

**ENVIRONMENTAL CHANGE AND FARMER RESPONSE  
IN THE  
FOREST-SAVANNA TRANSITIONAL ZONE OF GHANA**

**by**

**Matthew Gyamfi Kwasi**

**A thesis submitted in conformity with the requirements  
for the degree of Doctor of Philosophy  
Graduate Department of Geography  
University of Toronto**

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# **ABSTRACT OF THESIS**

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IN  
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**BY**

**MATTHEW GYAMFI KWASI  
DOCTOR OF PHILOSOPHY, 1998  
GRADUATE DEPARTMENT OF GEOGRAPHY  
UNIVERSITY OF TORONTO**

## **ABSTRACT**

Agricultural planners are divided over whether traditional farming methods can sustain or increase food production in regions like Ghana which are doubly disadvantaged as poor, and situated in the lower latitudes where agricultural impacts of global environmental change are projected to be felt most. Using the FSTZ as a case study, this research explores the potential of the traditional farming methods to increase production vis à vis the trends of the main environmental variables – rainfall, temperature, soil, and vegetation cover—that influence agricultural productivity in the FSTZ. Since 1930 the average rainfall for the region has declined by 217 mm while the average temperature has increased by 1.1°C since 1953. Soil quality has not degraded significantly from their original conditions though with continuous cropping displacing the fallow system of farming, there is a felt need

for fertilizers. Shortening fallow periods are causing the displacement of the forest vegetation with a drought resistant, fire-climax vegetation of an impoverished nature. The capacity of the farming system to alleviate the impact of these trends is discussed within the context of farmer-environment interaction. With increasing pressure on agricultural land due to rapid population growth rate, farmers have intensified land use by changing land use patterns, and adopting new farm management strategies. Farmers have also embarked on off-farm activities, and education of their children for off off-farm jobs to minimize the pressure on agricultural land. Contrary to expectation, food production in the FSTZ is increasing in the face of a rapidly growing population. Sixty-five percent of the farmers interviewed think they are better-off as a result of these responses. Though the adaptations strategies are saddled with formidable ecological and socio-economic problems, it is argued that food production in the region could increase further if agricultural planners build on, and complement the local technologies which have been selected by farmers' with appropriate modern technologies. Further, because socio-economic exigencies also influence farmer-environment interaction, farmers' responses to the environmental challenges must be expanded beyond farm level strategies and be placed within the broad socio-economic context which mediates agricultural adaptation to changes in the environment.

## **Acknowledgments**

Many people and agencies have contributed in diverse ways towards the writing of this thesis. My primary debt of gratitude goes to Professor Rodney White, my mentor and supervisor. He has always been there to give the advice and encouragement to see me through a project that did not seem to have an end. I am indebted to him for his informed advice and effective criticisms often delivered in a most pleasant manner. Thank you Rodney. A word of thanks to the members of my committee – Professors Michael Bunce, Reiner Jaakson Danny Harvey and Alex Clapp. Apart from general meetings, each of them offered expert advice on some sections of the thesis. They were ready to listen to my problems and help me out of them even when I did not have appointments. Thank you for your constructively critical comments and suggestions that helped shaped the ideas in this thesis. Your readiness to help me has been a great source of strength and inspiration for me.

In the university of Ghana I am most grateful to Professor Nabila, the Head of Department of Geography and Resource Development, for the office space offered me during the four months I spent doing research in Ghana, and for opening up the academic treasures of the Department for my use. To Professor Edwin Gyasi of the United Nations University in the University of Ghana, I say thank you for your time and for sharing with me some of your invaluable ideas on environmental change in the southern section of the Forest Savannah Transitional Zone and for the useful literature on the Transitional Zone in general. I am equally grateful to Professor Ofori Sarpong, of the University of Ghana for the information on the climatic trends in Ghana. Most of the maps in the thesis were drawn in the University of Ghana by Mr. S. B. Duodu.

I would like to thank Larry Asoma and the Staff of the Subinso Agriculture Research Institute – Seth Kobah, Francis Asare, J. K. Yeboah and Patience Atakora Agyeiwaa – for their hospitality and assistance in the fields during the two weeks research in the institute. My sincere gratitude goes to Mr. E. N. Dennis and his staff at the Soil Research Institute in Kumasi for the guidance on soil sampling and for conducting the laboratory test on the soil samples. I am grateful to Mr. A. F. Batuwuo and Mr. Ben T. Manor, the Marketing Research Manager of Produce Buying Company in Accra, for the data on trends of cocoa production and for other relevant information on the cocoa industry in Ghana. Mr. K. E. Ussher, Deputy Meteorological Officer, was most helpful in the retrieval and compilation of the relevant climatic data from the archives.

Mr. Agyei Boadi, the Chairman of the Wamanafo Town Development Council, and Mr. Gyabaa, the Secretary to the council, provided most of the information about Wamanafo – the village where this study was carried out. Thank you for the many hours you spent answering my questions. To the many farmers in Wamanafo and Wenchi who patiently answered my many questions and introduced me to the new methods of farming, I say “Thank You”. I hope this research will help to open up more opportunities to increase production. Ms. Miriam Kelly helped valiantly with proof-reading this thesis.

During the Ph.D. Program I received financial assistance from many individuals and organizations. The field work for this research was made possible by the University of Toronto Alumni Travel Grant Award, received through the School of Graduate Studies, and the McMaster Grant awarded by the Department of Geography in the same University. I am grateful to the School of Graduate Studies for the awards of the University of Toronto Open Doctoral Fellowship and the International Student Differential Fee Waiver Scholarships which significantly reduced my financial burden. I am also grateful to Bishop James Owusu

and Rev. Edward Jackman, and Ms. Helen Roman Barber for their financial support throughout these years.

I am most grateful to the many great people who have contributed in diverse ways towards my academic career over the years. Special thanks go to my friends Rev. Wilfred Firth, John Brennan, Seth Osei Agyemang and Philip Sae who have been a great source of encouragement to me throughout my academic career. Many people have helped me directly and indirectly to shape the ideas in this thesis, however, I remain solely responsible for the contents.

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## Acronyms

ADB	Cooperatives and the Agricultural Development Bank
AGDP	Agricultural Gross Domestic Product
ASIP	Agricultural Sector Investment Project
COCOBOD	Cocoa Marketing Board
CEC	Cation Exchange Capacity
CICS	Cooperative Inventory Credit Scheme
C:N	Carbon-Nitrogen Ratio
cT	Tropical Continental Air Mass
CRI	Crops Research Institute
ERP	Economic Recovery Program
FAO	Food and Agriculture Organization

<b>FSTZ</b>	<b>Forest Savannah Transitional Zone</b>
<b>GCMB</b>	<b>Ghana Cocoa Marketing Board</b>
<b>GFDC</b>	<b>Ghana Food Distribution Corporation</b>
<b>GCM</b>	<b>General Circulation Models</b>
<b>GDP</b>	<b>Gross Domestic Product</b>
<b>GFDC</b>	<b>Ghana Food Distribution Corporation</b>
<b>GLDB</b>	<b>Grains and Legumes Development Board</b>
<b>GNP</b>	<b>Gross National Product</b>
<b>IDS</b>	<b>Institute of Development Studies</b>
<b>IFAD</b>	<b>International Food and Agricultural Development</b>
<b>IITA</b>	<b>International Institute of Tropical Agriculture</b>
<b>ISSER</b>	<b>Institute of Statistical, Social and Economic Research</b>
<b>IPCC</b>	<b>Intergovernmental Panel on Climate Change</b>
<b>IMF</b>	<b>International Monetary Fund</b>
<b>ITK</b>	<b>Indigenous Traditional Knowledge</b>
<b>IITA</b>	<b>International Institute of Tropical Agriculture</b>
<b>JSS</b>	<b>Junior Secondary School</b>
<b>MI</b>	<b>Moisture Index</b>
<b>mT</b>	<b>Tropical Maritime Air Mass</b>
<b>NLC</b>	<b>National Liberation Council</b>
<b>OFY</b>	<b>Operation Feed Yourself</b>
<b>OM</b>	<b>Organic Matter</b>
<b>P</b>	<b>Precipitation</b>
<b>pH</b>	<b>Potential Hydrogen</b>
<b>PCI</b>	<b>Precipitation Concentration Index</b>

<b>PET</b>	<b>Potential Evapotranspiration</b>
<b>PNDC</b>	<b>Provisional National Defense Council</b>
<b>PPP</b>	<b>Progressive People Party</b>
<b>RPCI</b>	<b>Real Per Capita Income</b>
<b>RRA</b>	<b>Rapid Rural Appraisal</b>
<b>SAP</b>	<b>Structural Adjustment Program</b>
<b>SRI</b>	<b>Soil Research Institute</b>
<b>SMC</b>	<b>Supreme Military Council</b>
<b>SSS</b>	<b>Senior Secondary School</b>
<b>TDC</b>	<b>Town Development Committee</b>
<b>TEB</b>	<b>Total Exchangeable Bases</b>
<b>UCP</b>	<b>Universal Crop Protection</b>
<b>UN</b>	<b>United Nations</b>
<b>UNICEF</b>	<b>United Nations International Children's Emergency Fund</b>
<b>WMO</b>	<b>World Meteorological Organization</b>
<b>WTP</b>	<b>Willingness To Pay</b>

## **1.0 BACKGROUND TO RESEARCH: GLOBAL AND NATIONAL CONTEXT OF RESEARCH**

**"Human beings adapt to changes in their environment to minimize or maximize effects of the changes" (Markyanda 1992:142)**

### **1.1 PROBLEM STATEMENT, RESEARCH QUESTION AND OBJECTIVES**

Can Ghana rely on its traditional farming systems to increase food production in the face of current and projected trends in the agro-ecological environment? Most of the past and present agricultural policies in Ghana have been shaped by the view that the traditional methods of farming are incapable of producing enough to feed the people. Hence, policy makers in Ghana and donor agencies from developed countries continue to invest in imported large-scale capital-intensive methods of food production for the country. Recently it has been argued that since the current and projected agricultural impact of climate change will be felt most in poor, low latitude countries such as Ghana (Bazzaz and Fajer 1992; Downing 1992), these regions will need extensive irrigation systems and liberal application of chemical fertilizers to avoid total crop failure in the future (Parry and Rosenzweig 1994; Rosenzweig and Iglesias 1994). However there is an emerging school of thought which argues that traditional farming systems in these regions are the most suited for the special socio-economic and agro-ecological environment in which they operate (Roach 1994; White 1993:106; Adams 1992; Tsibaka 1989; de Haen and Runge 1989). While imported farming technologies offer some security against the whims of climate and environmental change, the majority of Ghanaian farmers do not have the financial resources to acquire these technologies (section 2.22). The imported package, which uses machinery such as tractor ploughs, is not sensitive to the delicate agro-ecosystem in the country (Dickson and Benneh 1988:90). Moreover, many of the large-

scale capital-intensive methods of farming suggested as feasible mechanisms for coping with current and projected impact of environmental change on food production are the same strategies already pursued by successive governments in Ghana without success (Agbodeka 1992; Ewusi 1985; Dickson and Benneh 1980:88; Miracle and Seidman 1968; section 1.44).

The history of food production in Ghana suggests that when smallholder farmers are given the right motivation, they are able to use traditional farming methods to increase food production. On the other hand, food production declines when large-scale mechanized farming is favored over the smallholder farmers and their methods (section 1.44). For the few times that smallholder farmers and their methods of farming were given the opportunity, the farmers demonstrated that, using local technology, they can be extremely productive in the local agro-ecosystem without degrading it. While the traditional farming methods have often been relegated to the background, it produces 90% of all staple food in the country (Sarris and Shams 1991; Dickson and Benneh 1988). Some experts have therefore suggested that traditional farming methods are capable not only of increasing food production but are also adaptable in ways that permit them to moderate the shocks of the changing biophysical environment (Barraclough 1994; Carr 1989; Lallement 1986). Thus, it was expected that with the current adverse climatic trends and land degradation, agricultural output would decline in Ghana (Chapter 4; Dadson 1983:1596). On the contrary, using predominantly traditional methods, Ghanaian farmers appear to have increased agricultural production (Dei 1984; Amanor 1994; section 1.42). Increased production in the face of recent adverse trends in the agro-ecological environment suggests that there are indigenous strategies in Ghana that can be used and adapted to mitigate the impact of climate change and land degradation on crop-yield. Hence the interest in traditional farming methods in this thesis. The main objective of the research is;

1. to identify the strategies that traditional farmers in Ghana are using in response to trends in the main biophysical factors – rainfall, temperature, soil fertility and vegetation cover – that determine agricultural productivity in Ghana and;
2. to evaluate whether these farming methods can alleviate the effects of current and projected negative trends in these variables so as to increase food production.

Given the fact that large-scale capital-intensive methods of food production have not been very successful in Ghana, and that traditional farming methods have apparently been successful in increasing food production, the critical questions which guide the discussions in this research are;

- what adaptations have farmers in Ghana made, or are making, in response to trends in the agro-ecological environment – trends in precipitation, temperature, length of fallow periods, vegetation cover, and soil fertility?
- how successful are these adaptations in the alleviation of the impact of trends in the variables above?

To answer these questions the thesis addresses a series of linked objectives which together establish the structure of the research. The specific objectives are;

- to identify rainfall and temperature trends;
- to examine the levels of degradation in soil and vegetation;
- to identify farmers' adaptation strategies to trends in rainfall, temperature, soil fertility, and vegetation cover;
- to evaluate the successes of, and constraints to, the adaptation strategies;
- to establish a typology of possible agricultural adaptation strategies.

The central argument of the thesis is that, given the climatic, environmental and socio-economic context of food production, the one option open to the Ghanaian farmer is to adopt low-risk, adaptable agricultural practices which are modeled after the smallholder traditional farming methods. Since the indigenous farming methods appear to be better suited to the delicate local agro-ecological environment than the imported production systems, the traditional farming methods constitute a better package for increasing food production. The best hope of an effective response to the shocks of current and projected climate and other biophysical environmental trends that affect food production in Ghana, therefore, lies in building on and complementing the farming skills of the traditional smallholder farmers with appropriate and affordable modern methods.

Since the differences in the ecological regions in the country require different responses from farmers in the different regions, targeting the whole country to explore the objectives of this thesis would have been unrealistic (section 1.5). The Forest Savannah Traditional Zone (FSTZ) was, therefore, selected as the target area for this research (Figure 1.8). It was selected as the focused region because it is the main bread-basket of the country. Accordingly, conditions of food production in the region are a true reflection of the food situation in the country. Also, its unique characteristic as a transitional zone between the forest and savanna regions of the country makes it possible for the region to support a wide range of forest and savanna crops as well as different farming systems. These features makes the FSTZ an important area for agricultural experimentation and therefore an ideal region for this research (section 1.514).

In view of the changes in Ghana's agro-ecological environment, the research discusses the agricultural options that are available to policy makers in Ghana. The research is conducted in the belief that it will provide new information that can guide policy makers in their search for solutions to the current and projected environmental problems

facing food production in the country. A further purpose of the research is to inform policy makers of the problems facing the traditional food farming system, and to highlight the potential of the indigenous farming system to increase food production in the face of current and projected trends in the agro-ecological environment. Since the Office of Development and Peace of the Catholic Church has programs that assist smallholder farmers in the FSTZ, the office will also find the research very useful. The new information will help the office to develop programs that assist farmers to alleviate the effects of the agro-environmental changes on food production in the region.

## 1.2 DEFINITIONS AND CLARIFICATIONS

The thesis is not based on any specific predicted climate or environmental change scenario. Rather, its premise is that variability is a fact of the Ghanaian agro-ecological environment, and that while changes in the climate and agro-ecosystem are occurring constantly, the smallholder farmer is also evolving strategies to lessen the effects of the changes.

The terms, *environmental change*, *changes in the biophysical environment* and *changes in the agro-ecological environment* are used interchangeably and in a restrictive sense to refer to the changing conditions—positive or negative—of the agro-ecological variables—vegetation cover, soil quality, rainfall and temperature trends, and other resources of the agro-ecological environment of the study area. The terms *adaptation*, *response*, and *strategies* are used synonymously to refer to the methods farmers are using at the farm level to lessen the impact of environmental changes on food production.

