with an estimated per capita consumption of 151.4 kg of cassava, 43.3 kg of yam and 56 kg of cocoyam, they account for 58% of the per capita food consumption. Cassava alone account for 34% of food crop consumption per annum (MOFA, 2003).

Agricultural productivity has been found to be affected by climate change and since such changes cause response in many human and natural systems, understanding climate variability will improve agricultural decision making and eventually productivity. Climate change has the possibility of degrading soil and water resources and subsequently subsistence agriculture production which is largely practiced by root and tuber crop farmers. Although impact of the climate change on agriculture is estimated to result in small percent change in global income, which is positive for developed regions but negative for developing countries like Ghana. The estimated economic impact indicates the lowering of income of vulnerable population and increase in people at risk to hunger.

Yields of root crops on farmers' fields vary according to climate and the crop. Climate has been identified as a principal factor that control crop distribution and growth. Whilst some crops have stable genotypes and therefore do not react to variation in environmental changes, others are excessively stressed with slight changes in climate. The main abiotic stress factors affecting root and tuber crops are drought, water logging, temperature extremes, solar radiation extremes and nutrient in balance.

In Ghana crop production suffered or reduced during the drought period in 1990 but picked up in 1991 – 1992 with the returns of more normal rains. Root and tuber crops are therefore vulnerable to the damaging effects of climate change. If the changes take place gradually, it may be able to adapt. But then sudden changes such as water shortages, increases in crop damage as a result of new unpredictable changes in interaction among crops, weeds, insects and diseases or pathogens could have drastic effect.

Options for responding to these changes are few, but then effective policies can minimize the climate impact on food production. Analyzing agricultural systems and their alternate management options experimentally and in real time is generally not feasible. A well tested simulation approach which allows for objective evaluation of alternative decisions at the farm, market or policy level offers a time and cost efficient alternative. And this was what was employed in this study.

2.2 METHODOLOGY

To achieve the objectives set out as a result of the terms of reference, the study was phased out into various activities and different approaches used.

Literature search on climate change and its effect on agriculture production were done to provide an initial or approximate indication of the types of impact to expect and the methods of analysis likely to be most effective. Geographical regions and rural populations most likely to be vulnerable were identified and scope of study defined.

Climate change impact analysis was done by using national climatic data (1960 – 1990) and scenarios created for 2020, 2050 and 2080. Natural yield variability was evaluated by describing the defined unit quantitatively and qualitatively; using production statistics; and general socio-economic data at household or village level.

Crop model – DSSATv4 was used to evaluate the root crops for their vulnerability; implications for future climatic change and project expected magnitude of impacts.

Economic impacts in terms of production, consumption and policy was evaluated using primary and secondary economic and agricultural information. These were sourced based on the following checklist:

a. Production; alternate crops, production techniques, nature and extent of resources use and cost of production information.
b. Consumption; role of crop in overall food consumption; percent consumed domestically verses exported, price fluctuation.
c. Policy issues relevant to Agriculture and in particular root and tuber crops production.

The interactions between impact of climate change on root and tuber crop yields and factors that determine final output such as national policies and economic issues or the indirect effects of climate change was examined. The methods used include the following; Computer aided modeling, Scenario analysis, Simulation gaming, Participatory assessment and qualitative assessment based on existing experience and expertise.

Finally potential adaptation measures were identified and examined.

2.3 SCOPE OF STUDY

The prioritized crops for the study are cassava, yam and cocoyam; based on their importance to economic, social development and vulnerability to climate change. Ghana has 10 regions which fall within the six agro-ecological zones - they are the Rain Forest, semi-Deciduous Forest, Coastal Savanna, Forest/Savanna Transition, Guinea Savanna and Sudan Savanna.

Cassava is grown in all regions of Ghana with the exception of Upper East. Cassava production within a period of time (1997 – 1998) was assessed based on regional production per annum. The regions were then classified as low (Central, Northern and Greater Accra) when production was less than 600,000 Mt, medium (Volta and Western) when yields ranged from 600,000 Mt to 1,200,000 Mt and high (Eastern, Ashanti and Brong Ahafo) when it produced more than 1,200,000 Mt of cassava per annum. The Central, Volta and Ashanti regions were selected as the representative regions for cassava based on their productivity levels (low, medium and high), utilization, commercial use and possibility of being vulnerability to climate change.

Yam is grown in the Brong Ahafo, Ashanti, Western, Eastern, Central, Northern and Upper West regions. Based on the production statistics of Yams in Ghana (1997 to 1998), the productive regions were categorized as high when production per annum was over a 300,00Mt and these are Brong Ahafo, Eastern and Northern. The medium productive regions with between 100,000 to 200,000 Mt were Volta, Ashanti and Upper west. And the least productive regions with less than a 100,000 Mt are the Central and Western regions. A representative region within the group was selected as a study region, based on their vulnerability to climate change and the importance of the crop to the populace. The Northern, Volta and Western regions was identified for the study but only Western region was studied under the yam section.

Cocoyam production is limited to the forest agro ecologies and these include the Western, Central, Eastern, Volta, Ashanti and Brong Ahafo regions. Based on the same concept of vulnerability to climate change and production levels, the 3 regions selected as representative sites are Ashanti, Western and Volta region**s.** Only Ashanti and Western regions were studied.

A district within each region was selected and a participatory / rapid rural appraisal conducted to determine the possible effect of the climatic change in terms of economic and social implications; such as farm income, rural employment and contribution to the national income. The perception of the rural farmers was sought on climate stressors and how they adapt to such stressors. For the vulnerability assessment, Ashanti Region was chosen and all three crops assessed with data available and reported.

SECTION THREE

3.1 CURRENT STATE AND TRENDS OF CLIMATE CHANGE AND ROOT AND TUBER CROP PRODUCTION

The rate of social, economic, and technological change in the agriculture sector will gradually transform the setting in which climate change is likely to interact with sensitive features of the food system. The current state of the sector and important trends that would transform it provides a baseline against which to examine the potential consequences of climate change. Hence the need to evaluate the state and trends in root crop production in Ghana.

Figures relating to production are generated by the Ministry of Food and Agriculture, statistical section. Climatic data on precipitation (monthly and annual) and temperature for the base year and climate scenarios for 2020, 2050 and 2080 developed by the Ghana Meteorological Services were sourced and analyzed (Appendix 1). And a participatory assessment study undertaken at 3 different districts within the various regions identified as being vulnerable is reported.

3.2 TRENDS IN CLIMATE CHANGE

Climate scenarios for Sudan Savanna, Coastal Savanna, Guinea Savanna, Deciduous Forest and the Rain forest zones was developed with the base year (1960-1990) rainfall data, rain days, minimum and maximum temperatures and a 10 year average solar radiation data for Ghana.

The eco zone with the least total rainfall (890.2 mm) for the base year is Coastal Savanna; the highest of 2092.7 mm is at the rain forest zone. Rate of change in total rainfall will increase from -1.1% to -20.5% for 2020 to 2080. This means that less amount of rainfall should be expected in future. Rainfall in the rain forest zones had the highest percent reduction of rainfall amount for all 3 rainfall scenarios created. The least was in the Guinea Savanna zone.

The number of rainy days and total rainfall was found to be highly correlated for some ecological zones, years with high number of rain days have higher total amount of rainfall. The least number of days of rainfall is in the coastal savanna. With the exception of the Sudan savanna and rain forest eco-zones that gave coefficient of correlations below 50% all the others gave valves above 80%, indicating a high positive correlation between rainfall amount and number of rain days within a year.

The mean base year temperature range from 26.4^{o}C (Forest) to 28.6^{o}C (Sudan) and the scenarios gave a possible mean temperature change from 0.6 to 4 for 2020 to 2080. A positive correlation exist between temperature and root crop yield, this relationship gave a correlation less than 40%. The temperature changes were the same for all ecological zones

3.3 CURRENT STATE AND TRENDS OF ROOT CROP PRODUCTION

National and Regional Root and Tuber yield values for 1974 to 2003 was assembled and their natural variability was assessed using different computer software. The current state of the crop within the rural populace was assessed using a rapid rural appraisal method. A district within the regions identified was selected and using a checklist obtained information pertaining to the state of the crops within their community and their perception of climate change and how vulnerable they are to changes in production levels (Appendix 1). Their readiness to such risk was also assessed and adaptation strategies to avert such risk were also discussed.

For the period 1970 to 2003, root crop production has severely increased as a result of increase in area under production, improved planting materials and technologies among others. Acreage under production was increasingly higher for cassava production when compared with yam and cocoyam (Fig.1.1). This makes cassava a major root crop in Ghana. Every household within the identified districts has a cassava field justifying its importance as a food and cash crop and confirming the report by the Ghana Living Standard Survey (1987) that 83% of households in Ghana growing cassava. The sharp increase in acreage under cropped in 1984 (Fig 1.1) was because of the hunger period during 1983 and this made a greater proportion of the population crop cassava or the other root crops because of the fact that those who had cassava farms had food to eat during that period.