The term *Modern methods of farming* is used in contrast to *traditional methods of farming*. Farmers who have embraced the modern methods of farming are large-scale farmers who employ capital-intensive equipment and techniques such as tractors,

harvesters, modern systems of irrigation, chemical fertilizers, monocropping, herbicides, and pesticides. They are commercial rather than subsistence farmers. Because the former can afford the capital-intensive machinery, their farm sizes, which range from twenty to eighty hectares, are larger than the farms of the small-scale farmers, which have an average size of one to four hectares (Dickson and Benneh 1984:88). *Traditional methods of farming* are labor-intensive, depend on rainfall rather than irrigation, and depend on bush fallow for soil regeneration. Farmers who use the traditional methods are smallholder farmers who use a minimum of modern farming technologies because they do not have the financial resources for the modern technologies, or because the farmers have reservations about the use of some of the modern technologies. Smallholder farmers produce mainly for subsistence and sell any surplus to provide for other needs. While the two farming systems are quite different in their operations they are not mutually exclusive. The use of appropriate modern methods that complement the traditional methods is necessary for increased food production.

The term *farmers' performance* refers to how farmers perceive their farming activities, that is, whether their production and therefore their financial benefits from farming are better or worse now than before.

It is acknowledged that other variables, notably local and international markets, capital availability, and government policies together with the main biophysical variables considered in the study, all influence agricultural performance and adaptation. The emphasis in this research, however, is not so much on how farmers are responding to the socio-economic variables, as to how they are responding to changes in the biophysical environment, though the influence of the former on the latter is given due attention in this research. Similarly, many biophysical factors influence agricultural production in the study area but only the four main variables—rainfall, temperature, soil and vegetation— that

directly affect the production of food crops in the study area are considered in this research.

On a more personal note, it is noteworthy that my many years of growing up and assisting my parents on the farm in the study area have been an asset in this research. I am familiar with the delicate ecosystem, the farming systems, and also conversant with the changes that have taken place and are taking place in the region. I speak *Akan*, the most commonly spoken dialect in the study area (section 1.431). Knowledge of the local dialect was an invaluable asset in the research, especially since it enabled me to communicate directly with the farmers during interviews and field seminars instead of through interpreters. Throughout this research I relied on this experience. While these have some advantages, I was always aware that this background could color my analysis and presentation of some of the issues. Conscious effort has been made throughout this research to minimize any biases resulting from my background as a farmer, and my professional interests as a Development Officer in the study area, to render an objective analysis of all issues.

### 1.3 SOME RESEARCH PROBLEMS

#### 1.31 Non-Existence of Proposed Categories for Interview

In the thesis, I assumed that there were four groups of farmers using four different adaptation strategies:

- farmers who had changed from tree crops since 1983 and were using modern methods to increase production,
- farmers who had not changed from tree crops since 1983, and were using some modern methods to increase production,

- farmers who had changed their crops but were not using any modern methods of production.
- farmers who had neither changed from tree crops, nor used any modern methods.

However, a pre-testing of the draft questionnaire in the study area revealed that while most farmers had changed their main crop from tree crops (cocoa/coffee) to food crops, the use of modern methods on a significant scale was practically non-existent. Thus, only two groups of farmers were identified in the field-- farmers who cultivated food crops and farmers who cultivated tree crops as their major crops. The preliminary interview showed that the proportion of those who still cultivated tree crops as their main crop was insignificant (section 5.1). All farmers were therefore considered as a homogeneous group that was engaged in food production. The change in the categories of farmers to be interviewed, from four to one, significantly affected the methodology that was originally proposed to test the success or otherwise of the different adaptation strategies. For example, since the four groups were non-existent, it was impossible to compare their success rates to determine which ones were doing better, as originally proposed. Instead, the interviewees were asked to compare their agriculture performance before 1983 with their agricultural performance since 1983, as a surrogate measure of the success or otherwise of the adaptation strategies they have made since 1983.

### 1.32 Soil Fertility Tests and Vegetation Cover

During the preliminary interviews, it became apparent that farmers were adapting not only to climate change impact but also to shortening fallow periods, and to changes in soil fertility. While they attributed the decline in soil quality to the changes in vegetation mix and

shortening fallow periods, they alleged that some of the new weeds, such as the *Chromolaena odorata* weed, have some fertilizing effect. Soil fertility tests were conducted to assess the condition of the soil as well as the alleged fertilizing properties of the *C. odorata* weed – issues that were not part of the thesis proposal.

### 1.33 Data Collection – Problems of Quality and Quantity

Because of the communal system of land tenure and the bush fallow system of farming, every farmer had more than two fields which were isolated pieces of land at different locations rather than being one continuous piece of land (section 1.433; Chapter Three). It was therefore difficult to estimate land and farm sizes. Since farmers had no standardized way of quantifying some food crops, such as cassava, plantain and cocoyam, it was impossible to quantify the crop production of individual farmers. Most of the farmers were illiterates and did not keep any records of their farm produce. The farmers' way of quantifying their produce or their farm sizes was to say that their produce or land had *increased or decreased* compared to a particular year. National production trends were, therefore, used as surrogate measures of production trends in the study area, on the assumption that since the FSTZ is the main producer of staples in Ghana (Amanor 1995), the national figures on the major staples are true reflections of production trends in the FSTZ. Since the farmers kept no records, the survey questionnaire was designed to elicit qualitative rather than quantitative data. The qualitative nature of the responses allowed for nominal measurements in the analysis of most of the responses from the questionnaire (section 1.641).

The traditional association of certain crops with the sexes presented formidable problems with respect to farm ownership (section 1.434). In the study area, a husband and wife may own the same farm, but they may not necessarily jointly own all the crops. On

some farms the husband owned all the maize exclusively while the wife owned the plantain, cassava, cocoyam and other food crops. On such farms, husband and wife pool resources to prepare the land for sowing and to clear the weeds around the crops. The men put more emphasis on strategies that enhance maize production, while the women use strategies that enhance their own crops on the farm. In such situations, I assumed that both parties owned different and separate farms since they owned different crops on the same farm.

Public officials were reluctant to give any information, or to give access to government records. Due to the political instability in Ghana in period 1976-1984, record keeping almost collapsed in the country. Therefore data for these periods were particularly difficult to come by. The determination of rainfall and temperature trends was hampered by inadequate spatial coverage and short record lengths. For instance, available rainfall data in the study area date back to 1931 while records on temperature date back only to the 1950s.

Some relevant data that could have been used to back up observations in the field were not available. For example, there were no data on the annual river flow rates and the flow rates of the bore-holes and springs. For information on these, I relied on members of the Town Development Committee (TDC) and on relatively older women who had used the wells and springs for a longer time. Their observations were used as indirect measurement of some of the parameters for which there were no records.

The rest of this chapter puts the research into perspective by discussing the global and regional context of farmers' adaptations in the FSTZ of Ghana. The chapter also surveys the socio-economic and environmental background to food production in Ghana. Next, the socio-economic and agro-ecological characteristics of the study area are

discussed, followed by the methodology for the research. The chapter concludes with a note on the organization of the rest of the thesis.

## 1.4 GLOBAL AND NATIONAL CONTEXT OF RESEARCH OF

### 1.41 Global Environmental Change

In recent years there has been a growing interest in human responses to environmental change, particularly in the area of agricultural adaptation. This interest is partly in response to a growing concern over the increasing temperatures due to atmospheric concentrations of carbon dioxide and other radiatively active trace gases. Global surface temperatures have increased by 0.3 to 0.6° C since the mid-19th century and by 0.2 to 0.3° C in the last 40 years (Houghton et al. 1996: 137). While there has been a 1% global increase in precipitation during the 20th century (most of it in the extra-tropical areas), yearly rainfall is declining in the tropics and sub-tropics of Africa (Houghton et al. 1996:137). The combined effects of increased temperatures and decreasing rainfall are projected to be particularly severe in poor countries that cannot afford the technologies to mitigate the agricultural impact of the climatic changes (Tegart et al. 1990; Parry 1990; Taylor et al. 1990). For countries, such as Ghana, that depend heavily on agriculture there will be added adverse effects on the social-economic systems (Chiotti and Johnston 1995).

In tropical Africa, the greater frequency and severity of droughts associated with prevailing climatic trends is expected to result in increasing aridity in the savannas, deforestation in the humid and sub-humid areas, and a decline in agricultural systems (Sivakumar 1993; Downing 1992; Ominde and Juma 1991). It is estimated that the 2-4° C warming and a 20% decrease in precipitation predicted for West Africa could cause a 10 to 20% decline in crop-yield in the sub-region by the year 2030 (Downing 1992). These harsh conditions are projected to prevail in the West African sub-region against the background

of a population growing at an average annual rate of 3.2% (UN 1993b). The region is also experiencing increasing soil degradation which has even greater adverse effects on the farming systems than climate change (Brinkman and Sombroek 1995).

#### 1.42 Environmental Change Impact in Ghana

The changes that are taking place in the agro-ecological environment in Ghana are an extension of the global environmental problems. The adverse effects of human activities such as farming, logging, mining and manufacturing are visible in the vegetation and the soil. The annual cost imposed on the environment as a result of these activities is estimated at US \$ 128.3 million<sup>1</sup> or 4% of GDP (ISSER 1992:143). Of this amount, the loss due to agricultural activity is US \$ 88.5 million (Figure 1.1). This loss to agriculture is a function of three environmental factors (ISSER 1992:143):

- soil degradation in the form of accelerated wind and water erosion,
- soil compaction, loss of soil fertility and shortening fallow periods;
- devegetation leading to the emergence of savanna vegetation in the forest regions and; the emergence of colonies of low grasses and thickets in the savanna areas;

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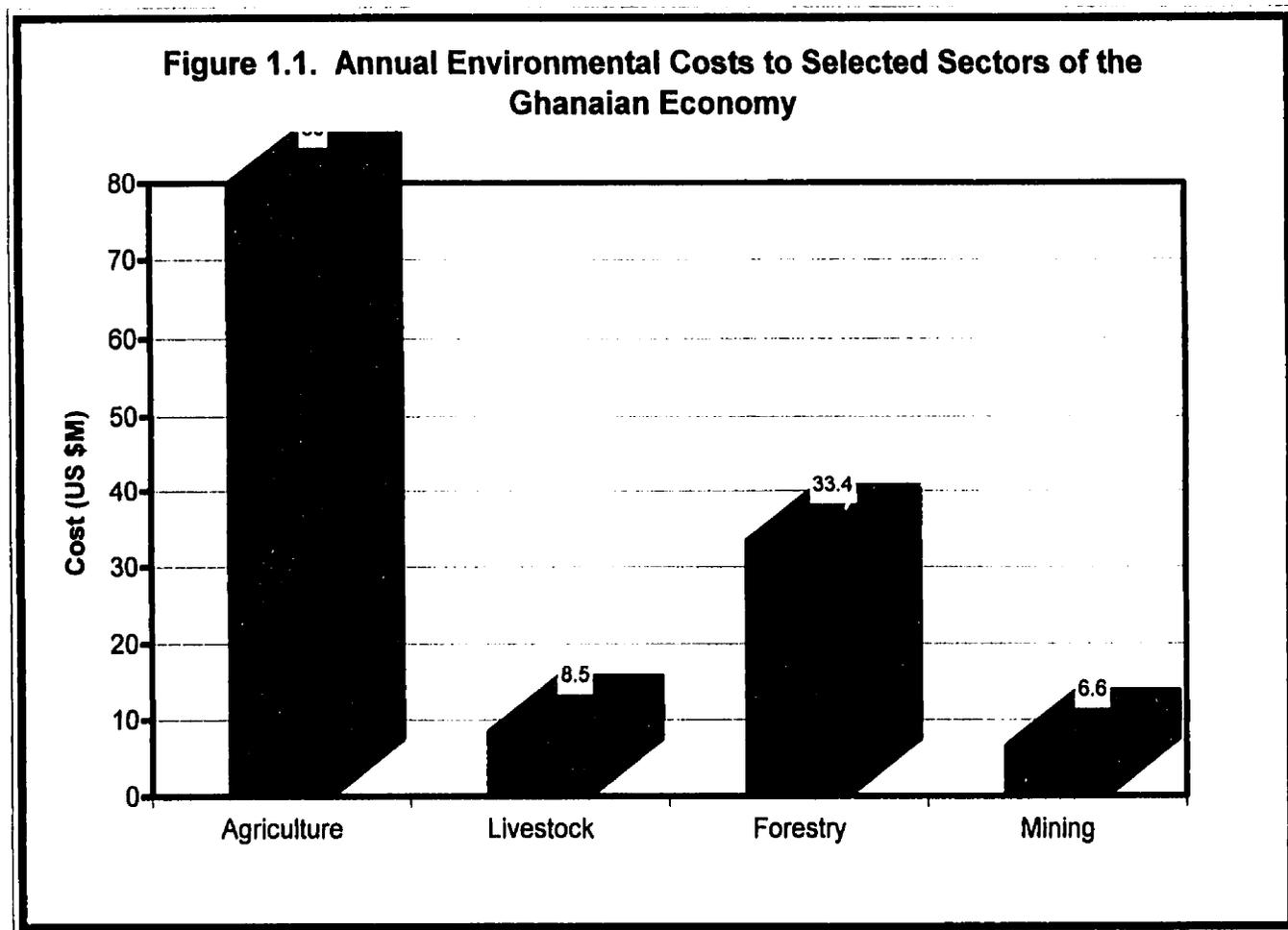
<sup>1</sup> The *willingness to pay* (WTP) approach to environmental costing was used to derive this figure. WTP is a method used in environmental accounting to give monetary value to natural resources. The method involves computing how much an individual or a group of people is willing to pay to restore a natural resource or to prevent a negative impact on the biophysical environment (Turner et al. 1993:94-96; 124-126). To estimate the monetary value of the damage to the Ghanaian environment, due to human activities, Ghanaians were asked how much money they were willing to pay to prevent the negative impact of farming, logging, mining and manufacturing (ISSER 1992:143).

- climate change<sup>2</sup> in the form of declining rainfall and rising temperatures.

The possible dangers of the gradual but persistent erosion of the Ghanaian agro-ecosystem's potential were manifested forcefully in the environmental disasters of 1980-1983, which culminated in the catastrophic droughts and the subsequent famine of 1983. In that period, droughts and bushfires ruined the dominant tree crops such as cocoa and coffee, exposed soil to erosion and opened up the vegetation to many new and exotic weeds. The food self-sufficiency ratio fell from the 83%, attained in the 1960s, to only 62% in 1982 (Nikos 1995). Per capita production of basic staples such as cocoyam, plantain and cassava dropped, respectively, to 26%, 45% and 52% of their 1970 levels (Sham and Sarris 1991, Ewusi 1989). While the annual rate of food production has averaged 1% since 1983, per capita food production is declining due to a 3% annual population growth rate (World Bank 1992; Figures 1.2; 1.3). Though food imports have increased in recent times to make up for the difference in food demand (Figure 1.4), 47% of the population still suffers from insufficient food (Downing 1992:45). The results of a further erosion of the agro-ecosystem, combined with the effects of predicted climate change, could be disastrous for the rapidly growing population. Some experts have, therefore, suggested a more detailed adaptation study on how vulnerable countries such as Ghana can respond to the projected decline in crop yields due to environmental

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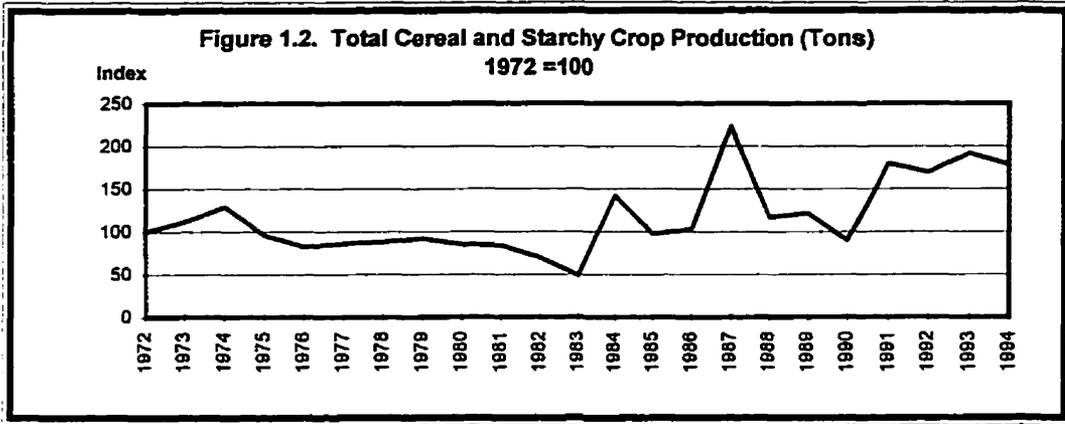
<sup>2</sup> The environmental cost due to declining rainfall and increasing temperatures was not included in the WTP estimates.



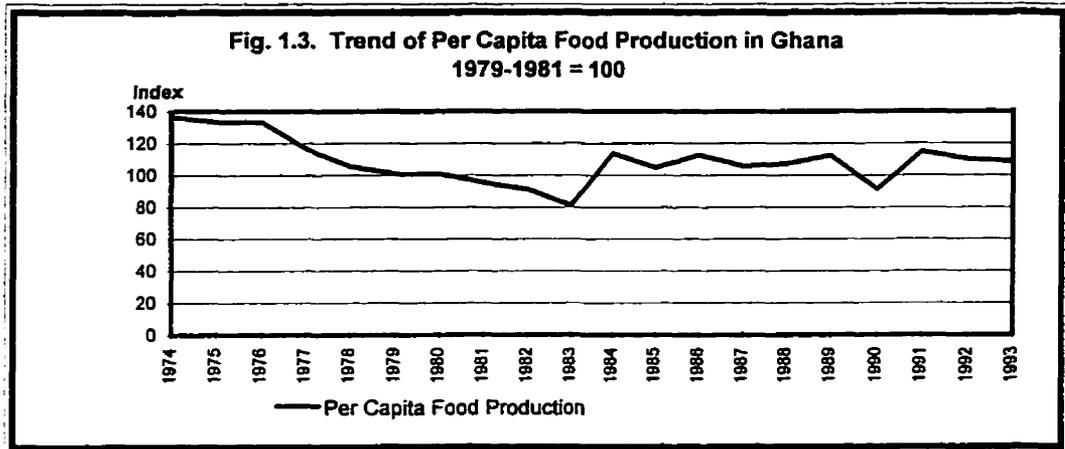
Notes:

1. The costs were estimated by computing how much Ghanaians are willing to pay (WTP) to prevent the negative impacts that these sectors impose on the environment

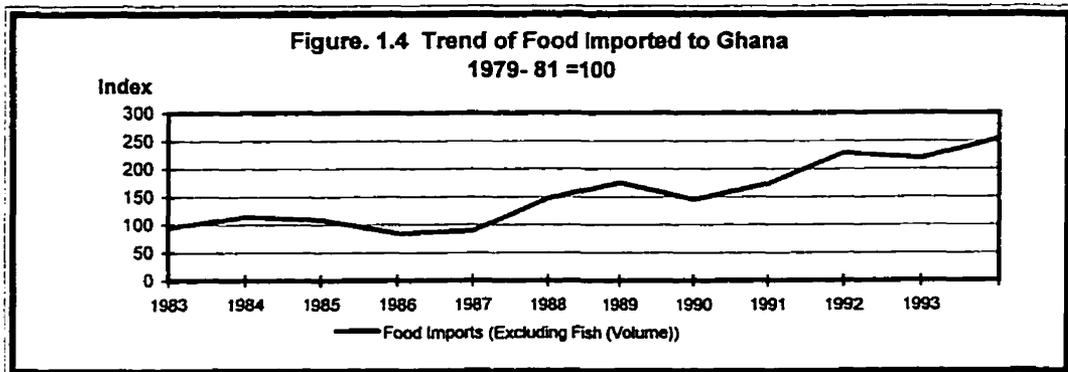
Source: Based on ISSER 1992:143



Source: Based on data in ISSER 1992; 1993;1994



Source: Based on data in FAO 1995:8(1/2); FAO 1987:10(4):13



Source: Based on data from FAO 1994:10(4):113

degradation (Rosenzweig and Iglesias 1994:13; Rosenzweig et al. 1993; Parry 1990). This research is in response to this need. However, to develop strategies which alleviate the effects of the biophysical environment on food production, it is important to identify, in addition to the bio-physical variables, the socio-economic factors affecting food crop farming in Ghana.

#### 1.43 Socio-Economic Context of Food Production

##### 1.431 Population

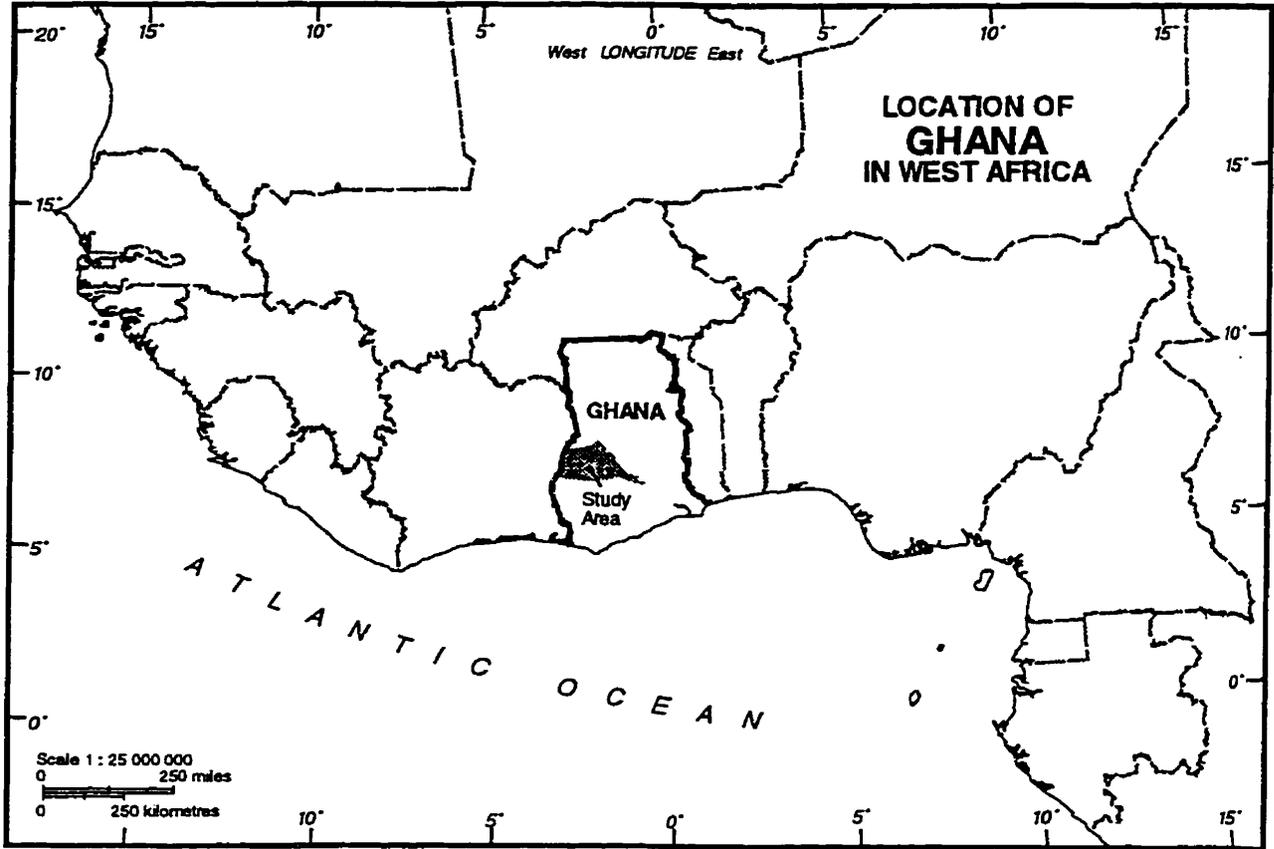
Ghana's total area of 238,538 sq. km is approximately demarcated by latitude 5° and 11° N, and longitude 3° E and 1° W (Figure 1.5). It gained independence in 1957 from the British, who had colonized it since 1872. Since then Ghana has been divided into 10 regions for administrative purposes. Ghanaians are not a uniform mass of people. They fall into different tribal or ethnic groups<sup>3</sup> with different languages, traditions, beliefs and customs. The literacy level in the country is 55% while functional literacy is estimated to be 35-40% (ISSER 1993:13). The index of human development is below 0.50 (UNDP 1991).

In spite of the fact that Ghana has had a population policy since the sixties, its population increased from 6.7 million to 8.5 million between 1960 and 1970. Between 1970 and 1984, the population increased by over 40% to 12.2 million, giving a growth rate of 2.6% per annum compared to the inter-censal rate of 2.4% for 1960-1970 (World Bank 1992; ISSER 1993:13; Figure 1.6). Ghana's current population is estimated at around 17 million. According to a World Bank Report, the population will grow at an annual rate of

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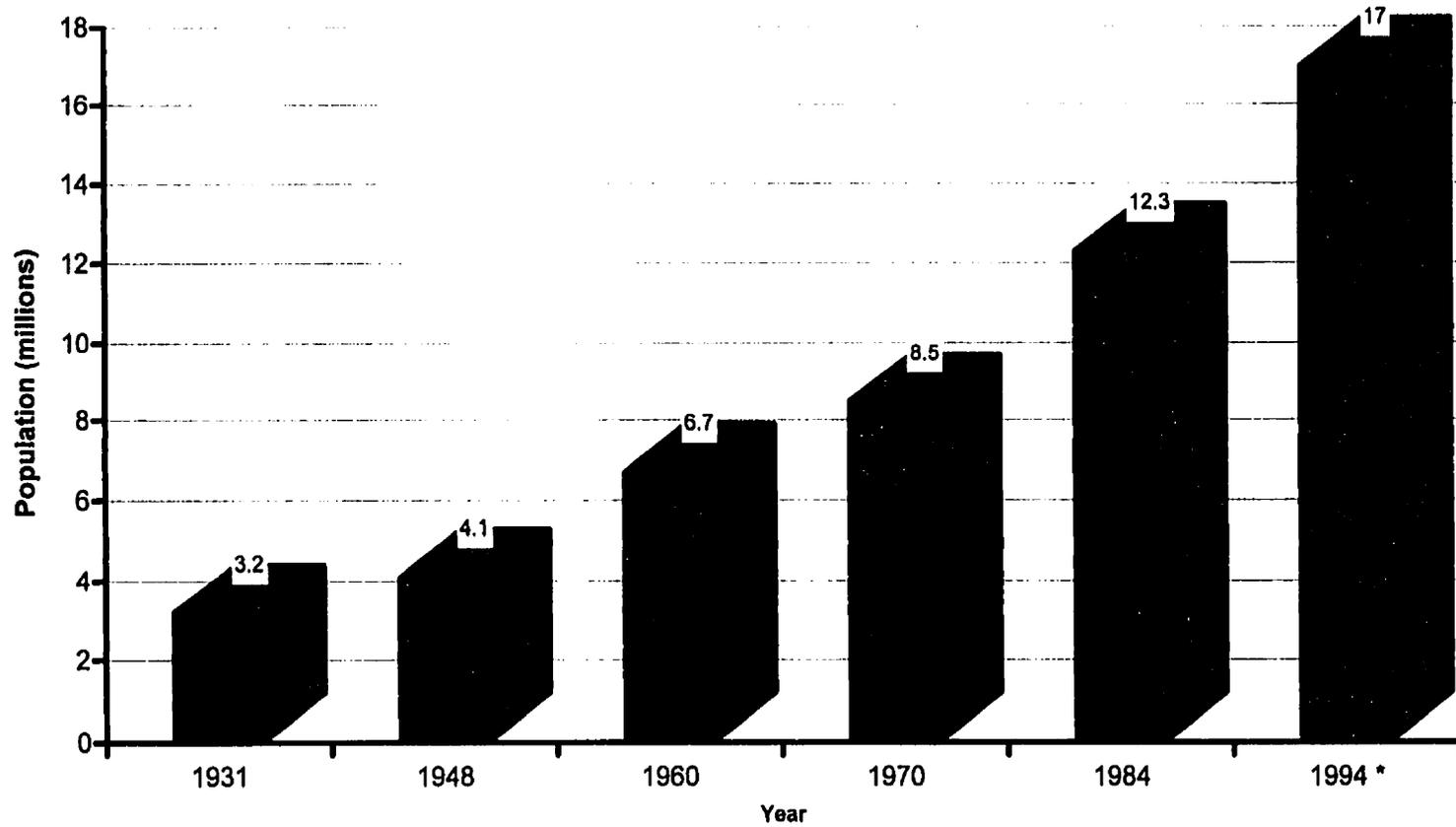
<sup>3</sup> There are 12 ethnic groups in Ghana. The major groups are the Akan, Dagaba, Ewe, Gonja and Mamprusi. This study was carried out among a section of the Akans, who form the largest ethnic group in Ghana-- making up a third of the population.

**Figure 1.5 Location of Ghana in West Africa**



Source: Produced by the Cartographic Office, Department of Geography,  
University of Toronto 1996

Figure 1.6. Population Growth in Ghana



Notes:

\* Computed, using the annual growth rate of 2.7%  
The latest census in Ghana was conducted in 1984

Source: Ghana Government, 1984; Dickson and Benneh, 1988:52

**Table 1.1 Population Growth in the Brong Ahafo Region  
Relative to Selected Administrative Regions in Ghana.**

	Area (person s/ sq. Km)	1960		1970		1984 *	
		Populatio n '000	Density (persons/ sq. Km)	Populatio n ( '000)	Density (persons/ sq. Km)	Populatio n ( '000)	Density (persons/ sq. Km)
All Region s	238 533	6 726.8	28.0	8559.3	36	12 205.6	51.0
Brong Ahafo	39 557	587.9	15.0	766.5	19	1 179.4	30.0
Greater Accra	3 245	541.9	167.0	903.4	278.0	1 420.1	438.0
Norther n Region	70 384	531.6	8.0	727.6	10.0	1 162.6	17.0

Note: \* The latest census in Ghana was conducted in 1984. The other censuses were conducted in 1931, 1948, 1960 and 1970.

Source: Adapted from Government of Ghana 1984.

3% between 1989 and 2000 (World Bank 1992:268). The average national population density – persons per square km – increased from 15 in 1931 to about 71 in 1996, though there are wide variations in density from region to region (Table 1.1). For instance, the 1984 Ghana Census Report – the latest census in Ghana – shows that the population density (per square km) ranges from 17 in the Northern Region to 438 in the Greater Accra Region (Table 1.1). In the Brong Ahafo Region, where this study was carried out, the density in 1984 was 30 persons per square kilometer (Government of Ghana 1984; Table 1.1). Generally, Brong Ahafo has been an area of *in*-migration since the late 1930s. Between 1960 and 1970, and 1970 and 1984 the population in the region grew by 30% and 53.9% respectively. These figures are higher than the national averages of 27% and 42% in 1960-1970 and 1970-1984 respectively. Dickson and Benneh (1980:55) attribute the relative high increase in population in the region to emigration of farmers from other parts of country into the Brong Ahafo Region between the late 1930s and early 1970s for cocoa/coffee cultivation. Most of the in-migrants, since the 1970s, are from the northern savanna regions of the country who have relocated for food production purposes (Dickson and Benneh (1980:55). With a male-female ratio of 103.2%, Brong Ahafo is the only region in Ghana where males outnumber females. Dickson and Benneh (1980) see the male-female ratio phenomenon in the Brong Ahafo region as a consequence of the immigration. They argue that since females in Ghana do not migrate, generally speaking, areas of in-migration in Ghana tend to have more males than females while the regions of emigration tend to have more and unusually low male-female ratio.

A general characteristic of the Ghanaian population, which has implications for land use, is that people are reluctant live outside their home areas (Dickson and Benneh 1980:55). As a result, some parts of the country are over-populated while other areas are

sparsely populated. The north-eastern corner of Ghana, for example, is over-populated (about 120 persons per hectare) leading to problems of soil erosion while the *middle belt*, is thinly populated (about 8 persons per hectare). While population control is an effective response to the food and environmental problem, it is a long term solution that does not address the immediate food problems. While planning for the long-term solution, it is important to address the immediate food needs of the people through increased food production.

#### 1.432 Economy

Ghana's population has been burgeoning while its economy has stagnated. With the exception of the first six years after independence, Ghana's economy has had little to be proud of. Between 1965 and 1990, its GDP grew at an average annual rate of only 2.2%, though it has grown at an average of 4.2% since 1990 (World Bank 1992; ISSER 1994). The service sector contributes 46.4% of GDP, while the industry and manufacturing sector contributes 15.6% (ISSER 1994:67). Logging and mining (gold, diamond, bauxite and manganese) are important sub-sectors in the economy, but agriculture is the mainstay. Agriculture contributes about 38% of GDP, employs 50% of the population and contributes 70% of the merchandise exports (Nikos 1995; ISSER 1994; 1993). Cocoa (the main cash crop) provides 40.3% of total foreign exchange earnings. Despite the contributions of agriculture to the economy, the government invests comparatively little in its development. Of what is invested, 45% goes to the development of the cocoa sector, compared to 50% for food production and livestock rearing (section 6.32).