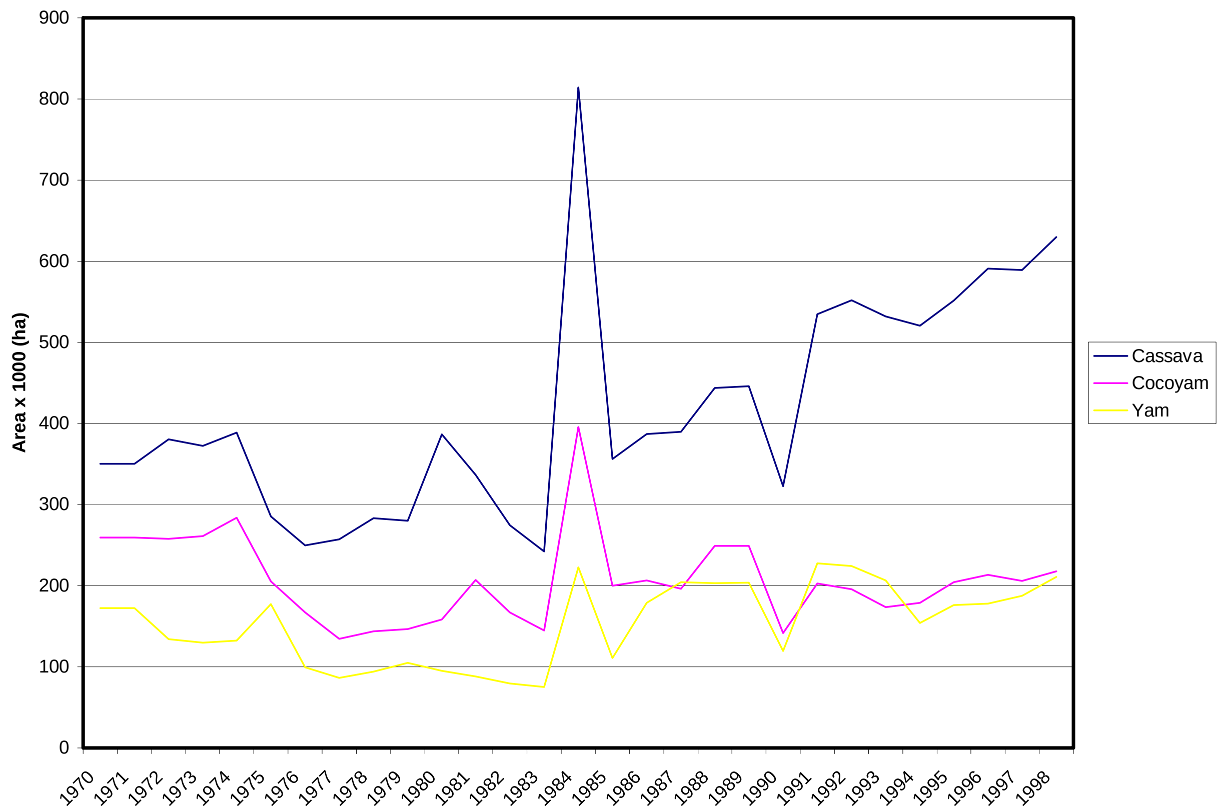


Fig.1.1: Trends in acreage under Root and Tuber Crops production in Ghana (1970-1998).

Root crop yield variability in relation to climate variables like rainfall and mean average temperatures were assessed graphically and statistically using correlation statistics. Root crop yields in Ghana were found to be positively correlated to total rain fall giving a highly significant correlation coefficient values between 0.89 – 0.92.

Although mean temperatures were positively correlated to yield, the level of correlation was below 0.50 indicating a low degree of association.

Graphical presentations of relationship between rainfall patterns in Ghana and root crops production in Ghana are presented in figures 2.1, 2.2 and 2.3. The RR max and RR min referring to the highest and lowest total rainfall recorded in the year respectively. The high rainfall amounts were recorded in the Rain Forest zone and the low in the Coastal Savanna zone. Increases in total rainfall within a year increased production. Increases were however highest in cassava, followed by cocoyam and then yam. This can be explained by the increases in acreages under production being higher under cassava production and lower under yam production when compared to cassava and cocoyam.

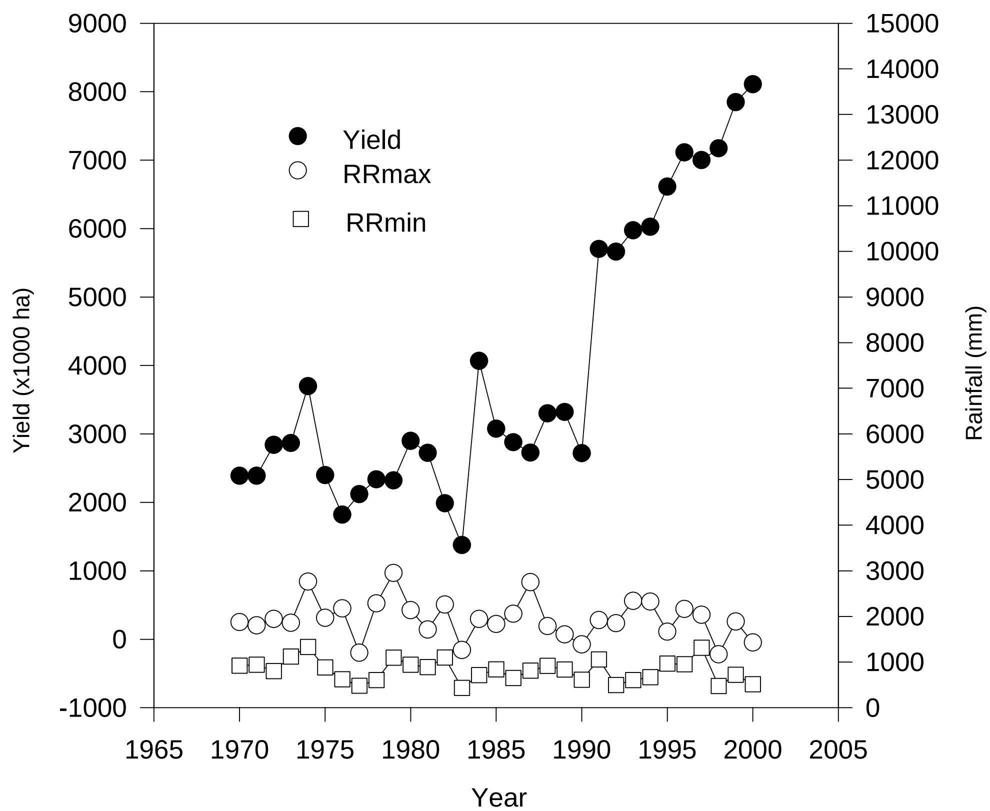


Fig 2.1: Cassava production trends and rainfall distribution patterns in Ghana (1970-2003)

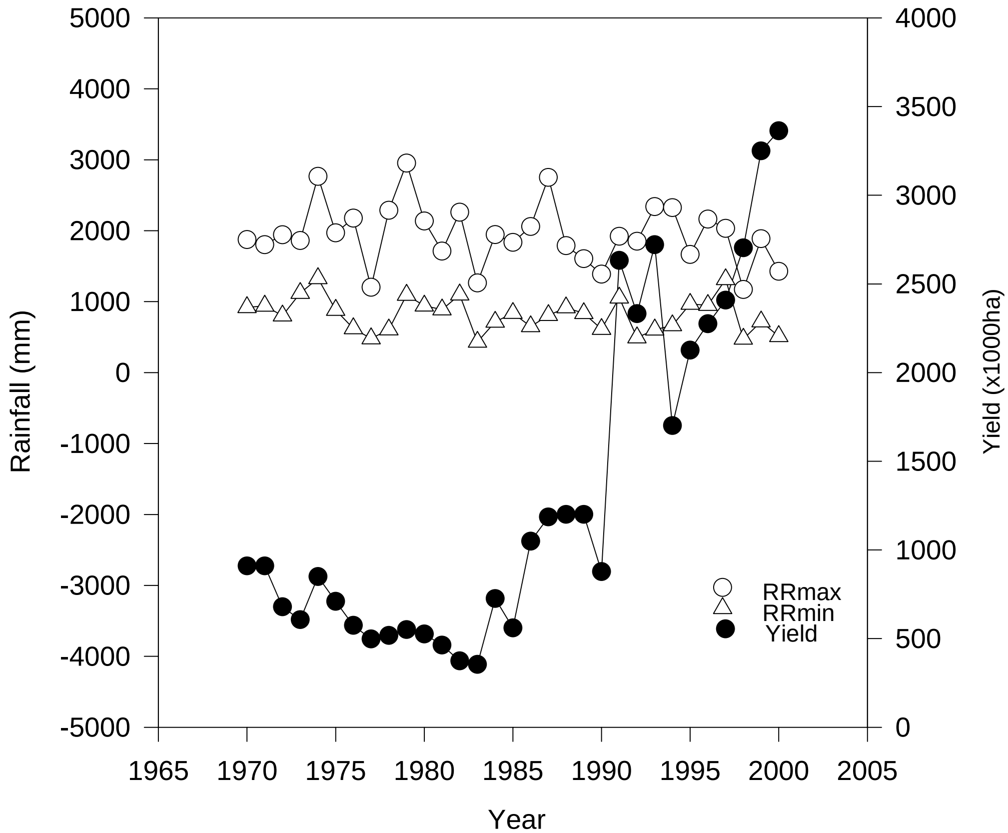


Fig. 2.2: Yam production trends and rainfall patterns in Ghana (1970 – 2003)