### 1.433 Farming systems in Ghana

Large-scale farmers specialize in commercial crops such as cocoa, coffee, maize and rice. They produce only 10% of domestic food supply. Bush fallow system is the prevalent farming system in the study area (see Chapter Three for a detailed analysis). Most farmers in this system are smallholders but they produce 90% of the nation's food, typically in a mixture of subsistence and commercial production (Sarris and Shams 1991). Almost every foodcrop farmer rears some livestock such as poultry, sheep and goats for home consumption, though some livestock rearing is done on a commercial basis. Since all smallholder farming is rain-fed, the length of the rainy season and the amount of rain determine which crops can be planted. Inadequate and unreliable rainfall in the farming season could mean a complete crop failure. Central to success of the farming systems is the way land is owned and distributed in the farming community, as well as the land use patterns developed by the people.

### 1.434. Land use patterns and land tenure systems <sup>4</sup>

About 13.58 million hectares of land are available for cultivation in Ghana. Of the cultivable land, only 50% is actually cultivated. Most of the uncultivated areas forms part of the *middle belt* of Ghana -- a sparsely populated area that stretches north-south across the middle of the Interior Savannah Zone. The middle belt is uncultivated for physical and historical reasons. In addition to the unreliable rainfall in the *middle belt*, the area is also full of harmful flies such as the tsetse and similium flies, whose bites infect both humans and livestock. But most importantly, the *middle belt*, which was once populated, was depopulated in the 16th and early 17th centuries as a result of the wars and slave raids on

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<sup>4</sup> The land-use and tenure practices described here are what pertains among, but not exclusive to the Akan people of Ghana (footnote 3). The people in the study area are Akans and have the same land tenure systems described here.

the area by the Dagomba, the Asante<sup>5</sup> and the armies of the notorious slave raiders, Samori and Babatu (Dickson and Benneh 1980). The few people left, after the slave trade, could not do much to check the spread of such harmful insects as the tsetse and similium flies which came to make the land less attractive for settlement and for cultivation.

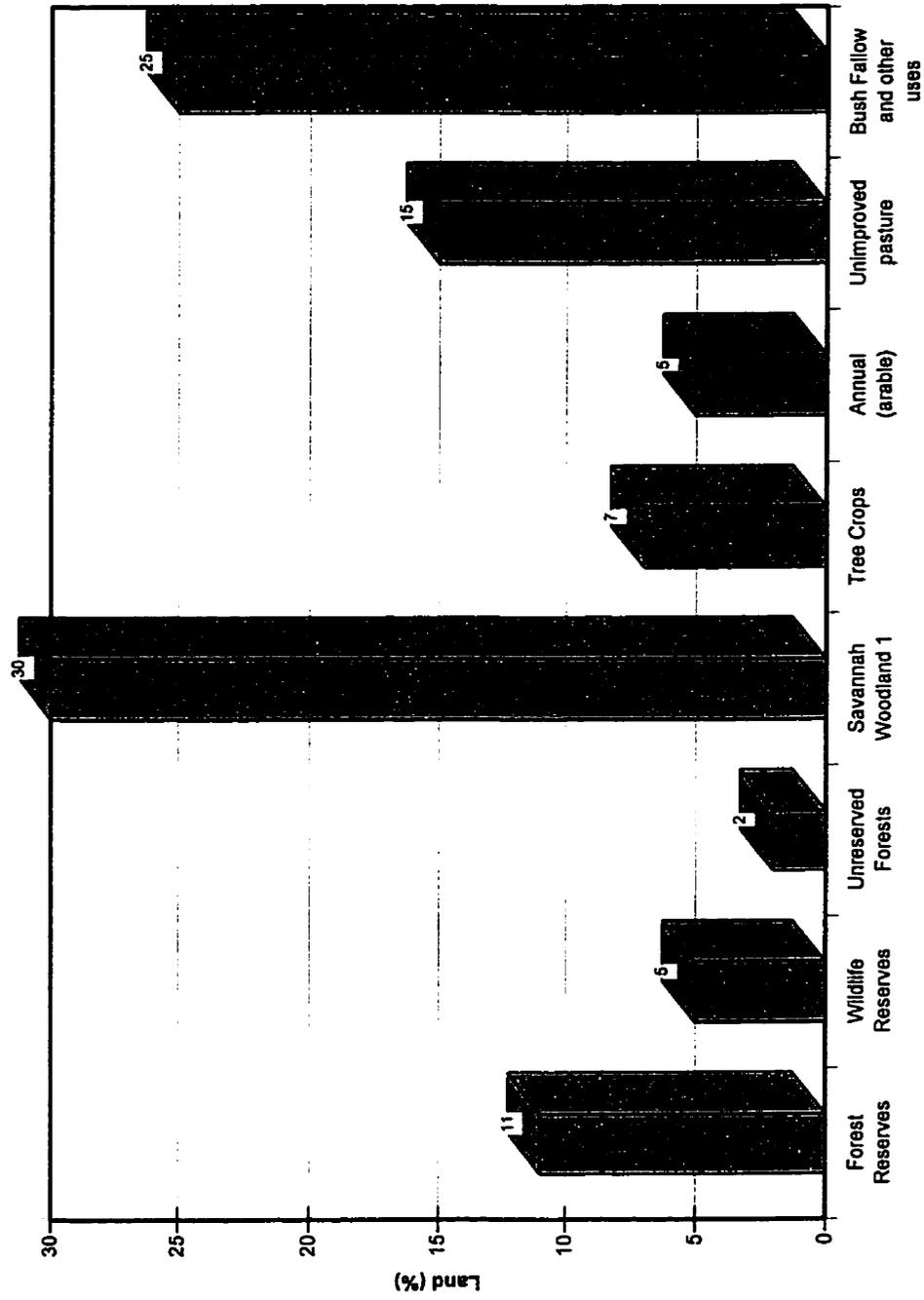
Seven percent of the total cultivated area in Ghana is allotted to tree crops and 5% to annual crops (Sarris and Shams 1991; Figure 1.7). Because Ghana does not have local expertise for the planning, design and construction of irrigation projects, only 17 000 hectares of the 120 000 hectares of irrigable area is actually irrigated (World Bank 1986b). Hence, generally speaking land availability for food production is not a constraint in Ghana. Rather, the main farming system in Ghana – the bush fallow – and the way land is controlled and distributed are what affect land development and productivity.

The bush fallow system, the main farming system, is an extensive rather than an intensive farming method. It involves leaving fields that have been cultivated for two or three continuous years to lie fallow while the farmers farm new plots of land (section 3.1; section 5.45). Before the exhausted fields are cultivated again, they are left to fallow for at least three years, depending on how much land the farmers have at their disposal. Consequently, at any time the farmers have more of their land under fallow than cultivation. The implication of the fallow is that since it requires so much land to be effective, the system constrains the amount of agricultural land put to productive use at any time. Whether this system of farming is viable in the face of population pressure, and whether there is an alternative to the fallow system is discussed in section 3.1.

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<sup>5</sup> The Asante and the Dagomba were powerful kingdoms in the 17th and 18th centuries. The middle belt, which was sandwiched between the Dagomba, on north and the Asante on the south, was settled by weak states –a fact which made the middle belt vulnerable to the two powerful kingdoms which raided the area for slaves.

Figure 1.7. Land Use in Ghana



Note:

1. Most of the savanna woodland is part of the middle belt region of Ghana. Even though it is not a forest nor a wildlife reserve, it is sparsely populated and remains uncultivated for the most part, for reasons discussed in section 1.434.

Source: Based on ISSER 1992:142-146

The land tenure system among the *Akans* of Ghana ensures easy access to available land for food crop farming, but the tenure and farming systems have serious shortcomings with respect to land development and productivity. The basic customary land tenure of all the ethnic groups in Ghana may be described as communal tenure or corporate ownership, though each ethnic group has its own unique way of practicing the communal land tenure (Sarpong 1974). As an example, among the *Akans*<sup>6</sup>, one may have access to land by one of five ways (Rattray 1923):

- (a) the allodial title – an absolute ownership right which is supposed to be the highest grant or right in land;
- (b) the customary freehold – access to land by virtue of being a member of a land owner group;
- (c) the leasehold – usufructuary right for an agreed period in exchange for an initial agreed payment;
- (d) the *abunu*, *abusa*, and sharecropping tenures – under the terms of *abunu* and *abusa* share-tenancy, the rent is a stated proportion of the tenant farmer's yield, either in kind or in cash. Traditionally the ratios for *abusa* are one-third to the tenant. In *abunu* the tenant and the land lord share either the farm or the yield equally;
- (e) The *nto* – a cash rental tenure in which the tenant pays a cash rent equivalent to 10% of the value of the yield each year.

Categories (a) and (b) primarily concern members of owner groups, while (c), (d), and (e) affect the “stranger farmer”.

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<sup>6</sup> The Akan system of land tenure prevails in the northern *FSTZ*, the focus area of this research.

Among Ghanaians, every clan – a group of families with a common ancestor<sup>7</sup> – has a piece of land for use by the members of the clan. The common ancestor of a clan owned the land, either by first occupancy, that is, taking possession of a piece of land which had never been occupied or claimed by other persons, or as gift from the chief for the ancestor's heroic deeds or service to the chief. In principle, all members of a clan including those yet unborn have the right to the use of lineage land. A member of the clan wanting to farm a piece of land will apply to the head who will apportion to the member a piece of land for his/her use. As the members in a family increase the land is divided into smaller plots among the members.

Although land may be heritable and can be pledged against debts, it is not a commodity that can be sold because it belongs to the ancestors. The one who rents land has only the use of it. The land remains the property of the community from which s/he rented it. Even when there has been an exchange of money for land, it is the use of the agricultural rights that has been sold, not the ownership of the land (Obeng 1986:56; Sarpong 1974:118; Rattray 1923). This system of land tenure has implications for land development and productivity. First, because land cannot be relinquished or, for that matter, acquired through purchase, people cannot give up even their infertile plots of land for a more fertile piece of land. Therefore, a farmer with limited land continuously cultivates it, making the land more degraded. Secondly, because land is communally owned, and no member of the family is allowed to use it on a permanent basis. Since no family member owns the land, nobody invests in its sustainable use.

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<sup>7</sup> Ancestors are deceased clan or family heads who commanded respect from their families. They are believed to maintain contact with the family. In a restricted sense the term also refers to all the deceased members of a family.

While land cannot be bought or sold, it can be inherited. The inheritance of lineage land may be determined patrilineally or matrilineally. In patrilineal societies succession moves from a man to his children. Females may have a right to inherit property, but their share is usually smaller. Therefore, they depend on their husband's land. On the other hand, in matrilineal societies such as the one in which this research was carried out, inheritance of family land is from mother to her children. Within such systems, both men and women in the same family have equal access to the family land. However, because succession is through females, women have more rights to land than males. While males in the family may use the family land, they, unlike females, cannot bequeath land to their children since the children belong not to their father's but to their mother's family.

#### 1.435 Land use and gender issues

Closely related to how land is distributed in the farming communities is the new role that women are assuming in the communities as the social structure adjusts to the environmental changes. Traditionally, women and men farmed together on the same plot of land, producing solely for the household's consumption. The introduction of cocoa and coffee cultivation brought a new division of labor between the sexes: men were cash crop producers, while the burden of growing food crops to feed the family fell heavily on the women. Since 1983, food crops have become the main cash crops for farmers in areas, such as the study area, where cocoa farms were destroyed by bushfires, or died of natural causes. Women, who grow more food crops, therefore tend to earn more income than the men who are reluctant to get into food crop farming which is traditionally considered as *women's work*. Thus, both the land tenure system and the division of labor between the sexes favor women more than men as both sexes adjust to the agro-ecological changes in the study area.

## 1.44 Agricultural Policies In Ghana

### 1.441 Colonial policies towards food farming

The environmental conditions favorable for food production were particularly difficult in the early 1980s. However, the deteriorating trends leading to the agro-ecological and food production crises in the 1980's are best appreciated against the background of many years of colonial agricultural policies and the often conflicting mandates of the post-colonial state on agriculture (Jorosz 1996:152). The policies of both colonial and post-colonial governments favored cash crops such as cocoa and coffee but discriminated against the smallholder food farmers growing crops for local consumption.

The local colonial administration from 1872 to 1957, could not formulate a clear policy on food production, since on the one hand they supported food imports from Europe to promote food production in Britain, and yet on the other they needed cheaper local food supplies to avoid social unrest in the colony (Agbodeka 1992; Nimako 1991). The poll tax law, passed by the colonial authorities at the beginning of the century, compelled a significant number of peasant farmers and fishermen to find wage employment on cocoa plantations, or urban-based public projects (Ewusi 1985). The number of farmers working in the fields decline significantly as a result. The inadequate labor for local food production led to food shortages, but the duties on cocoa production provided sufficient revenue to finance an aggressive food import policy. By 1931 local food production had almost collapsed. Food imports rose from £ 1 million in 1931 to £ 6 million in 1950. Between 1951 and 1961 food imports increased by 9% (Ewusi 1985). But the real price paid for the food import policy was the institutionalized distortion of the food economy, which was the beginning of a persistent cycle of dependence on food imports throughout the colonial and post colonial periods. The government's poll tax and emphasis on export production created increasing production pressures and increasing demands on environmental

resources. Since the most fertile areas were used for the cultivation of export crops, cultivators cleared the marginal lands for food production. Fallow periods became shorter because most land was under permanent tree crop cultivation. Since the regeneration of vegetation depends on the length of the fallow period, the shortening fallow periods marked the beginning of a steady change in the vegetation.

The colonial government's neglect of the food sectors was exacerbated by its transportation policy, which connected coastal ports with mining, timber and cocoa growing areas to the neglect of feeder roads and cheap transportation from farms to consuming centers (Agbodeka 1992; Ewusi 1985). The lack of efficient transportation made food crop farming unattractive since local food crops became very vulnerable to price fluctuations. Another factor that affected the food production during the colonial era was insensitivity of colonial officers to the gender dimension of food production. Traditionally, most food crops were cultivated, harvested and marketed by women. Yet the few government programs to help farmers were biased towards men while credit, technology and information were denied to women. Furthermore, the official bias against local food production in particular and agriculture in general was institutionalized in the colonial educational system that held firmly to the mistaken belief that agricultural and technical training had no place in higher education (Ewusi 1985). Most importantly, the colonial government considered small-scale farming employing traditional methods as primitive and inefficient. The colonial government discouraged indigenous methods of farming, although it provided no alternative techniques to enable traditional farmers to increase production. Between 1939-45, when food imports were curtailed as a result of the Second World War, the indigenous food producing sector had deteriorated to the extent that it was unresponsive to the increased demand for home-grown food for which prices had more than doubled (Ewusi 1985). Thus, at independence in 1957, the post-colonial governments inherited the results

of policies by successive colonial regimes which emphasized food imports, accorded very low priority to local food production, and undervalued indigenous methods of farming.

#### 1.442 Post-colonial governments and food farming

With emphasis placed on the export sector in agricultural programming, successive post-colonial governments, as did the colonial administrations, discriminated against the small-scale food producer and his/her farming methods. The attitude to agriculture of the first post-colonial government – Convention People's Party (CPP) from 1957 to 1966 – was that the peasant farmer wielding the hoe and the cutlass and practicing shifting cultivation could not be depended on to meet the food requirements of the rapidly growing population (Miracle and Seidman 1968). Instead, the administration emphasized large-scale mechanized capital-intensive farming, and improvement of farming practices on European and North American models. By the early 1960s, large-scale mechanization had proved to be a serious failure. Among the main reasons for the failure were the transfer of a new technology into a country that lacked adequately trained personnel to handle the technology. Moreover, large-scale mechanization was not appropriate for labor-based intensive agriculture in which individual household plots tended to be relatively small and spatially fragmented (see Pingali et al. 1987). But most especially, tractor plowing, which was a big component of the imported package, was not suitable for the shallow soils in Ghana (Agbodeka 1992).

The National Liberation Council (NLC) Government (1966-1969), and the Progressive People's Party (PPP) Government (1969-1972), gave higher priority to industrialization and large-scale capital-intensive methods of agriculture under private enterprise than to the smallholder food farmer using the hoe and cutlass. Food production in Ghana actually declined in that period (Figures 1.2 and 1.3). Under the National

Redemption Council (NRC) and Supreme Military Council Government (SMC) regimes (1972-1979), the Operation Feed Yourself (OFY) program was established. Unlike past policies, the policy of OFY operated on the assumption that increased agricultural production would be generated mainly in the private sector by smallholder farmers by means of acreage expansion. Import substitution programs emphasized national food self-sufficiency through increased production of rice, maize, livestock, sugarcane, yam, cassava, plantain and sorghum, upon which most Ghanaians depend. Using hoe and cutlass and bush fallow methods, smallholder farmers increased domestic production of most food crops, and produced a surplus within the first three years of the OFY (Ewusi 1985; Figure 1.2). Following the progress made in 1973 and 1974, the government decided to import tractors and combined harvesters to support special sub-sectors in agriculture, especially that of rice farming. Thus, after three years of success with the small scale-farmers, the NRC government shifted emphasis once again to large-scale, capital-intensive production units. The smallholder community was once more ignored and food production started another downward trend, a trend which was exacerbated by the droughts and bush fires of 1982/83 (Figure 1.2).