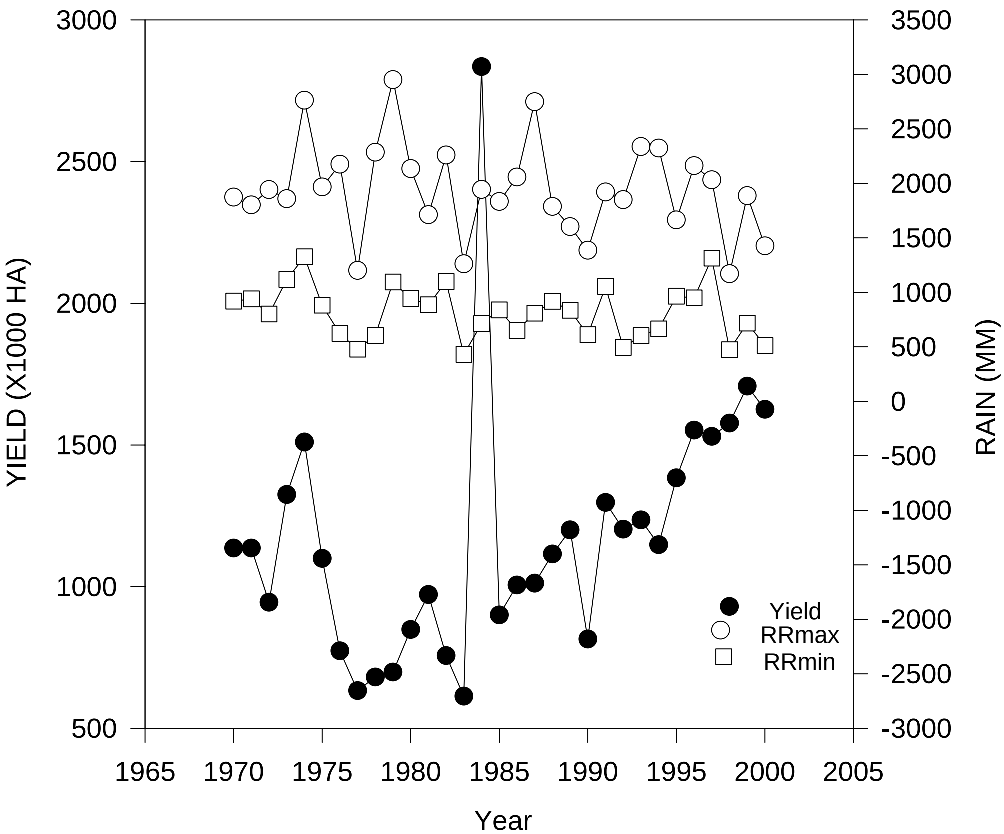


Fig. 2.3: Cocoyam production and rainfall patterns in Ghana (1970 – 2003)

3.3.1 CASSAVA PRODUCTION IN GHANA

Cassava yields range from 5 – 12 t/ha within the Forest and Forest/Savanna Transitional zones but improved varieties are capable of giving 20 – 25 t/ha. The annual domestic rate of consumption is estimated to be 155 kg/caput which is 4 times as great as cereals which range between 4 – 14 kg / caput. The Ghana Living standard Survey of 1987/88 reported 1.73 million households (83%) were engaged in cassava production. This was confirmed by the case study which shows that all household within the communities visited have cassava fields. *Nkaakom* and *Nyamebekyere* in the Nkawie (Ashanti Region) and Cape Coast (Central Region) districts respectively were selected for the participatory assessment study.

Traditionally cassava varieties in Ghana cover a wide range of maturation periods and many are flexible with regard to the length of time they are left in the ground after maturation without deteriorating significantly. Therefore different local varieties (14) and a few improved varieties (3 – mainly for processing) are grown per household within the study area. Cassava was said to be grown mostly for food and excess for sale. 90% of cassava produced in the study area is for human consumption, 10% for animal feed and in industry. Both communities have their main source of income from farming and petty trading which is normally practiced by females.

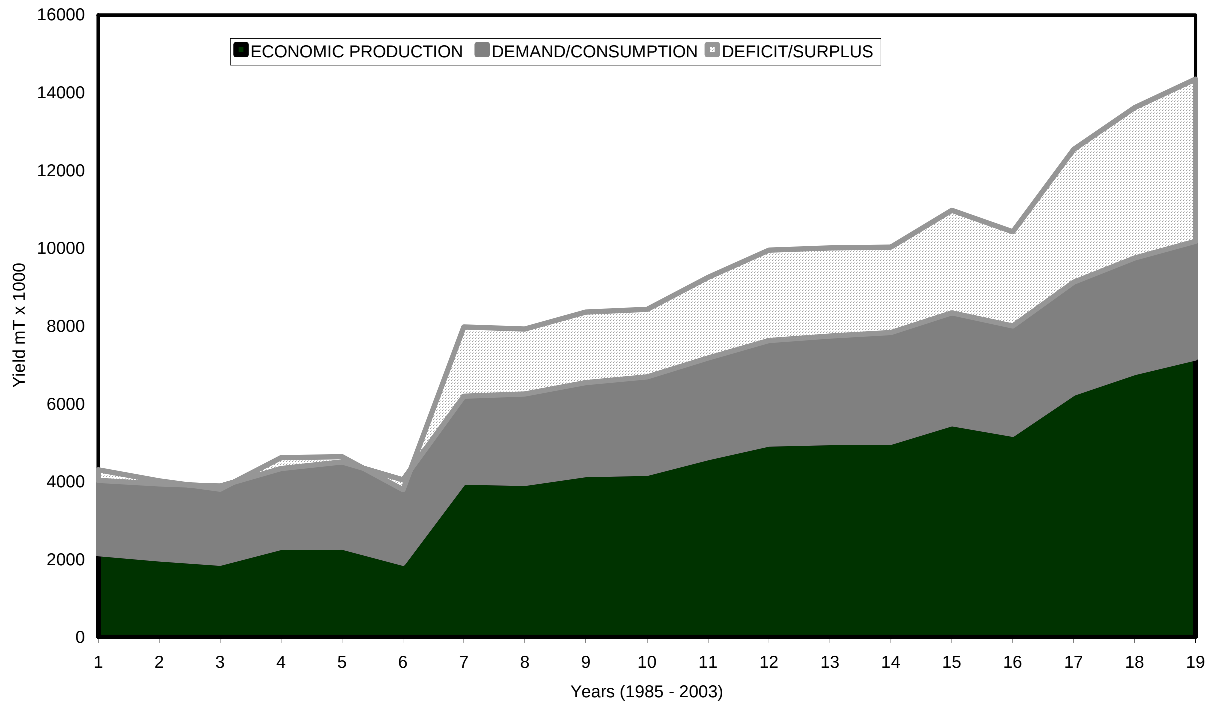
Production and consumption patterns in Ghana tend to fluctuates for the past years. A Food Balance Sheet for 1987 to 1990 indicates surplus as indicated in figure3.1. Prices also fluctuate seasonally, with bumper harvest reducing prices as indicated by farmers within the study area. The excess production could be channeled into industrial use as flour for bakery or starch for the plywood, paper and textile industries.

Under the Ministry of Food and Agriculture (MOFA), the Food and Agriculture Development Policy has a main goal of creating a sustainable environment for the sector that will ensure food and raw materials security, higher employment and income for farmers, reduce poverty and create wealth and contribute to the GDP through increased foreign exchange earnings and government revenues. Cassava policies that exist to help achieve the goals stated and confirmed by the Ministry of Food and Agriculture's directorate include the following:

- Planting material multiplication and distribution to make available to farmers improved planting materials for good crop yields.
- Training of Agricultural Extension Agents and farmer groups in value addition to the crop. This improves the shelf life of cassava and therefore guarantees a more stable price.
- Facilitation of loan for farmers from banks.
- Assistance in the form of loan from Village infrastructure Project (VIP) to purchase equipments for processing cassava.
- Technical assistance from MOFA in the form of appropriate technology for high productivity was stressed by farmers.