#### 1.443 Current agricultural policies

Between 1983 and 1985, the Provisional National Defense Council (PNDC) government initiated a number of *ad hoc* programs designed to reverse the decline in food production. With the support of these programs, farmers increased production well above the expected for 1984 (Figure 1.2). Under the Sasakawa Program of Global 2000, featuring the Japanese philanthropist, Sasakawa, some farmers have adopted new techniques, such as planting improved seeds that increase yields tremendously, particularly those of maize and sorghum.

In 1994, the government set up the Agricultural Sector Investment Project (ASIP) to provide incentives to small-scale farmers to increase agricultural production (ISSER 1994:95). These infrastructural developments include:

- construction or rehabilitation of small water schemes in rural areas for drinking and irrigation;
- construction of new market places, and upgrading or rehabilitation of existing ones;
- construction of new access roads, and rehabilitation of existing ones leading into remote food production areas; and
- construction and operation of village-level food processing units.

Another major development in agricultural policy is the research into and production of improved planting materials of plantain, yams and cassava. The Grains and Legumes Development Board (GLDB) has also ventured into the production of improved planting material of grains. The hope is to help farmers, increase production by cultivating improved high yield, shorter gestation cultivars of crops. Food production has recorded some modest increase under recent government policies that are directed at the smallholder farmer (Figure 1.3). However, the Economic Recovery Program (ERP), pursued by the government through the IMF Structural Adjustment Program (SAP) and the associated trade liberalization allow imports of cheaper food to compete with local food crops. While the imported food helps bring down food prices, the lower local food crop prices discourage the small scale farmers from increasing production since they do not get adequate prices for their crops.

#### 1.444 Marketing of agricultural produce

##### 1.4441 *Cash crops*

Most of the prices that producers receive for their produce are determined in the open market by the interaction of supply and demand forces especially since the Economic Recovery Program (ERP) was implemented in 1983. The few commodities whose producer prices are administered include cocoa and some industrial crops such as cotton, tobacco and palm fruits. The prices of industrial crops are arrived at through negotiations between producers and processors and those of cocoa and coffee are determined by government through the Cocoa Marketing Board (COCOBOD). The government realizes that competition in the internal marketing of cocoa will promote increased marketing efficiency and higher producer prices as buyers compete for the crop. To this end, two new buyers, Universal Crop Protection (UCP) Ltd. and Cashew and Spices Products, were licensed towards the end of 1992 to buy cocoa alongside the Produce Buying Company (PBC), a subsidiary of the COCOBOD (ISSER 1993:100). This presumably re-introduces competition into the internal purchasing of dry cocoa beans. The positive effects of the policy change on marketing efficiency will, however, be apparent only in future years, when the new buyers have established themselves, and will greatly depend on the ability of cocoa buyers as a whole to compete effectively price-wise.

##### 1.4442 *Food crops*

There are two systems for public marketing of food in Ghana: the formal and informal distribution systems. The government controls the formal distribution of food through the Ghana Food Distribution Corporation (GFDC), while the informal system of food distribution is operated by private individuals popularly called middlemen. Until 1983, the Ghana Food Distribution Corporation (GFDC) controlled food prices by dictating the prices above which

it would not buy food crops. Even though the government tried to control prices in Ghana, the diversity and small-scale nature of the food crop trade, combined with the large number of producers, made it difficult for the government to monopolize the food crop market. Since the implementation of the ERP in 1983, the prices of food crops are determined by the forces of supply and demand. Both the GFDC and the middlemen buy food crops at farm-gate prices and retail the crops at higher prices in the urban centers. Unlike the GFDC, which limits its marketing activities to a few food crops such as maize, rice, yams, plantain, cassava, and cocoyam, the private sector distributes these food crops in addition to a wide variety of other food items including edible oils and vegetables – tomatoes, pepper, garden-eggs, okro, beans, onions and *kotomire*.

The farmers can sell their produce to the middlemen, who usually offer better prices, but the middlemen do not have the resources, such as trucks that the GFDC has, to compete in the remote food producing area. Even though the government has replaced its controlled and fixed pricing with a flexible pricing policy, the forces of supply and demand do not make much difference in the prices offered for food crops in the most remote food producing areas. At the beginning of the harvesting season, the farmers flood the markets with their produce because they do not have adequate storage facilities for the perishable crops, and because they are in desperate need of money. The GFDC and the middlemen take advantage of the food glut on the market to buy food crops at low prices. The GFDC, since it has storage facilities for cereals, is able to store cereals until the lean season when they are retailed at higher prices. The perishable crops such as cocoyam, cassava, and plantain are retailed at the urban centers to restaurants and to government institutions, such as the hospitals and schools. By buying and storing cereals in harvesting season, the GFDC is able to reduce post-harvest losses, and to bring food price down during the lean season by selling its stock of food, something the middlemen cannot do.

#### 1.445 Agricultural Credit

The establishment of the Cooperative Inventory Credit Scheme (CICS) is one of the recent attempts to give financial assistance to small-scale farmers while helping them get better prices for their crops. The (CICS) was introduced in 1989 by Technoserve, a non-governmental organization which works in close collaboration with the Department of Cooperatives and the Agricultural Development Bank (ADB). The scheme is based on the fact that soon after harvest when most farmers sell their produce, market prices tend to be very low and thereafter rise to a peak just before the next harvest, increasing by 100% in many cases (ISSER 1994:89). Under the scheme, the cooperative stores the farmers' produce as collateral for bank loans which are repayable when the produce is sold. The farmer then receives a loan of 75-80% of the current value of the stored produce. In this way the farmers receive incomes at the time they need them most. Two options are open to the farmer regarding the sale of the stored crop. They can pay back the borrowed money plus interest, storage, and administrative expenses and retrieve their produce or they can authorize the cooperative to sell the produce on the open market. In the latter case, the borrowed money plus expenses are deducted from the sale receipt and the difference paid to the farmers. Farmers have realized net incremental benefits averaging about 70% from price increases between harvest and the time of sale, partly from a reduction in storage losses as a result of this scheme (ISSER 1992:104). Another advantage of the scheme is that farmers are able to save considerable amounts of money by selling later in the season. However, the scheme faces two major problems which can wipe out the incremental benefits, namely; food imports which can flood the market and result in lower prices; and unchecked infestation of the stored produce (ISSER 1992:104).

As with other areas in West Africa, the first post-independence agricultural efforts failed because the strategies were misconceived. Governments made a dash for

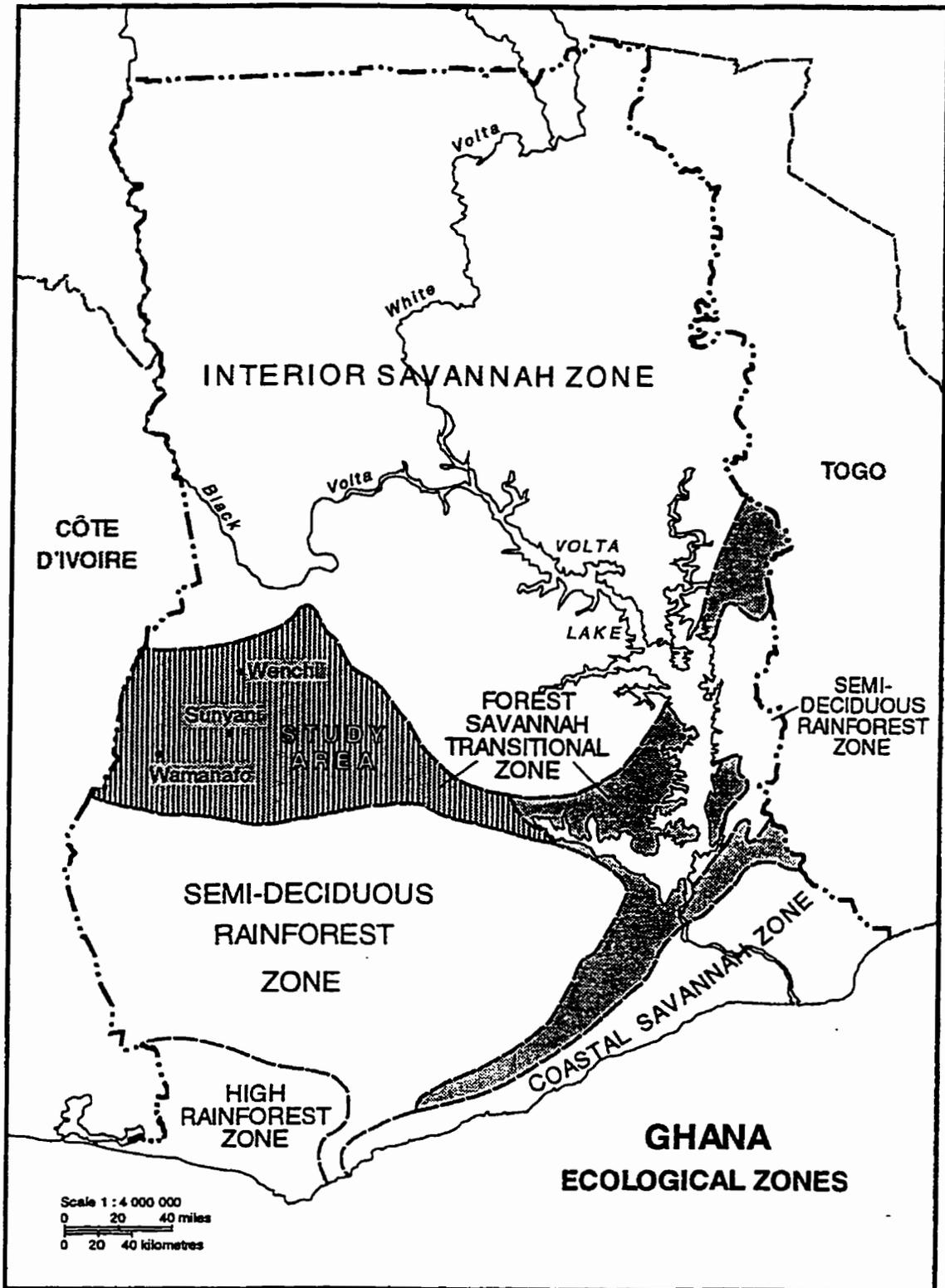
modernization, copying but not adapting. This top-down approach demotivated the ordinary farmers (World Bank 1986:3, 36). In recent years, however, many elements of this vision have been challenged. Alternative paths have been proposed. These paths give more attention to agricultural development that emphasizes not only prices, markets and smallholder involvement but also better environmental practices.

#### 1.5. AGRO-ECOLOGICAL ZONES AND THE STUDY AREA

While the socio-economic context of food production is similar in all the country, farmers in different parts of the country are adapting to different ecological conditions. On the basis of soils, climate, and vegetation, Ghana is divided into three main ecological zones: the rain forest, the forest-savanna transitional zone, and savanna regions (Figure 1.8). Apart from the clayed, alluvial, bottom-land soils, most Ghanaian soils are old and have been leached of all nutrients derived from the parent material from which they were formed (Sarris and Sham 1991). Soils have very low reserves of nitrogen, phosphorous, and organic matter, particularly in the savanna regions (section 1.513).

All regions in Ghana, except the interior savanna region, have two main seasons: the wet season, and the dry season. With slight variations from region to region, the dry season spans the time from the middle of November to early March. The wet season starts in March and ends in November.

**Figure 1.8 Ecological Zones in Ghana**



Source: Produced by the Cartographic Office, Department of Geography,  
 University of Toronto 1996

The Rain Forest has a bi-modal rainfall distribution totaling 1 700 mm to 2 100 mm per annum. The high rainfall results in soil leaching and erosion leading to relatively poor and acidic soils (Dickson and Benneh 1988:36). Consequently, acid-tolerating tree crops such as oil palm tree, coconut, and rubber; and annual crops such as plantain, rice, cocoyam and cassava, are some of the principal crops cultivated in the region. The Semi-Deciduous Forest has a bi-modal rainfall distribution in the range of 1200 mm. to 1600 mm per annum. Soils are gravelly and relatively less acidic with good permeability. Some of the main crops cultivated in the area are perennial crops such as cocoa, coffee, and oil palm; and annuals such as cocoyam, yam and cassava, plantain and maize. The Coastal Savanna zone is the driest region in the country with a mean annual rainfall between 740 mm to 890 mm. Maize, cassava, groundnuts, vegetables and shallots are the main crops grown in this region. The erratic rainfall in this region sometimes makes rain-fed cropping of annual food crops marginal, with wide fluctuations in yield.

The guinea savanna, or the interior savanna zone, has one rainy season, commencing in April/May, reaching a peak at the end of August or early September, and ending in October. Drought is a frequent cause of crop failure in this zone. Vegetation is predominantly fire-resistant trees and bushes mixed with grass. Soils are generally less fertile than the FSTZ soils but they support crops such as maize, millet, sorghum, cotton, groundnuts, tobacco and rice. The vegetation also supports unimproved pasture that is good only for extensive grazing.

#### 1.51 The Forest Savanna Transitional Zone –The Study Area

Sandwiched between the deciduous forest and the guinea savanna zones of Ghana is an approximately 6200 sq. km region called the forest savanna transitional zone (FSTZ),

which is the focus area in this research (Figure 1.8). It has unique characteristics which make it an important agricultural region and an interesting area for this study.

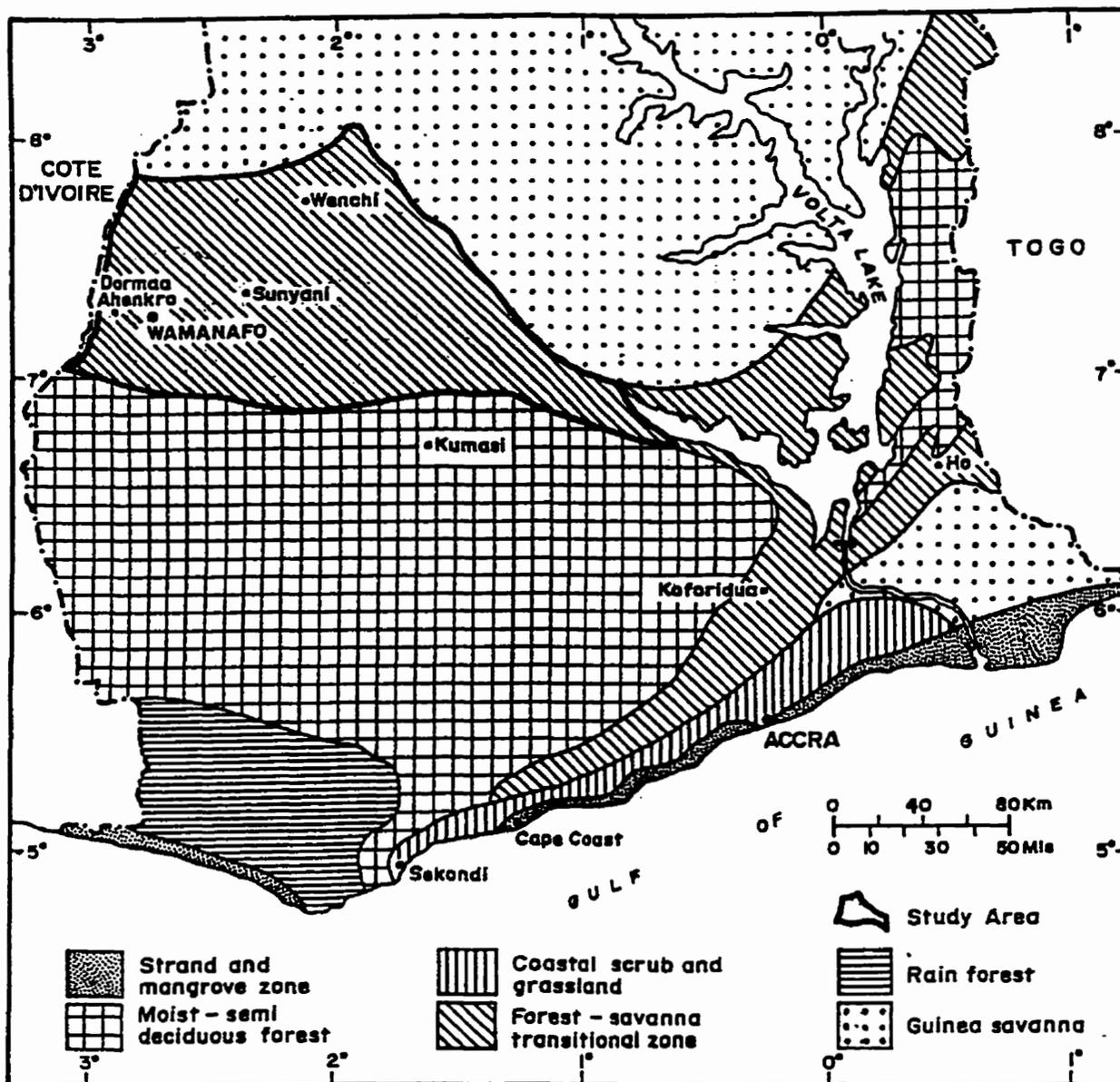
#### 1.511 Climate

The region's maximum mean monthly temperature of 30° C occurs between March and April, while the minimum monthly temperature of about 26° C is recorded in August. Total annual rainfall is between 1 300 mm and 1 800 mm, most of which falls in May/June with a second minor peak in September/October. The first rainy season is separated from the second rainy season by a relatively dry period in August, which makes it possible for farmers to plant twice in a year. Average monthly relative humidity is between 75%-80% during the two rainy seasons and between 70-80% during the rest of the year. The major dry season, spanning from November to February, is quite severe.