The farmers claim no marketing policy that guarantees fixed price and ready markets exist. The need for such intervention to reduce poverty levels was stressed.

Fig. 3.1Cassava production and demand patterns in Ghana



3.3.2 COCOYAM PRODUCTION IN GHANA

Cocoyam yields range between 4 to 7.5 t/ha and it is confined to the wetter forest zones because of its high moisture requirements for growth. It is produced mainly for cash and food because of the high stable price that exist for the commodity. The annual domestic rate of consumption is estimated to be 56 kg/caput and this has not changed for the past 20 years.

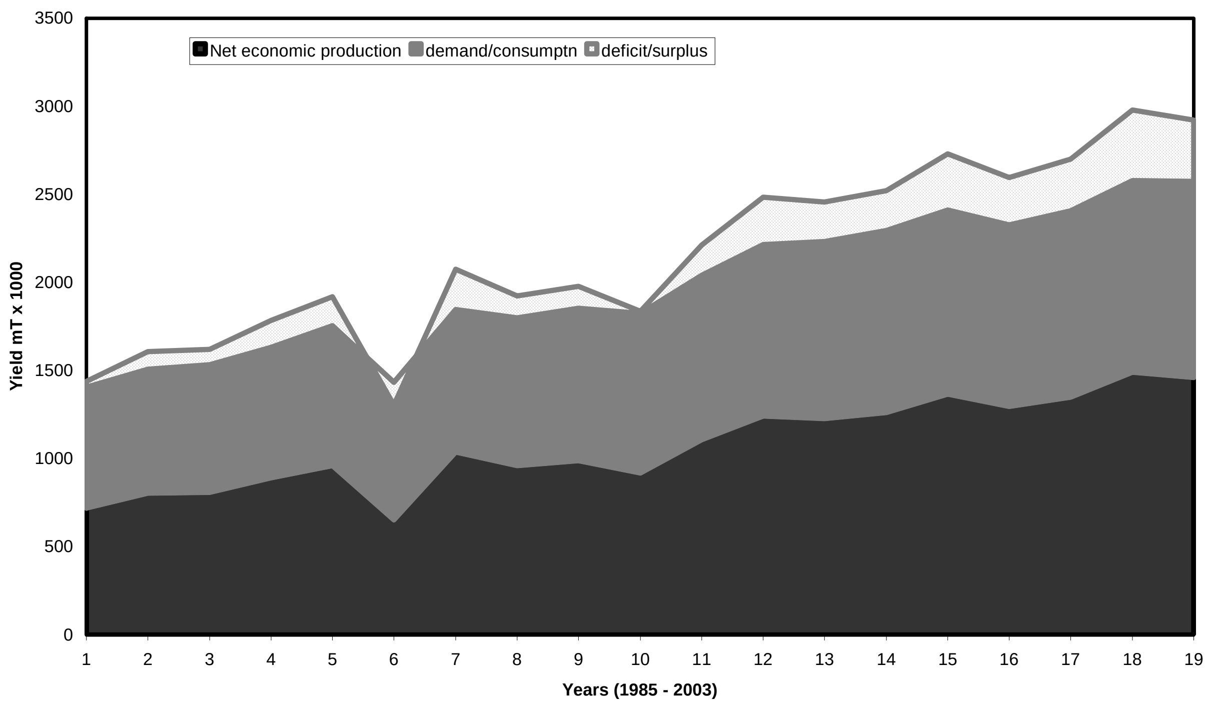
Production for the past years have been increasing in acreage but not per unit area Poor soils, decreasing rain days and total rainfall has been identified as the cause of reduction in cocoyam production. In Ghana trends in its production and demand for its consumption are similar to yam and cassava production in Ghana (Fig. 3.2). Increasing demand results in increase in production with slight surpluses when compared with cassava. Demand was in short supply in 1990. No policies exist for its production or marketing.

Out of the three regions selected as representative sites Ashanti and Western Region were assessed. Nkawie (*Nkaakom*) and Ahanta West (*Boekrom*) districts were selected with the assistance from the district directorate of the Ministry of Food and agriculture (MOFA).

Two types of cocoyam, the white and red types were being cultivated in the areas visited. Cultivation is mainly by cutlass and hoe and planting materials are purchased from other farmers. Corm setts or suckers that sprout after land is cleared for farming are the main source of planting materials used for its establishment. It is normally harvested between 12 to 18 months after field establishment. Prices of produce are more stable and they will normally harvest crop when there are buyers.

Cocoyam stores better in the soil and prices are more stable, this makes it a food security crop. Most farmers within the study area crop it for its leaves or roots on subsistence level while a few crop it mainly for cash. It is mainly cropped intercropped with plantains or bananas and sometimes with other food crops such as maize and cassava.

Fig. 3.2 Cocoyam production and demand patterns in Ghana



3.3.3 YAM PRODUCTION IN GHANA

Yam yields are relatively high (7 – 15 t/ha) and it is an expensive crop to cultivate, requires soils with high fertility status and a much lesser amount of rainfall. They are therefore being grown mostly in the Savanna and Transition zones. Some varieties do well in the Forest ecological zones. Yam is grown in all regions except Upper East and Greater Accra region. The annual domestic rate of consumption is estimated to be 42.3 kg/caput. This has also not changed but there has been a steady increase in amount exported.

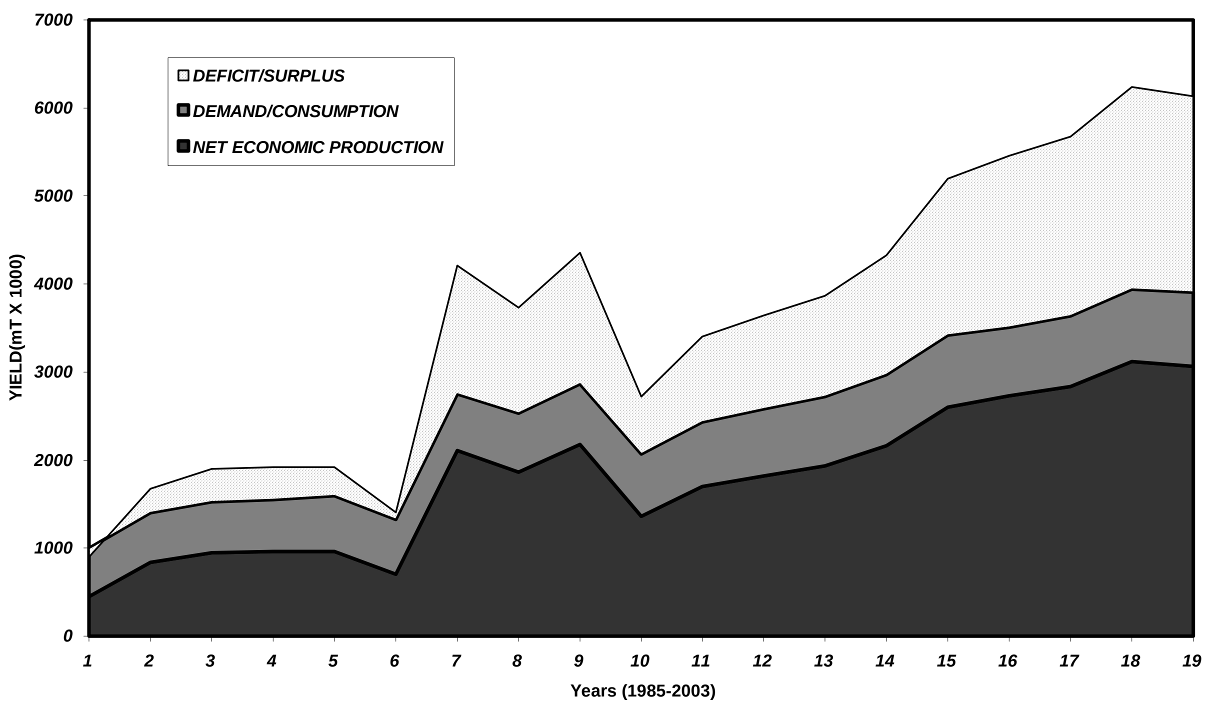
The Northern, Upper West and Western regions were selected as study sites based on their vulnerability to climate stressors, production levels and importance of the crop to these areas.

Yam production and consumption or demand trends are similar to other root crops (Fig.3.3). With the exception of 1985 where demand exceeded production, surpluses increase with increase in demand and production. Although it is an important export crop, yam prices were found to fluctuate with the time of season and the type or variety of preference.

Boekrom in the Ahanta West district of the western Region was assessed.