#### 1.512 Vegetation

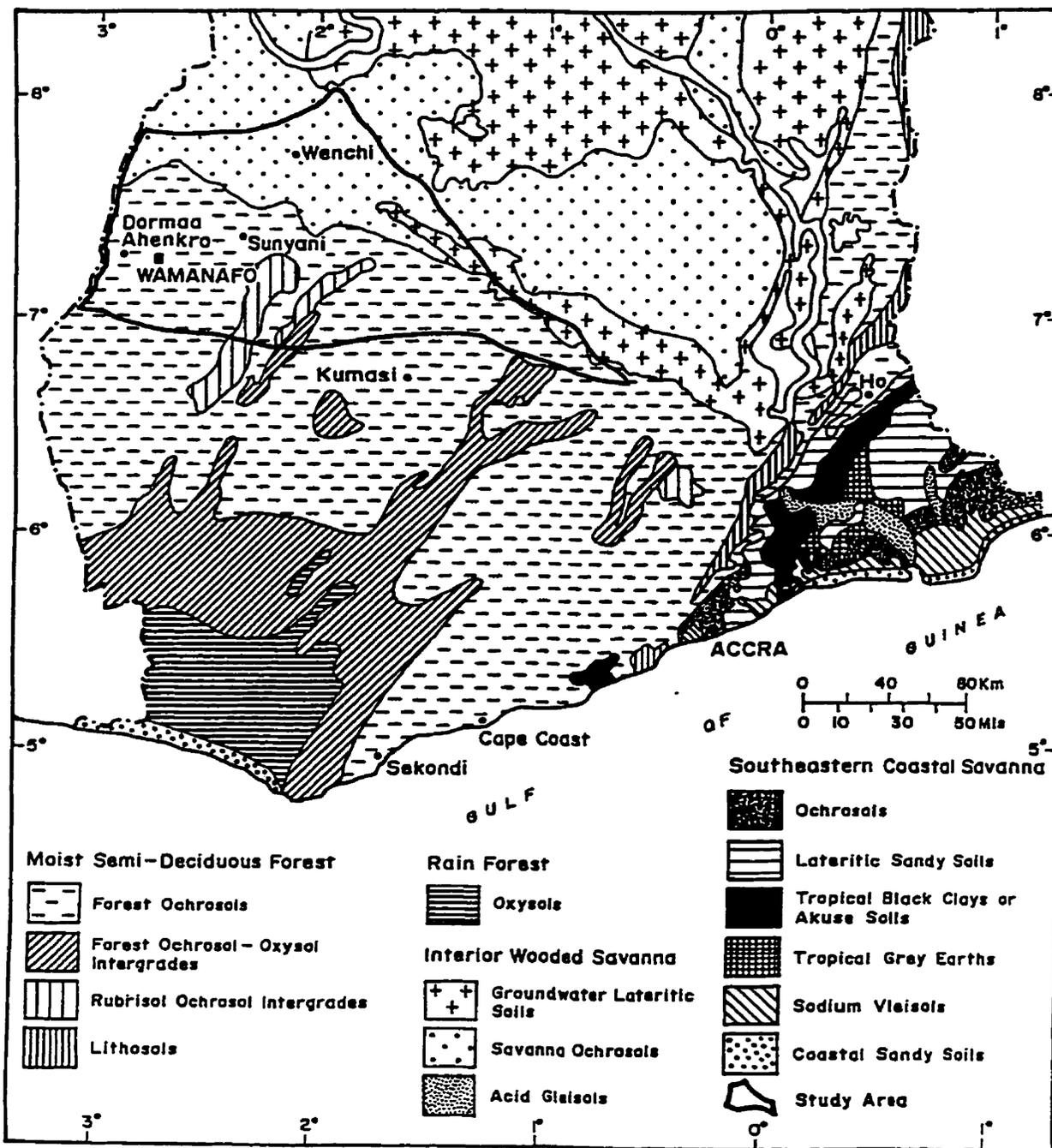
The indigenous forest vegetation has an upper canopy in the range of 35-45 m, a dense undergrowth of herbaceous plants and climbers, and a dense leaf litter. In this vegetation, trees such as *Antiaris toxicaria* (Kyenkyen), and *Milicia excelsa* (Odum) achieve their greatest abundance (Gyasi et al. 1995). The size of the trees in the secondary forest depends on how long the forest has been abandoned by farmers for the soil to recover. In sparsely settled areas where there is no great pressure of population on the land, secondary vegetation may be left for up to 15 years or more. Near large settlements, on the other hand, the pressure on land is great and the fallow period may be as short as three years. Hence, apart from the larger trees which farmers usually leave standing on their farms, the secondary forest vegetation consist of climbers, shrubs, and soft woody

Figure 1.9 Ecological Zones in Southern Ghana Showing the Study Area



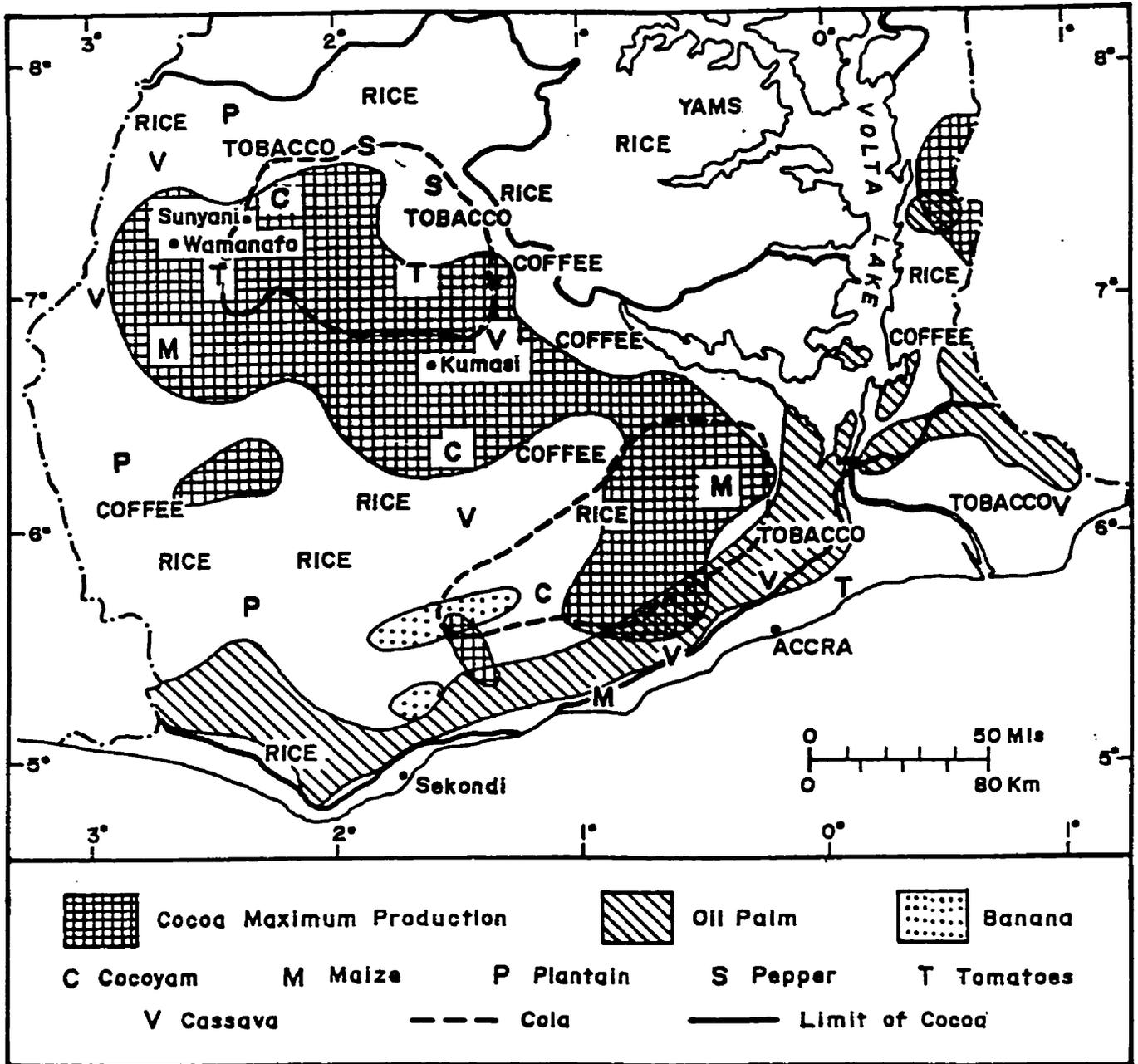
Source: Produced by the Cartographic Office, Department of Geography and Resource Development, University of Ghana

Figure 1.10 Major Soils in Southern Ghana



Source: Produced by the Cartographic Office, Department of Geography and Resource Development, University of Ghana

Figure 1.11 Major Food Crops in Southern Ghana



Source: Produced by the Cartographic Office, Department of Geography and Resource Development, University of Ghana

plants. Because of the prolonged dry season in the FSTZ, the region as a whole is more and more prone to desiccation. The prolonged dry season allows frequent invasion by savanna grass species which serves as fuel for frequent bushfires, which in turn promote *savannization* of the indigenous vegetation. Because the region supports both savanna and forest vegetation, it also supports both savanna and forest crops.

### 1.513 Soils

The principal soils in the FSTZ are the forest and savanna *ochrosols* (Figure 1.10). At the northern tip of the study area, savanna *ochrosols* are the dominant soils (Figure 1.10). The savanna *ochrosols* differ from the forest *ochrosols* in being less richly supplied with organic matter and nutrients. They are well drained, porous and loamy soils developed over granites, *Birimian*<sup>8</sup> rocks and sandstone (Dickson and Benneh 1988). On the other hand, the forest *ochrosols* are developed over a wide range of highly weathered parent materials, including granite, *Tarkwaian*<sup>6</sup> and *Birimian* rocks, giving a workable, loamy, porous soil (Dickson and Benneh 1988). The soils are gravelly on the gently sloping topography, making them easily erodible. However, under the reduced rainfall in the area, erosion and leaching of soil nutrients is appreciably less intense than in the soils in the rain forest. The profile dries out seasonally in the upper horizons but remains moist in depth.

The vegetation, climatic and soil conditions described above provide a favorable environment for a wide variety of crops. Among the crops grown in the area are perennial crops which benefit from a dry season, and which tolerate strong acidity and desaturation, e.g. cocoa and coffee. Annual crops requiring a long growing season, e.g. yams, are also

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<sup>8</sup> The *Birimian* and *Tarkwaian* are rock formations consisting of metamorphosed sediments. They cover more than three-fourths of the closed forest and FSTZ of Ghana. The *Birimian* is the most important geological formation in Ghana since it contains all the minerals (gold, diamond, manganese, bauxite) exported from the country.

cultivated. Although the trend in this zone is towards continuous cropping, this method raises problems of soil management, including loss of soil structure, pan formation, and soil capping (Sarris and Shams 1991).

#### 1.514 Other unique features of the FSTZ

As an ecotone between the deciduous rain forest and the savanna zone, the FSTZ shares in the climate, vegetation and soil of both the forest region and of the savanna zone. These make it the only agricultural region in the country that supports both forest and savanna crops as well as a considerable diversity of farming systems (SRI 1971). Important among the main cash and subsistence food crops grown in the region are sorghum, millet, maize, cassava, plantain, cocoyam, yam, groundnuts and industrial crops such as tobacco, cotton, and cocoa (Figure 1.11). Cattle, sheep and goat rearing is also gaining importance in the region as the increasing grass composition in the vegetation offers ready fodder for livestock.

As noted above, the two rainy seasons separated by a short dry season in August, allow farmers to plant and harvest crops twice in a year. The major farming season begins between January and April, depending on when the rains start. The second or minor farming season begins in August, when the short dry season is used for the preparation of land for the minor crop season (Table 1.2). The relatively dry conditions in August also provides ideal conditions for harvesting short-gestation crops such as maize, rice, millet and sorghum, that are planted at the beginning of the main crop season. Perennial crops such as yam, cassava, and cocoyam, planted in the major season, usually mature some time after the minor dry season (Table 1.2).

**Table 1.2 Seasonal Farming Cycle in the Forest Savannah Transitional**

Period	Ecological Conditions	Farming Activity	Food Cycle (Food Supply)
A November- February	Main dry season; Harman period. Land is dry and parched, water is scarce except in rivers and permanent springs.	Harvesting of minor season crops at the end of November. December - January is period of rest. Land preparation for major farming season in anticipation of first rains begins in January: clearing, cutting, and burning. Yams may be planted in mounds before rain starts.	Food supplies available from previous harvest season. Annual crops such as cassava and cocoyam continue to be harvested. A second maize planted in late August is harvested at this time.
B March-June	Major rainy season with June being the wettest month	Sowing of seeds and crops continues at the onset of the rains. Weeding around crops.	Food stores could be nearing exhaustion with planting of reserves. Lean season for food continues until June.
C July-August	low rainfall.	Weeding around and attending to crops. Harvesting of short-gestation crops. Preparation of land in July-August for minor farming season..	End of lean season as short-gestation crops such as maize and vegetables are harvested in early July, assuming there was early rain.
D September - October	The second rainy season begins in September and continues through October. Rainfall is intense.	Minor farming season. Planting short-gestation crops. Intense harvesting of annuals such as yams, cassava and cocoyam.	A season of relative plenty and abundance of food supplies. Trucks cart food to urban centers. Excess food in remote areas rots for lack of markets and access roads.

Source: Adapted from Dei 1990:103

The selection of the FSTZ for study is also motivated by the fact that it is an area which has guaranteed food production for all of Ghana since the 1970s (Amanor 1994). Therefore, any impact on food production in the region has repercussions on the food supply for the whole nation. Moreover, the region sustains a wide variety of crops and different farming systems. For these reasons, it is an ideal field for this research which seeks, among other things, to identify what adaptations farmers are making on their farms to alleviate the effects of the changing agro-ecosystem (Parry 1985; Young 1976). Familiarity with the *Akan* dialect, the most commonly spoken language in the FSTZ, affected the choice of that area especially since the study involved person to person interviews with farmers who did not speak English.

#### 1.515 Agriculture and the Environmental Change

Farmers' responses to the environmental conditions in the FSTZ are best appreciated against the background of many years of cocoa cultivation and its subsequent decline in the region. The farming system in the region has evolved from a subsistence-oriented staple crop before the 1920s, through commercial production of cocoa with other staple crops (cocoyam, plantain, yam) from the 1930s, to commercial production of staple food crops since the 1980s (Gyasi et al. 1995). From the 1920s until 1983, most farmers in the study region cultivated cocoa and coffee. Food production remained a secondary but significant economic activity. Clearing frontier land for food production did not ensure private ownership because after fallow any member of the family could cultivate the land. Cocoa cultivation, on the other hand, ensured *private ownership* over frontier land since cocoa/coffee are perennial crops. By putting family land into private hands, cocoa cultivation helped shape the existing land ownership system which is at the heart of food farming in the region (section 6.41).