Six types of yams – white, water, *Asobayere*, yellow, Chinese and potato yams are grown in the community in addition to other types of food crops produced. Their main food crop is cassava. Yam within the study area when grown for cash is mostly sole cropped whilst subsistence yam cropping is intercropped. Yam within the study area is mostly cropped as a subsistence crop. Simple tools like the hoe and cutlass are use in the cultivation of the crop. Yam production is decreasing because of scarcity of good land.

FIG. 3.3 Yam production and demand patterns in Ghana



3.4 PERCEPTION OF CLIMATE STRESSORS

The participatory assessment determined how the communities perceived climate and its stressors. Total amount of rainfall and the poor deteriorating nature of the soils were their main source of worry or cause of low yields. Climate factors considered within the limits of the study includes the following;

- Rain fall within the community was unreliable, irregular and unpredictable. Duration of rain has been shortened and it is either too much (flooding) or too little (drought) as phrased by the community.
- Daily temperature was perceived as hot or high when the sun shines too much, thus scorching crops. They attributed this condition to indiscriminate deforestation.
- Poor or degraded soils as a result of intensive and bad cultivation practices, erosion and deforestation subsequently reduce yields.
- Prolonged drought increases the population of variegated grasshoppers which destroy cassava.

SECTION FOUR

4.1 ASSESSING THE VULNERABILITY OF ROOT CROPS PRODUCTION

The model DSSATV4 that simulate crop growth and yield was used to estimate changes in root crop yields for Ashanti Region which is within the semi deciduous forest zone of Ghana. The crop model CROPSIM-cassava and CROPGRO (ARGRO980) tanier was validated using data averaged from fields in the Kumasi area. These models simulate growth, development and yield for cassava and cocoyam in response to weather, soil conditions, cultivar characteristics and crop management.

4.2 CASSAVA

Cassava production in Ghana is normally grown throughout the year and more than one variety is cropped by an individual farmer because of the varying uses and maturity periods of growth. To run the model cultivar characteristics of the default was used and it was also assumed cassava was cropped as a mono cropped in Ghana. In the Ashanti region cassava is mostly grown on well drained sandy clay loam (Orthic-Ferric Acrisols) at a spacing of 100cm by 100cm. Soil conditions for Kumasi series as published in the Soil Research Institute MEMOIR number 8 was used (Adu, 1992).

Predicted yield potentials were evaluated against the averaged yield estimates observed for Kumasi. Results are as indicated on Table 4.1 and graphically presented on figure 4.1. A correlation statistics between the predicted cassava yields and the observed Kumasi averages gave a positive coefficient of correlation value of 0.21. Observed cassava yields were generally lower than the predicted average yields. Cassava yields simulated at 100% does not reflect the total harvest reported for country statistics, so the results from the model was reduced by 30% representing the small roots which are left in the field and not quantified as explained. Using 1990/1991 growing season as the base year and assuming rainfall amounts remain the same, increasing temperature in 2020, 2050 and 2080 by 0.6^0, 2^0 and 3.9^0 respectively reduced cassava yields. The rate of reduction increased with an increase in temperatures. Comparing the predicted values less 30% for waste with the predicted and observed values for the baseline year gave similar trends. Cassava yields would decrease by 13%, 23% and 58% (observed Kumasi yields) and 3%, 13.5% and 53% (predicted yields) in 2020, 2050 and 2080 respectively.

With such low cassava yields, the best bet is to use varieties which are highly productive and soil nutrient efficient to increase productivity per unit area. This could be deduce from the fact that the default used in simulating these yields were improved varieties as against the local or mixed varieties used by farmers in the Kumasi area or representative sites. In addition supplementary soil nutrients may have to be added to improve growth and development. This was because the same base soil nutrient status was used for simulating the climate change yields for the various years.

Table 4.1: Predicted and Observed Cassava Yields.

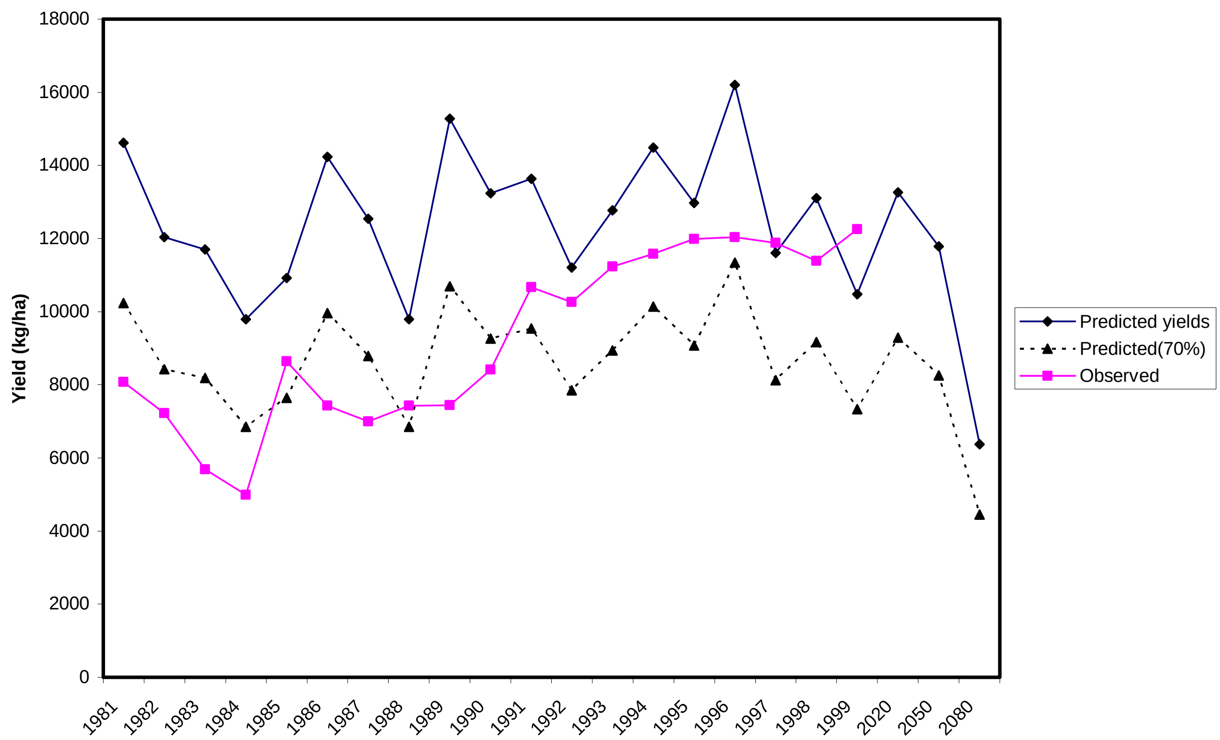
YEAR	PREDICTED YIELD KG/HA	Actual Predicted yield (less 30% waste)* kg/ha	KUMASI AVERAGE YIELD- kg/ha	GHANA AVERAGE YIELD-kg/ha
1981	14,619	10,233.3	NA***	8075.4
1982	12,032	8422.4	NA	7227.9
1983	11,695	8186.5	NA	5682.6
1984	9,793	6855.1	NA	4993.9
1985	10,922	7645.4	8161	8637.6
1986	14,228	9959.6	8000	7428.2
1987	12,545	8781.5	7420.8	6998.2
1988	9,796	6857.2	7649.6	7432.4
1989	15,282	10,697.4	8276.1	7444
1990	13,231	9261.7	8400	8417
1991	13,631	9541.7	10,658	10,663
1992	11,207	7844.9	10,257	10,259
1993	12,769	8938.3	11,227	11,231
1994	14,481	10,136.7	11,587	11,578
1995	12,967	9076.9	11,998	11,992
1996	16,195	11,336.5	12,032	12,038
1997	11,607	8124.9	10,002	11,878
1998	13,105	9173.5	10,002	11,389
1999	10,482	7337.4	8,474	12,253
2020**	13,263	9,284.1		
2050**	11,789	8252.3		
2080**	6,367	4456.9		

*- A third of the harvested roots are normally below sizes not sold or quantified when farm yields are being recorded.

** - Yields of climate scenarios developed for the various years.

*** - Statistics not available

Fig. 4.1: Cassava yields in Ghana



4.3 COCOYAM

Predicted cocoyam yields were simulated using the CROPGRO model ARGRO 980 – Tanier. This model simulates growth development and yield in response to weather, soil conditions, cultivar characteristics and crop management. To run the model the cultivar characteristics of the default *(Blanca)* was used and it was also assumed cocoyam was cropped as a mono cropped in Ghana. In the Ashanti region cocoyam is always grown on well drained sandy clay loam (Orthic-Ferric Acrisols) at a spacing of 100cm by 100cm. Default soil parameters for sandy clay loam were used to predict yields.

Productivity which refers to production per unit area was assessed and this revealed a higher productivity of cocoyam production in Kumasi as against the national averages. Cocoyam yields per unit area were lower for Ghana when compared with values obtained for Kumasi. Predicted yield potentials were evaluated against the averaged yield estimates of Kumasi and Ghana and this is presented graphically in figure 4.2. Productivity for 1980s' was higher but lower in the 1990s' for the simulated results. Estimated soil parameters used in running the model could explain the discrepancies in observed and predicted yield averages. And farmers in the Ashanti Region will only crop cocoyam on virgin soils with higher organic matter or newly opened forest with high soil nutrients hence the high average yields observed per hectare (productivity). The fact that cocoyam is normally grown as an intercrop could also account for the wide difference between yields. Plants growing as intercrop may exhibit different growth and development characteristics from crops grown as mono crop.

To validate the results obtained a correlation analysis gave a positive correlation coefficient of 0.29. Projected yields for 2020, 2050 and 2060 are also shown in Table 4.2 using 1990/1991 cropping season as the base year. Analysis of the predicted results revealed a reduction in cocoyam productivity by 11.8%, 29.6% and 68% for 2020, 2050 and 2080 respectively; with productivity in Kumasi being reduced by 3%, 22.7% and 65% for the 2020, 2050 and 2080 respectively. These reductions with a predicted rise in population will definitely affect food availability and hence food security.

Fig 4.2: Cocoyam productivity in Ghana

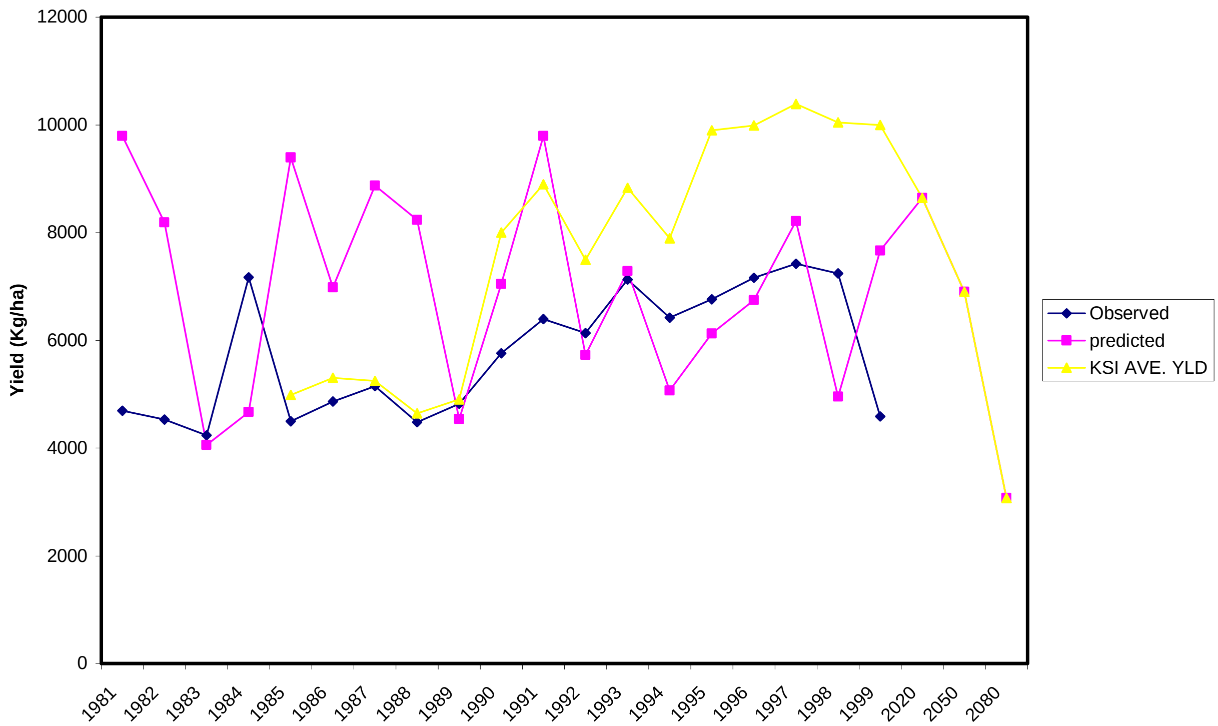


Table 4.2: Cocoyam yields as predicted and observed

YEAR	Predicted Fresh Yield - kg/ha*	Observed Kumasi average yields - kg/ha	Observed Ghana average yields - kg/ha
1981	9795.8	NA***	4693.4
1982	8191.4	NA	4528.7
1983	4056.5	NA	4237.7
1984	4664.1	NA	7168.1
1985	9394	4986	4500
1986	6982	5300.2	4865.4
1987	8873.2	5245.3	5151.7
1988	8234.1	4646.8	4477.9
1989	4535.3	4707.4	4819.3
1990	7045.5	8000	5755.7
1991	9795.8	8900	6391
1992	5726.7	7495	6137
1993	7284.9	8833	7129
1994	5064.5	7891	6419
1995	6125.7	9900	6764
1996	6745.9	9991	7262
1997	8215.2	10,387	7419
1998	4951.1	10,048	7239
1999	7665.7	7006.7	4585
2020**	8640.1		
2050**	6897.1		
2080**	3073.0		

*- Model predicted 200% root moisture
** - Yields of climate scenarios developed for the various years.
***- Statistics not available.

SECTION 5

5.1 LINKAGES WITH OTHER SECTORS OF THE ECONOMY

The economy of Ghana has been described as agrarian, employing over 70% of the population and generating about 2/3rds of the export earnings. The government of Ghana also identifies root crops as a possible vehicle for national economic growth and food security. Some government policy to alleviate rural poverty, improve household food security and the nutritional status of individuals can be achieved by improving the overall food availability and increase income earning opportunities in farming. Root crops also contribute about 40% of the country's Gross Domestic Product. Climate impact as a possibility of reducing food production and therefore making all these polices unrealistic. This section identifies and analyzes linkages that exist with some aspects of the economy and describes adaptation strategies available for mitigation.

5.2 WHOLESALE PRICES OF ROOT AND TUBER CROPS

Wholesale prices of root and tuber crops in Ghana were sourced from the Statistical section of the Ministry of Food and Agriculture and documented (Table 5.1). The economic production values which is the amount available for consumption was found to be positively correlated with the wholesale prices; giving high positive coefficient values of 0.8 for cassava, 0.87 for cocoyam and 0.83 for yam. Years that had higher production had higher wholesale prices per unit sale. Cassava, yam and cocoyam had increases in wholesale price with time. Yam had the highest unit price, followed by cocoyam and then cassava.

Prices for cocoyam and yam are more stable in Ghana than cassava, because of the highly perishable nature of cassava and the form Ghanaians prefer to purchase the commodity. Processing the root crops would give a higher purchase price for the farmer as suggested by farmers involved in the participatory assessment. Further since most of the increases in production is mostly due to increase in cropped area as against productivity, a climate change would definitely affect yield.

Table 5.1 Root and tuber crops production and wholesale prices (1985 to 2003)

YEAR	Cassava economic production X 000 MT	Cassava wholesale prices/91kg – cedis	Cocoyam economic production X 1000 MT	Cocoyam Wholesale Price/ 91kg - cedis	Yam net economic production	Yam wholesale prices per 250 kg – cedis
1985	2153	795	720	1041	448	6813
1986	2013	1409	804	2101	838	9012
1987	1908	3184	810	4396	948	10769
1988	2310	1605	892	4677	960	19387
1989	2324	2481	960	5327	960	23600
1990	1902	4433	652	7984	702	30102
1991	3991	4000	1038	7680	2106	29469
1992	3963	4048	962	9117	1865	29070
1993	4181	5421	989	12059	2176	40098
1994	4217.5	5733	918.2	16017	1360	53310
1995	4627.7	9550	1106.6	26679	1701	82219
1996	4978	10289	1242	25301	1820	97487
1997	5005	15878	1228	42305	1934	142086
1998	5020	28160	1261	60939	2162	239536
1999	5492	19235	1366	55518	2599	166434
2000	5217	33797	1298	70232	2729	215284
2001	6276	80807	1350	98332	2837	357500
2002	6810	64685	1490	128991	3120	420004
2003	7179	57532	1461	128636	3066	463571

Source: Statistic, Research and Information Directorate (MOFA, 1986 - 2003)

5.3 EXPORT OF ROOT AND TUBER CROPS IN GHANA

Export data available for 1990 – 2002 was sourced from the Ghana export Promotion Council (GEPC). These were compiled from the Exchange Control Form A2 - non traditional products received from Customs, Excise and Preventive Services (CEPS). Cassava, yam and cocoyam exported were classified under the non traditional horticultural products.