During the cocoa/coffee era most of the forest vegetation was cut down and replaced with tree crops. A typical cocoa/coffee farm was a mixture of the tree crops and shade trees. In addition to its physical resemblance to forest vegetation, this mixture of crops and trees also had some of the advantages of a forest vegetation, such as prevention of soil erosion. The negative effects of tree crop farming on the ecosystem was not felt immediately because tree crops mimicked the forest vegetation. Nevertheless, the replacement of the forest vegetation with tree crops, marked the beginning of a persistent deforestation. Because large tracts of the land were allotted to cocoa cultivation, the pressure on the fallow lands increases leading to shorter fallow periods. Consequently, more frequent cropping and less fallow, the vegetation on the food crop land was invaded by the savanna vegetation. The declining rainfall, droughts and the flammable savanna vegetation resulted in the bushfires in the early 1980s which not only destroyed most of the tree crop farms, but also made tree crop rehabilitation difficult and risky. As a result, most farmers changed to food crop production as their major economic activity. Before the bushfires, the area had already become the major food-producing zone for the urban markets, displacing the southern transition zone in the 1970s as the major food producing area for the home market (Amanor 1995:36). Traditional farming methods on smallholdings with an average size of 1 to 4 hectares are the main means of food production in the area, though there are a few large-scale private farmers in the region as well.

## 1.6. SURVEY METHODS

### 1.61. Time Frame for the Research

The research is focused on the period from 1970 to 1995. This time frame is significant because the 1970s marked the period when the effects of degradation of the agro-ecological environment began to be seen in the decline of cocoa production, which was the

main farming activity in the area. For the purpose of comparison, the time frame is divided into two periods: the decade before 1983 (1973–1983) and the period after 1983. The year 1983 marks a watershed in farmers' activities because in this year bushfires destroyed most cocoa and coffee farms. Most farmers therefore shifted from tree crops to food crops cultivation as a response to the changing biophysical environment which did not favor tree crops. Since 1983 marks this transition, it provides a reference point for farmers to compare their agricultural performance to determine the success or otherwise of the change to food crops and other adaptive responses to the biophysical environmental changes.

#### 1.62. Data Collection and Analysis

Most of the data for this study were collected from March to June of 1996. Two main types of data were collected: biophysical variables; and data from a questionnaire survey. The data on the biophysical variables – rainfall, temperature, soil, and vegetation cover – were used to measure the present conditions and trends of the agro-ecological environment. Temperature and rainfall data were extracted from the Ghana Meteorological Services Department's records. To assess the soil quality, soil samples collected from the field were analyzed in the laboratory. References were also made to the relevant literature and official statistics.

The questionnaire survey explored farmers' responses to changes in the biophysical variables. The timing – March to June – of the formal and informal questionnaire survey and visits to farms, coincided with the major farming season (Table 1), offering the opportunity to observe some of the farming practices and a range of other options available to the farmer. The rapid rural appraisal approach (RRA) was a major tool for the formal and informal questionnaire survey. The technique involved identifying and

learning from key informants – social workers and community leaders, direct observation, informal interviews — and asking questions about what was seen (Barnett, 1979, Chambers 1981; Longhurst 1981a; Rhoades 1982; Oxfam 1980). In addition to opening up the research to leads other than those which were directly sought, this approach allowed the focus of the research to be expanded to include what was noticed and considered relevant to the research. The approach also generated other information that was beyond the scope of the structured questionnaire. In a rural area such as Wamanafo where record-keeping was virtually non-existent, the approach was a fast and cost-effective way to gather preliminary information to serve as the starting point for the field work. The informal nature of the technique – unscheduled visits, walking with the farmers and asking about things that were seen, not having a special planned program and avoiding the impression of being interested only in specific information in the community – all reduced the suspicion the farmers might have had of why I was interested in only particular information (section 1.642). By these means, the dangers of misleading impressions and responses from the farmers were minimized.

Though the RRA method offered a quick and an inexpensive way of collecting valuable data, the verification of each piece of information and the identification of interconnections among the various data required a more detailed study, involving more time and financial resources, beyond the scope of this research. Moreover the informal nature of the technique makes it difficult to gather information in a manner that allows for a rigorous statistical measurements. The use of this method as one of the tools for data gathering and appraisal was not an attempt to detract from the importance of statistically rigorous research. Rather, RRA was one method which fitted the resources, problems, needs and data availability of the area under study (section 1.33).

### 1.63. Village Selection

Since the human and financial resources to study all farming settlements in the FSTZ were beyond the means of this research, and since farmers in the general study area were responding to similar environmental problems in their farming activities, one settlement which embodied the farming characteristics of the study area was chosen for detailed study. The selection of the settlement was based on a set of criteria that enabled the exploration of the specific objectives of the research. Among other things the settlement should:

- have a relatively large population (over 3000), most of whom have farming as their main economic activity;
- have food crop farming as the main farming activity, though tree crop farming could still be an important activity;
- have a significant number of farmers experimenting with, and evolving new regenerative technologies in response to the environmental changes which affect agricultural production in the region;
- have farmers who cultivate most of the major crops grown in the general study area should;
- have a significant number of farmers relying on traditional methods of farming.

Any agricultural community in the general study area which satisfied these conditions was assumed to be an appropriate representative settlement for the general study area, and could be studied to show how farmers were adapting to the general environmental conditions in the FSTZ. Since the study involved interviews and discussions with farmers who did not speak English, it was expected that in addition to satisfying the above criteria,

the settlement also spoke the dialect (*Akan*) which was familiar to me. Informants' tips and answers to informal interviews provided the leads to settlements which met these criteria. Using this process, Wamanafo was chosen for a detailed study (Figure 1.8).

Wamanafo is a farming community founded around 1854 by farmers and hunters escaping from inter-tribal wars in the central part of Ghana. When cocoa was introduced in the early 20th century, many of the settlers moved from subsistence food crops and hunting into cocoa farming. In 1960 the population of Wamanafo was 2 723. The population increased to 3 440 between 1970 and to 4 821 in 1984 (Government of Ghana 1984). At present, the population is estimated at 6 500, assuming a growth rate of 3% per annum<sup>9</sup> since 1984.

The community is served by five elementary schools, three junior secondary schools, a senior secondary school, and a maternity home. The nearest hospital is 21 Km away. The sources of domestic water are a pipe-borne water, natural springs and bore-holes. Because Wamanafo is a nodal settlement, trading is an important economic activity in the community. There are five villages within an eight kilometer radius of the settlement. The residents of these villages come to sell their produce and to buy other needs on market days (Sundays). The market attracts traders from the nearby towns such as Dormaa Ahenkro, Wamfie, Berekum and Sunyani who buy most of the farm produce and retail it in the urban markets.

In addition to Wamanafo, I visited five farms in Wenchi, and had group discussions with eight farmers (Figure 1.8). The purpose of these visits and discussions were to identify any differences there might be in the responses of farmers to agro-environmental changes in other areas in the general study region. Wenchi was chosen for this purpose since it has

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<sup>9</sup> The average annual growth of population for Ghana between 1989 and 2000 is estimated at 3% per annum (World Bank 1992:268)

soil and vegetation characteristics that are different from those of Wamanafo. Since Wenchi is nearer the savanna zone, its vegetation has more grass than the one in Wamanafo. Moreover, the soil in Wenchi belongs to the savanna ochrosol group of soils while the soil in Wamanafo is forest ochrosol (Figure 1.10)..

#### 1.64 Questionnaire Survey

##### 1.641 Questionnaire design

The main objective of the questionnaire survey was to identify and evaluate how farmers were responding to environmental change at the farm level. A draft questionnaire designed to explore farmers' adaptive techniques in response to the major biophysical variables that influence agricultural productivity in the study area—rainfall and temperature, soil fertility, and vegetation cover— was pre-tested on 15 farmers from the settlement. The questionnaire also explored the major constraints to farmers' efforts and how farmers perceive their performance now compared to the period before 1983. On the basis of the results of the pre-testing, direct observation and informal interviews of key informants such as agricultural extension officers, the draft questionnaire was revised to accommodate new questions, and to eliminate irrelevant ones (Appendix 3).

##### 1.642 Sampling methods

The target population for the interview was all farmers in the chosen settlement. Since all of the farmers faced similar environmental and socio-economic conditions in their farming activities, they made a homogeneous group. It was therefore assumed that a sample of 100 farmers randomly chosen would sufficiently reflect the farming characteristics of all

farmers in the settlement (Echardt and Ermann 1977:161). The sampling process further assumed that there was at least one farmer in each household<sup>10</sup>.

A simple random sampling approach was used to select 100 households as the basic sampling units. The house number of each of the 401 houses in the settlement was written on a separate piece of paper. The 401 pieces of paper were put together and 100 of them were picked at random. The houses corresponding to the selected numbers were chosen for interviews. In each household, the first available farmer was interviewed; however, preference was given to the head of the household if s/he was in the house at the time of the visit. The head was preferred because s/he would have more experience in farming. In the absence of the head, anyone in the house who was a farmer was interviewed.

There was a non-response rate of 22% as a result of a number of factors, the most common of which was people's suspicion that I was a secret agent sent by the government to spy on them. This suspicion stems from the distrust of the community, especially the illiterate farmers, of government officials, some of whom did not treat the farmers fairly in the past. Whenever there was a non-response, I chose, for interview, any one of four houses immediately adjacent to the sampled house, and whose number was numerically closer to the sampled house.

#### 1.643 Interviews

The revised questionnaire was administered in face-to-face interviews to the 100 sampled farmers. By the face-to-face interview, I was able to explain the questions in detail to the farmers, and to ask other relevant questions arising from their answers. In each house

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<sup>10</sup> *Household* is operationally defined as one or more families and their dependents sharing the same house or compound. Usually the different families in a household belong to the same extended family.

there was a group discussion component to the interview. More often than not, other farmers in the household would sit around to listen and to contribute by refreshing the memory of the interviewee. Even though other members in a household helped the respondents to remember their answers, the questionnaire was administered to, and had the responses of, only one respondent. At the end of the interview the respondents were encouraged to offer any other information on environmental problems affecting their farming activities, how they were responding to them, and what could be done to support their efforts. The other farmers in the household also participated actively in the informal discussions on trends in the agro-ecological environment and how they were responding to these trends. Since mail and telephone survey methods were inapplicable because most farmers were illiterate, and telephones were non-existent in the area, the face-to-face interview was the most relevant method in the study area.

The information obtained from the questionnaire survey was supplemented by three informal group discussions with farmers and some community leaders in the village. Each of the three meetings was attended by 20-30 people, some of whom had been interviewed in the course of the survey. Visits to 15 farms also offered an opportunity to observe some of the adaptation techniques farmers mentioned in the formal and informal interviews.

#### 1.65 Determination of Biophysical Trends

##### 1.651 Rainfall and temperature trends

Records from Wenchi and Sunyani meteorological stations were analyzed for rainfall and temperature trends in the general study area (Chapter 4). These stations were chosen because their climatic characteristics are similar to Wamanafo. In addition, they were among the few meteorological stations in the study area that had consistent records dating as far back as 1931. For the purpose of comparison of changes in climate, temperature

and rainfall trends for two thirty-year periods (1931 to 1960 and 1961 to 1990) were analyzed. A thirty-year period was considered because it is the World Meteorological Organization's (WMO) time frame for the determination of average climatic values for a region (Houghton et al. 1996:30). In the analysis, temperature and rainfall trends were expressed relative to 1961-1990 averages — the official reference period used by the World Meteorological Organization and member states (Houghton et al. 1996:30). Since data on temperature for the two stations go back to 1958, temperature trends were analyzed relative to the 1979-1994 average — the average used by the IPCC to assess global and regional temperature trends (Houghton et al. 1996:148). The use of the same reference periods as the IPCC to analyze temperature trends in the FSTZ also allows easy comparison between the temperature trends in the FSTZ and trends in other areas.

#### *1.6511 Rainfall trends*

Since food crop farming in the study area is rain-fed, rainfall trends and variability determine the viability and productivity of farming systems in the region. To determine whether rainfall was declining or increasing, monthly rainfall values were summed up to give the yearly values from 1931 to 1995. The yearly rainfall anomaly from 1931 to 1995, relative to the mean rainfall for 1961-1990, was then calculated. Rainfall trends were estimated by regressing the yearly rainfall anomaly values (from 1931-1995) on the respective years<sup>11</sup> using the simple linear regression equation:

$Y = a + bX$  where:

$Y$  = the rainfall amount in any year

$a$  = the  $Y$  intercept

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<sup>11</sup> Since 1931 is the starting point for analysis, 1931 has a value of 1, 1932 = 2 1933 = 3 ..... 1995 = 65.

$b$  = the regression co-efficient

$X$  = any value of the  $X$  variable (footnote 11)

The difference in decline or increase in rainfall amounts from 1931 to 1995 was computed by finding the difference between the  $Y$  value in 1931 and the  $Y$  value in 1995. The  $t$ -statistic was calculated as a measure of the statistical significance of the slope coefficient ( $b$ - coefficient) of the observed trend line. The  $t$ -test was carried out to determine whether the linear trend for rainfall was statistically different from 0 mm, when taking into account the variability characteristics of the rainfall data. The test was carried out on the following assumptions:

- (a) Hypotheses to be tested:
- i. Null hypothesis ( $H_0$ ): The slope co-efficient ( $b$ ) is not statistically different from 0, when taking into account the variability characteristics of the rainfall data ( $H_0: b = 0$ )
  - ii. Alternate hypothesis ( $H_A$ ): The slope co-efficient ( $b$ ) is statistically different from 0, when taking into account the variability characteristics of the rainfall data ( $H_A: b \neq 0$ )
- (b) Level of significance: 95% confidence level. That is, there are only about 5 chances out of 100 that the assessment of the significance of the trend is in error.
- (c) Decision rule:
- i. Reject null hypothesis and accept alternate hypothesis if absolute value of  $t$ -calculated  $> t_{0.025}$  at  $n-2$  degrees of freedom (df)
  - ii. Accept null hypothesis and reject alternate hypothesis if absolute value of  $t$  calculated  $< t_{0.025}$  at  $n-2$  degrees of freedom (df)

### *1.6512 Measure of trends in rainfall distribution*

Annual rainfall amounts are important, but its equitable distribution throughout the year, especially in the farming season, is even more important, since food farming in the study area is rain-fed. Yet, the rainfall pattern in Ghana is characterized by seasonality, and variability from year to year (Ofori-Sarpong 1986). The precipitation Concentration Index (PCI) is used to measure the trends in the seasonal distribution of rainfall.

The PCI is estimated by the equation;

$$PCI = 100 \frac{\sum X^2}{(\sum X)^2} \quad \text{where } X = \text{rainfall for each month of the year.}$$

Theoretically, the PCI ranges from 8.3 for equal monthly increments, to 100 for the extreme monthly distribution. A PCI of less than 10 suggests a uniform distribution while values between 11 and 20 denote a tendency towards seasonal distribution. An index above 20 represents a marked seasonal difference (Oliver 1980). But still more important to farming is the length of the farming season, which is the length of time between the beginning of the planting season – marked by the first time in the year when the moisture index (MI) becomes positive – and the end of the farming season – marked by the first time in the year that the MI becomes negative.

### *1.6513 Estimation of shifts in the length of the farming season*

Since the farmers have no irrigation systems, they start planting most of their crops only when the net water balance is positive. Significant shifts forward or backwards in the time when the water balance becomes positive can shorten or lengthen the farming season, with serious consequences for crop yield. Average monthly precipitation (P) and potential evapotranspiration (PET) values for 1931 - 1960 and 1961 - 1990 were used to estimate

any shifts in the beginning and ending of the planting season and therefore in the length of the farming season.

To estimate these shifts, the average monthly rainfall for each month in the year for the periods 1931 - 1960 and 1961 - 1990 were taken. The average PET values for each month for the same periods were extracted from the records of the Ghana Meteorological Services Department (Appendix 5). Monthly water balance was determined by the difference in the average monthly PET and average monthly precipitation (P) for the respective periods. The monthly water balance diagram for 1961 - 1990 was superimposed on the water balance diagram for 1931 - 1960. Both diagrams were then compared and contrasted to determine any shifts in the commencement and ending of the farming season.

#### 1.6534 *Temperature trend*

Increasing temperature means increased evapotranspiration. The effects of high evapotranspiration can be detrimental to crops if the increased evapotranspiration is not accompanied by more rainfall. To estimate the temperature trends, the mean monthly temperatures ( $^{\circ}$  C) for each year were summed up and averaged to give the respective yearly mean temperatures (Appendix 4). The temperature anomaly for each year was then computed by finding the difference between the mean annual temperature value for each year, and the mean temperature for 1979 to 1995. Yearly anomalies were regressed on the respective years. Temperature trends were determined by regressing the yearly temperature anomalies on the respective years (1957 - 1995).

The change in temperature over the period was computed using the equation for the simple regression line:

$Y = a + bX$  where:

$Y$  = the temperature in any year

$a$  = the  $Y$  intercept

$b$  = the regression coefficient

$X$  = any value of the  $X$

The degree of change in temperature since 1957 is the difference between the  $Y$  value in 1957 and the corresponding  $Y$  value in 1995. The  $t$ - statistic was calculated to test the statistical significance of the slope coefficient ( $b$ - coefficient) of the observed trend line. The null hypothesis – that the observed linear trend of temperature is statistically different from  $0^{\circ}$  C, when taking into account the variability characteristics of the temperature data – is tested using the assumptions and criteria in Section 1.6511 above.