Quantities of cocoyam and yam exported were recorded as one export commodity with 2 products and these include cocoyam leaves (Table 5.2) and cassava products exported includes the following; fresh roots, dried or chipped roots, gari, flour and dough (Table 5.3). Cocoyam and yam exports contribute from about 3% to 10% of the total horticultural export commodity as shown in table 5.1. Cassava and its other products contribute from 0.1% to 1.2% of the total horticultural exports from 1990 to 2002 (Table 5.3).

The number of persons exporting yam and cocoyam products was more than cassava exporters. And the number of yam and cocoyam exporters between 1990 and 2002 increase with time (61 – 249), a correlation analysis (correlation coefficient of 0.97) indicates an increase in quantities exported increase with number of exporters. The number of cassava exporters was also found to be positively correlated with cassava quantities exported, the coefficient of correlation (0.2) however was low. This therefore means that an increase in the number of exporters does not necessary mean an increase in amount of cassava products exported or vice versa. Cassava exporters ranged from 25 to 159 persons within the limits of data available. This increase was in consistent and gives an indication of a not too organized export market or drive as compared with yams and cocoyam export market which seems to be increasing with time in terms of quantities exported and persons involved with export.

The export drive or the well organized export market for cocoyams and yams would be the reason for the relatively higher wholesale price for the commodity even with increases in production. The coefficient of correlation also revealed a closer relationship between pricing of cocoyam and yam than cassava. The participatory assessment also revealed a reduction in prices of cassava in bumper periods but the opposite is the situation for cocoyam and yams. To remain economically viable in the internationally competitive markets for yams and cocoyam, which is the driving force behind the high wholesale price; farmers have to devise management options that can produce long term sustainable profits in such a variable environment. Households without cassava farms may go hungry within the year; therefore a period of low rains or any climate change which would reduce production such that demand exceeds production will create a hunger situation.

TABLE 5.2: COCOYAM AND YAM EXPORTS IN GHANA

YEAR	QUANTITY (MT)	PERCENT CONTRIBUTION TO EXPORT	Number of exporters
1990	2121.8	3.37	61
1991	3051.2	7.45	120
1992	2728.073	9.57	143
1993	3574.06	7.79	112
1994	5322.78	7.81	188
1998	7531.55	6.16	215
1999*	9938.511	7.78	243
2000*	12648.285	9.71	278
2001*	14654.775	9.59	280
2002*	13344.433	9.73	249

* - Cocoyam leaves export data inclusive.

**SOURCE: Ghana Export Promotion Council - Comparison of export performance of non-traditional products 1990-2002

TABLE 5.3: CASSAVA EXPORT IN GHANA

Year	Quantity(MT)	Percent contribution to export	Number of exporters
1990	NA**	0.58	25
1991	2745.633	1.15	159
1992	638.452	0.51	108
1993	429.56	0.28	91
1994*	2130.225	0.01	38
1995*	3.45	0.01	48
1996*	NA	NA	NA
1997*	NA	NA	NA
1998	1278.84	0.12	87
1999	8546.19	0.92	75
2000	1779.346	0.22	99
2001	1598.325	0.22	130
2002	2437.489	0.26	118

*- Data on Gari export not available; ** - data not available

***SOURCE: Ghana Export Promotion Council - Comparison of export performance of non-traditional products 1990-2002

5.4 ADAPTATION STRATEGIES

Agriculture production has shown an ability to adapt to changing conditions like natural resource availability, technologies or economics. Most crops may adjust unnoticed especially when climate changes are gradual. Farmers on their own do have options that help them bear and share loses or modifies threats. Appropriate technologies and improved varieties also exist to prevent or help share losses that may occur when climate changes. The PRA conducted during the study identified the following as adaptation options for climate change.

5.4.1 Improved Farming technologies or practices

These are normally referred to as on farm adaptation options and they include planting more than 2 varieties with different maturity periods and / or introducing drought resistant varieties in farm fields. Farmers in the study area already crop different varieties of a commodity to ensure food maturation (food security) even in the event of an unpredicted harsh weather.

Integrated nutrient management under the various crops which is not being practiced could be introduced. Under this different soil amendments in the form of organic or in organic or including leguminous crop in the cropping system could be applied to the degraded soils. This would increase the nitrogen to take full advantage of the CO_2 effects, while some may protect the soil structure and therefore increase soil moisture availability.

Afforestation / reforestation which involve the planting of trees within the degraded forest lands will be encouraged. Farmers perceived this to be the cause of the irregular rains and the degraded soils. Some communities visited are already pursuing this option while others think it is not their responsibility. This point raises the issue of extensive education on tree planting.

Alternate cropping could be encouraged. This practice allows farmers to change cropping systems. For instance farmers in the *Akumadan* areas of Ashanti Region who use to grow cocoyam now grow vegetables which are short duration crops and cereals like maize. Members of *Boekrom* (Western Region) also grow more of cassava than cocoyam and yam because of lack of good soils.

To achieve the above mentioned strategies the following researchable topics needs to be studied;

- Drought tolerant and early maturing root crops need to be identified and made available to farmers.
- Tree planting as part of the root crops production systems – yam and cocoyam need to be introduced.
- Identification of fast growing trees that cope with root crops production

The vulnerable groups most likely to benefit from this adaptation strategies are the farmers and rural folks, fisher folks, women and the urban poor in a decreasing order of severity.
For farmers and rural folks, the adoption of these technologies will increase productivity / production should there be a change in climate. This will make them secure and guarantee income for them. The fisher folks are mainly subsistence in their activities and therefore depend on root crops as their main staple. Being assured of food at a constant price is making them food secure. Women are important actors in root crops production. Their involvement in the implementation of this option is critical and an improvement in production will definitely give them a plus. They act as middle men in the marketing of the commodities and are mostly responsible for the cultivation of cocoyam. Since they provide food for the household a reduction in the availability of root crops which is a staple in almost all diet will be disastrous. For the urban poor, since they are migrants from the rural communities, a stable production system would prevent their migration and encourage them to crop the land.

Key persons that can promote or undermine these adaptation strategies are Researchers, Extension agents, non-governmental agencies and community members.

5.4.2 Post harvest technologies

This adaptation option provides insurance against local supply changes through storage which tends to store the crop for a longer period and also guarantees a good price for the commodity.

This option requires the identification of processing techniques that will preserve root crops and provide an alternate use of the crop. Some processing techniques already exist, the need to source for them and adapt to our conditions is very important. Training on these post harvest technologies and the establishment of cottage industries for processing root crops can not be overemphasized.

To achieve the above mentioned strategies the following researchable topics needs to be studied;

- Research into potential processing techniques and adapt to local conditions.
- The need to study a community which is already into processing of the root crop – cassava (Volta Region).

The main actors to support this option are the Researchers and extension agents who will identify, modify and disseminate the technologies. The Government and the NGO (non governmental organizations) that provides support for training and logistics. The community members' preparedness to accept technology will support the implementation of this option. Non availability of logistics to fund the study and support training and dissemination would undermine the project.

Vulnerable groups likely to benefit from this option are as follows;

- Farmers and rural folks - The adoption of these technologies will create the market condition for an increase in productivity / production should the change in climate bring about a glut. This will also guarantee income and make them feel secured should there be a shortage.
- Women - Women are important actors in root crops production and processing. Their involvement in the implementation of this option is critical and an improvement in processing and production will definitely give the project the support it needs.
- Fisher folks - Root crops in its fresh and processed state are their main staple. Being assured of food is making them food secure.
- Urban poor - This will preserve excess root crops for lean periods or eventualities; resulting in food security and stable price for the urban poor who feed on root crops. This will further prevent out migration which is a major cause for increase in urban poor population. Job created for the rural poor in their environs prevents out migration.

5.4.3 Alternate livelihood

Alternate livelihood development especially those that give fast income was identified as a household or village adaptation option. Communities will be trained on occupations other than root crop production; these are bee keeping, poultry production, piggery, snail rearing, mushroom cultivation etc. This will involve the provision of start up capitals or some sort of loans for project establishment and training in the prescribed trade.

A detailed household studies to identify an alternate livelihood which is more feasible and acceptable by the populace will support the option.

Farmers and rural folks will have an added income for their household if climate change reduce or destroys farm produce. But for the fisher folk, since root crops are their staple food an alternate crop or livelihood which will prevent the production of root crops will render them food in secure. Prices may also go up and in effect reduce their purchasing power.
Women will gain extra income for their household budget. And since the urban poor are persons who migrate from the rural areas because of lack of jobs the presence of jobs will reduce their population in the urban areas. Alternate jobs will be created in the villages for them.

These programs are on going in certain localities and should therefore be given full support by the government.

5.4.4 Marketing policies

Marketing channels exist for the sale of most root crops. These are normally through middlemen or women who price the commodity anyhow resulting in unstable low prices within the harvest season especially with cassava. Policies to address such issues and create market avenues for these root crops are necessary.

Identification and implementation of policies that address marketing issues in relation to root crop production needs to be done. The following persons are involved in the implementation of this strategic project; Policy makers, Researchers, Processors and Community members

Women and the urban poor are vulnerable groups fully integrated in marketing root crops a stable price as a result of the marketing policies will mean a stable income as against a fluctuating root crop pricing. Farmers, fisher folks and rural folks are another group who will be affected by this adaptation option. This option will ensure a ready market for possible increases in root crop yield and guarantees a stable market price and income for them.

5.4.5 Irrigation under root crops production

Small scale irrigation schemes as supplementary water source for crop growth would be established in farm fields. The need to identify and design the appropriate irrigation system for root crop production is crucial. Funds for its establishment will require the presence of policies that allow the acquisition of such implements at affordable price. Actors that can support or undermine the proposed adaptation activity are the Policy makers, Researchers and Community members.

The provision of irrigation as supplementary water for root crop production will increase soil moisture and finally yield. Prices will be stable as a result of increased productivity for the fisher folk, urban poor and women who are part of root crops production and its utilization.

SECTION SIX

6.1 INTERGRATED ASSESSMENT

Root crop plants, like plants in general, are more strongly affected by the direct effects of increased atmospheric CO_2. Increased CO_2 alters the physical structures and the carbon/nitrogen balance in plants which in turn alters the plant's growth rate, yield, susceptibility to pest attack, and susceptibility to water stress. These effects interact with the effects of climate change itself in complex ways. In addition, the effects of climate change are buffered in agricultural systems as farming methods are altered to adjust to current climate conditions e.g., irrigation practices and / or crop varieties used. Attributes like low yields resulting in low household income may be possible indicators of climate change effects. This section addresses the in direct implications of climate change.

6.2 Ecological and indirect climate effects

In qualitative terms, many indirect effects of climate change on agriculture can be conjectured. Most of them are estimated to be negative and they receive most of the attention of the populace especially the communities visited during the study. These effects include:

- Predicting weather and climate has been difficult, making the day-to-day and medium-term planning of farm operations more difficult;
- Loss of biodiversity from some of the most fragile environments, such as tropical forests and mangroves as a result of the quest for fertile land to crop especially yam and cocoyam and trees to use as stakes in its production;
- Sea-level rise could submerge some valuable coastal agricultural land and therefore make land per person not sufficient;
- The incidence of diseases and pests, especially alien ones as a result of change in temperature and humidity and long droughts could increase their presence and damage to crop yield especially cassava;
- Present (agro) ecological zones could shift such that some plants, especially trees cannot follow in time, and farming systems cannot adjust themselves in time;
- High temperatures in warm areas in Ghana can cause reduced productivity as evinced by the results obtained in table 4.1 and 4.2;
- Scarce labor or high cost for root crop (yam) production as a result of ill health and out-migration.

These effects stress the need to have well defined policies that support farmers financially and technically to adopt some level of adaptation options.

6.3 Integration across sectors of the economy

The adaptation options identified were reviewed in relation to other sectors of the national economy affected by climate change. Changes in one sector as a result of climate impact were found to affect another. The water, coastal and forest resources are possible productive sectors that can affect agriculture production particularly root crop production. Socio-economically agriculture production may also be affected as a result of poor human health, nutrition and population growth or migration.

In Ghana climate change have been found to reduced ground water discharge by 5-22% by 2020 and 30-40% in 2050; this change will therefore affect the availability of water for irrigation which is one of the adaptation options identified (GINC, 2000). Sea level rise has a result of climate change may result in loss of coastal agricultural land, displaced population and raised water tables which may render the production of cassava along the coast land difficult. The forest resources will result in the unavailability of good soils for yam and cocoyam production. And the forest resources being an alternate source of income for farmers living along the fringes will definitely affect the economic livelihood of the farmers. Land use change for the production of other crops that requires the use of virgin soils will be practiced.

Declining human health as a result of increase incidence of diseases, mal nutrition and out migration may cause a reduction in the human capital of the farmers. Labor for certain activities in crop production will suffer. So an impact from any of the above sectors as a result of an adaptation strategy will definitely serve as a significant impact for the other.

6.3.1 Integration of adaptive options

Adaptive measures identified under root crop production were assessed with those under fisheries, cocoa production, land degradation, human health and policies under the Ghana poverty and reduction strategy.

The identified adaptation options for mitigating root crop production were the same especially the improved farming technologies and irrigation schemes to support root crop production. This was because cocoyam and yams are normally grown in association with cocoa and new technologies in the pipe line suggest the use of cassava as shade trees in cocoa production. These options also tend to support adaptation options identified to prevent land degradation.

Improve household income as a result of a better marketing strategy for root crop farmers, improved post harvest technologies and an alternative livelihood will support most of the adaptation options under human health. However irrigation systems if not managed sustainably may act as breeding grounds for raising vectors for diseases.

Adaptation options strongly support policies that will prevent poverty as outlined in the Ghana Poverty Reduction Strategy. And the promotion of inland fish farming under the fisheries sector would make water available for irrigating food crops if they are integrated into our farming system.

6.4 CONCLUSION

Agricultural production and marketing policies have been found to affect food availability and food security. There is a widespread tendency for us to cry for policies that effectively subsidize agricultural production, or policies that tax or discourage agricultural production in certain areas, or pursue policies that promote food self-sufficiency. Although all of these policies tend to reduce the efficiency of agricultural resource utilization in low- and high-income countries, they have not changed trends in food supply and demand.

Relatively few studies have attempted to predict likely paths for food demand and supply beyond 2020. There are reasons for optimism that growth in food supply is likely to continue apace with demand beyond 2020. For example, population growth rates are projected to decline into the 21st century (Bos *et al*., 1994; Lutz *et al*., 1996), and multiple lines of evidence suggest that agricultural productivity potential is likely to continue to increase. However, Rosegrant and Ringler (1997) projected that current and future expected yields will remain below theoretical maximums for the foreseeable future, implying opportunities for productivity growth. These conditions were similar to Ghana situation (tables 4.1; 4.2); increases in food demand are mostly due to increase in population and supplies are due to increase in acreage under production and not productivity, similar to observations by Ruttan (1996).

These concerns about future productivity growth, if correct, mean that simple extrapolation of yield for impact assessment may be overoptimistic. The implication is that confidence in predictions of food demand and supply balance and price trends beyond the early part of the 21st century will be low.

Climatic conditions often interact with socio-economic conditions to undermine food security. Climate variability tends to have the greatest impact on people who are landless, poor, or isolated. Changes in socio-economic conditions can lead to dramatic changes in food security. Disadvantageous terms of trade, poor infrastructure, and armed conflict also make it more difficult for people to cope with the effects of climatic extremes. For example, while food security would anyway have been a problem in Sudan during the severe drought of the 1980s and 1990s, economic recession and civil strife were major causes of the widespread famine. Thus for Ghana the reduction in cassava and cocoyam productivity may increase wholesale price and also encourage persons to increase acreage under production to increase production and therefore cause deforestation in the case of either yam or cocoyam production which requires new forest land.

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APPENDIX 1:

CHECK LIST OF INFORMATION TO BE COLLECTED IN EACH REGION

1. Identify a district or 2 within each region for household survey /RRA. This was based on production levels and / or vulnerable to climate stress factors.
2. Information on household structure – size, composition, income & decision making.
3. Farming systems available – rainfall pattern & distribution, major crops and acreage, gender specific crops and planting date of major crops.
4. Production (Region and District level).
    - Alternate crops available
    - Varieties (maturity time and preference?)
    - Problems (yield & area under cultivation whether increasing or decreasing)?
    - Land preparation (mechanical or manual)
    - Planting (spacing, time of planting, gender (who does what?)
    - Weeding (chemical or manual)
    - Fertilizer application.
    - Pest and diseases (relate to climate change)
    - Harvesting and storage (who, how & when; yield loses; storage method & duration)
    - Planting material (source, storage, treatment & selection criteria)

5. Consumption
    - role of the crop in overall food consumption
    - percent consumed verses sold / exported
    - pricing (fluctuates or stable)

6. Resource allocation
    - Land (availability, tenancy, control of land – gender?)
    - Labor (availability, family or hired, mechanized or manual)
    - Cash (availability, main source of income, time of scarcity, gender controlled?)
7. Policy
    - Do they exist at all?

8. What is their perception of climate variability?
9. What aspects of temperature, rainfall, storm events / drought are important or relevant to their crop production?
10. Specific examples of these climate stress factors should be stated.
11. How vulnerable are the farming systems to uncertainty and variability in climate?
12. What adaptation strategies are suitable and/or feasible to consider as potential responses to climate variability?
13. What criteria would you use to establish priorities among these adaptation strategies? The adaptation strategies are broadly classified under **farming practices, post harvest technologies, health and nutrition, livelihood developments.**
14. What developmental approaches will they adopt to achieve identified adaptation strategies? ***ie*. Program / project designs.**