#### 1.652 Trends in vegetation cover

More frequent cropping and less fallow resulting from population pressure are mainly responsible for changes in plant cover. Characteristics of the plant cover that dominate a soil are, to a considerable degree, determinant of the soil's organic content, structure, fauna, and nutrient recycling capability and, therefore, the soil's production potential (Goudie 1996:29). The determination of the extent of degradation in the vegetation was done visually. Since the average fallow period in the study area is three years (section 6.221), the mix of vegetation on land that had been left fallow for three years was compared with a secondary forest that had fallow for 15 years, to determine the extent of degradation in the former. Farmers were interviewed on what changes, if any, they had observed in the vegetation mix, especially since 1983, and to identify some of the advantages and disadvantages of the newer weed species in the region. The corresponding scientific terms for the local names of trees and shrubs were taken from a

botanical book on local plants – “Useful plants of Ghana” (Abbiw 1990; Appendix 2). Because the main method of soil regeneration in the farming system was by bush fallow, it was expected that changes in vegetation cover would also affect soil quality.

#### 1.653 Measuring soil quality

To determine the level of soil fertility in the study area, soil samples from the field were collected and analyzed in the laboratory, under the guidance of the Soil Research Institute (SRI) in Kumasi. Differences in vegetation cover were used as the criteria for soil sampling, since plant resources are indicators of the state of soil efficiency and productivity; and since changes in type of plant cover can lead to modification of soils (Goudie 1996; Dennis 1995; Young 1976:41). Three soils under different vegetation cover were sampled for analysis:

1. soil under virgin forest<sup>12</sup>. This sample served as the control against which the fertility of other soils could be checked;
2. soil which had been under plantain and cassava inter-crop for three continuous years – the average cultivation period after which a field is left to fallow (section 5.45). This sample was used to test the level of soil fertility after three years of cultivation;
3. soil which had been under *Chromolaena odorata* plant for three years. This sample was used to estimate the level of soil fertility, after three years of fallow under the dominant weed in the area.

Three year fallow period was chosen because it is the average fallow period prevailing in the area (preliminary interview with farmers; section 6.221). Fallow under *C. odorata* plant

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<sup>12</sup> In the soil analysis virgin forest is operationally defined as a secondary forest that is over 25 years old the ideal fallow period needed to sustain and vegaetation and soil quality in the FSTZ

was chosen because of its alleged fertilizing effect. The nutrient status of this soil category is therefore a reflection of the average fertility levels of soils in the study area.

#### *1.6531 Soil sampling and analysis*

Sampling and analyses from a sufficiently large number of cores to obtain means and confidence limits of all layers involve substantial time and expense which are beyond the means of this research. The *composite sampling* method was therefore used to collect soils for laboratory analyses. The procedure of collecting *composite samples* consists of taking a number of samples adequate to represent the soil under study, and thoroughly mixing them in a sample bag to form one sample. A sub-sample of this composite sample is then taken for laboratory analyses (Crepin and Johnson 1993:12; Young 1976:366; Petersen and Calvin 1965:70; Table 1.3).

Composite samples are the samples common for agricultural advisory purposes such as this research (Young 1976:366). Analysis of composite samples offers a cost-saving but efficient measure of soil fertility. It gives reliable information about mean<sup>13</sup> values of soil properties (Petersen and Calvin 1965:71). The precision with which the mean values of composite samples are measured can be increased by increasing the number of units included in the sample (Crepin and Johnson 1993:6; Young 1976:366; Petersen and Calvin 1965:70).

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<sup>13</sup> The mean is the most familiar and important statistic in soil science (Crepin and Johnson 1993:12).

**Table 1.3. Sample Frame for Soil Fertility Analysis**

Soils	Depth (cm)	Sample Size (n)	Total Weight of soil sampled from 40 cores (g)	Weight of composite sample for laboratory analysis (g)	Number of composite samples sent for laboratory analysis
Virgin forest soils	0 - 2	40	4000	500	1
	2 - 20	40	4000	500	1
	20 - 40	40	4000	500	1
Soil under plantain and cassava inter-crop	0 - 2	40	4000	500	1
	2 - 20	40	4000	500	1
	20 - 40	40	4000	500	1
Fallow soil under <i>C. odorata</i>	0 - 2	40	4000	500	1
	2 - 20	40	4000	500	1
	20 - 40	40	4000	500	1
<b>Total</b>		<b>360</b>	<b>36,000</b>	<b>4,500</b>	<b>9</b>

Source: Author's Field Survey

The plots from which the soils were collected were adjacent to each other on moderately undulating ( $5^{\circ}$  - $10^{\circ}$ ), well drained land approximately 330 meters above sea level. Using the T-auger, the samples were collected randomly at regular intervals of 20 meters along a zigzag-track (that was marked and cleared of weeds) across each of the one-hectare plots. Since the nutrient conditions at various root limits differ, three layers of the soil were sampled on each plot: the top 2 cm, 2 - 20 cm, and 20 - 40 cm (Table 1.3). At each core, three separate samples, each corresponding to one of the three layers, were collected. In all, forty<sup>14</sup> cores were made on each plot and 120 samples collected on each plot (Table 1.3). The 40 samples, collected for each layers, on each hectare were thoroughly mixed and quartered until a representative 500 g composite sample was obtained. In all, nine-500 g composite samples, corresponding to each of the three layers on the three different plots, were sent for laboratory analysis (Table 1.3).

The composite samples were tested for their physical properties such as soil texture, and their chemical properties such as pH level, carbon nitrogen ratio (C:N), organic carbon content, and nitrogen and phosphorous levels (section 4.3; Appendix 6). To determine the level of soil degradation, the means of the chemical and physical properties of the two soil samples under fallow were compared with the physical and chemical properties of the virgin soil (Young 1976:300). Since the virgin forest soil reflects the original states of the other soils before they were cultivated, it is assumed that the closer the properties of a soil sample are to the virgin forest soil the better the soil is (section 4.322). Because the *C. odorata* soil was left to fallow after three years of cultivation, it is also assumed that its nutrient status, at the time it was left to fallow, was similar to the

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<sup>14</sup> It is estimated that a composite sample made from 40 cores on a hectare provides a 95% confidence level that the actual population mean is within two standard errors of the sample mean (Dennis 1995:7; Crepin and Johnson 1993:6).

nutrient status of the soil under plantain and cassava inter-crop for three years<sup>15</sup>. The *C. odorata* soil was, therefore, compared to the plantain and cassava soil for any changes there may be in soil quality as a result of three years of fallow.

For the determination of soil conditions in the general study area, only one set of samples collected on three sites was analyzed (Table 1.3). These samples were taken from fields that reflected the average conditions in the general area. The results of the fertility tests are therefore assumed to reflect the average soil conditions in the study area (section 1.653). However, there were a significant number of fields that were more degraded than the ones that were sampled. Similarly, there were fields which were in better conditions than the ones sampled. The results of the analyses, and hence the conclusions from the analyses, could have been more representative of the general study area if more sets of soil samples from plots in different conditions and locations in the study area had been analyzed. Such samples would have made it possible to estimate the variability in soil conditions in different parts of the region (section 1.653). The conclusions from such analyses would have been more representative of the average soil conditions in the FSTZ.

#### 1. 66 Methods for Analysis

The fieldwork generated both interval and nominal variables, which call for different methods of analysis. Inferential statistics (regression analysis, and t-tests) were used for the analysis of rainfall and temperature trends, since these were interval variables. On the other hand, descriptive statistics (frequencies, means) and chi-square tests were used for the analysis of data from the questionnaire survey. Since the farmers did not keep records

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<sup>15</sup> The same farmer own the fallow plot as well as the intercrop plot. According to this farmer, both plots have the same cropping history. That is, the fallow plot is cultivated every three years with the same crops that are cultivated on the intercrop plot. Moreover, the same farming methods are used on both plot.

of their incomes and production, it was impossible to generate ordinal, interval, or ratio data from their responses with respect to these variables (section 1.33). The responses to some of the questionnaire were also necessarily qualitative rather than quantitative. It is acknowledged that rigorous statistical analysis could have provided more information, but the realities in the field were such that it was impossible to get data that would allow such rigorous measurements (section 1.33). Consideration of the nature of the responses (mostly nominal), reliability of conclusions drawn from the responses, and the need in this research meant that descriptive statistics made most sense in the analysis of farmers' responses to environmental change.

Analyses for both sets of variables are presented as frequency tables, bar charts, and linear graphs. Relevant pictures of adaptation strategies, farming methods, and environmental conditions are also used for illustration and emphasis. A primary purpose of the analysis was to determine the success or otherwise of farmers' response to the changing biophysical environment. An indicator used for this determination is how farmers perceive their overall agricultural performance in 1996 as compared to the pre-1983 period. If farmers see their agricultural performance (production and income levels) as better now than before 1983, then their adaptation is assumed to be successful. The adaptations are judged to be unsuccessful if their answers are negative. Other indicators of the success or failure of adaptation are extrapolated from the farmers' responses as to whether they see their general well-being, housing, diet, children's education etc., as improving or otherwise. These are appropriate surrogate measures of the success or otherwise of farmers' adaptation, since farming is the main source (and in most cases the only source) of livelihood for the farmers.

## 1.7 THE ORGANIZATION OF SUBSEQUENT CHAPTERS

Chapter Two is devoted to a review of the literature dealing with global climate change and its implications for agriculture in the West African sub-region. It also reviews the theories and concepts of adaptation, as well as the literature dealing with indigenous farming technologies, in the light of climatic and environmental changes taking place in the West African sub-region. Chapter Three assesses the strengths and weaknesses of existing farming systems in Ghana with respect to the resiliency of the agro-ecosystem. Chapter Four is an analysis of trends in the three environmental factors — soil fertility, climate (rainfall, temperature) and vegetation cover — that directly affect food production in the study area. The adaptive and experimental innovations farmers are using in response to these trends are the subject of Chapter Five. Chapter six is an evaluation of the adaptation strategies identified in Chapter Five. It assesses whether farmers' adaptive strategies have been a success or a failure. The chapter also examines the potential of the adaptation strategies to increase food production in the face of the trends in the three major variables affecting food production. The major constraints to the smallholder farmer's response to trends in the biophysical environment are also discussed in this chapter. Chapter Seven is the concluding chapter. It is devoted to a summary and discussions of the major conclusions of the thesis. It also outlines some of the possible adaptation strategies that could be implemented, and research that could be done consequent to this study to address some of the major constraints to agricultural adaptation in the FSTZ.

## **2.0 CLIMATE CHANGE AND ADAPTATION**

This chapter is a review of the literature on the impact of climatic change on West African agriculture. It also explores the concept of adaptation, with special reference to the smallholder farmer's interaction with changes in the biophysical environment.

### **2.1 GLOBAL CLIMATE CHANGE**

In recent years there has been a growing interest regarding human interactions with climatic change, particularly in the area of agricultural adaptation. This interest is in response to growing awareness of the effects of the increasing atmospheric concentrations of carbon dioxide and other radiatively active trace gases such as methane, nitrous oxide, tropospheric ozone, and chlorofluorocarbons (Wheaton 1994; Rosenzweig and Iglesias 1994; Handel and Risbey 1992; Downing 1992:32; Henderson-Sellers 1991a). While some land areas have cooled, the average global surface temperature has warmed by 0.3 to 0.6° C since the mid-19th century and by 0.2 to 0.3° C in the last 40 years. Most of this warming has occurred over continents lying between 40° and 70° N (Houghton et al. 1996) and has been concentrated in the period since 1975 (Parry 1990). The five warmest years in the century occurred in the 1980s (Houghton et al 1996:137). Furthermore, the results of climate models show that if no further action is taken to curb the emissions of greenhouse gases, there could be an increase of 0.8 to 3.5° C in the average global temperature by the year 2100. Despite whatever action is taken to curb emissions, the world still faces a further average temperature increase of 0.5 to 2° C as a result of the effects of radiative gases already emitted into the atmosphere (IPCC 1990:4). The available evidence is inconclusive as to whether global warming is a function of natural variability; or of chemical emissions due to human activity; or whether the warming is a combination of both factors.

Similarly, there is not enough information to determine whether natural variability in the climate is offsetting human induced global warming, or whether chemical emission, due to human activity, is promoting a faster, natural increase in global temperatures. The general consensus of the experts is that the warming of the last century, and especially of the last few years, is unlikely to be entirely due to natural causes; and that a pattern of climatic response to human activities is identifiable on the climatological record (Houghton et al. 1996). An enhanced greenhouse effect may lead to substantial changes in hydrological regimes such as increased evaporation, drought and alterations in precipitation patterns (Houghton et al. 1996:152; Taylor et al. 1990). For example, while there has been a positive (1%) global increase in precipitation during the 20th century, mostly in the extra-tropical areas, there is a trend towards decreased rainfall in most of the tropics and subtropics of Africa (Houghton et al. 1996:137).

## 2.2 AGRICULTURAL IMPACT OF CLIMATE CHANGE

Climate change driven by an increase of greenhouse gases, mainly carbon dioxide, may affect crops in one of two ways. First, since crops need carbon for photosynthesis, an elevated carbon level may enhance net photosynthesis because more carbon dioxide tends to enter the leaves of plants when the atmospheric concentration goes up (Wolfe and Erickson 1993:154). The increased carbon dioxide concentration can also cause a partial closure of stomata, thus, making water use per unit leaf area more efficient (Pearcy and Bjorkman 1983). These two factors – enhanced photosynthesis and increased water use efficiency – may induce increased crop yield and help plants resist the impacts of temperature increase (Strain and Cure 1985; Wolfe and Erikson 1993). Conversely, the increase in temperature and the changes in the precipitation pattern can lead to excessive transpiration. This situation can adversely alter the growth and development of crops by

causing wilting and reduction of crop yield (Wolfe and Erikson 1993; Idso 1990; Gourdiaan and Unsworth 1990). Alleviation of these effects would require extensive irrigation systems, new breeds of crops, and other capital-intensive technologies (Wolfe and Erikson 1993). Poorer underdeveloped nations which cannot afford these resources stand to be worse-off than they are today (Rosenzweig and Iglesias 1994; Rosenzweig et al. 1993; Bazzaz and Fajer 1992).

Studies on the implications of climate change for world agriculture show that negative effects on crop yields in mid- and high-latitude regions are less than in the low latitude regions where most of the developing countries are located (Rosenzweig and Iglesias 1994; Bazzaz and Fajer 1992; Downing 1992). For example, when adaptations at the farm level such as change in planting date, switch of crop variety, and changes in fertilizer application and irrigation were tested, recovery from the detrimental effects of climate change was found to be more successful in developed countries than in developing countries (Rosenzweig and Iglesias 1994; Rosenzweig et al. 1993; Bazzaz and Fajer 1992). It is therefore expected that the most severe negative effects of climate change will occur in the present-day high vulnerability regions that are least able to adjust technologically to the changes. Especially vulnerable are the countries whose social and economic systems still depend very heavily on agriculture (Chiotti and Johnston 1995; Tegart et al. 1990; Parry 1990; Taylor et al. 1990). These findings have adverse implications for the West African sub-region since the economies and social systems of the countries in the region are based on agriculture.

## 2.21 Climate Change Impact on West African Agriculture

West Africa is one of the regions most vulnerable to the shocks of climate change (Rosenberg 1992). Though considerable uncertainty is attached to the GCM estimates of

trends in precipitation in the West African sub-region up to the year 2030 (Houghton et al 1996:137). Available results of General Circulation Models (GCMs) on climate change show that expected warming in the West African sub-region in the next century, ranges from 1-3° C. In summer, area mean precipitation increases in the region but area mean soil moisture decreases though there are areas of both increase and decrease in these parameters throughout the region (WMO and UNEP 1990:19).

With regards to recent trends, several independent climatological studies in the region point to a trend towards increasing aridity and a rainfall pattern characterized by fluctuations and low periodicity (Amanor 1995; Adejuwon et al. 1990; Farmer and Wigley 1985; Dennet et al. 1985; Nicholson 1985; 1983; Hutchinson 1985; Ogallo 1979; Ayoade 1973). The historical climatology of the region shows a pattern of long-term cycles of dry and wet periods, with drier periods in which major droughts occur, such as during 1738-56, and 1800-30 (Nicholson 1994a, 1994b, 1981; Ofori-Sarpong 1987; Marion 1974; Grove 1973). In this century, a dry period occurring from 1900-1920 was succeeded by a wet period peaking between 1940 and 1960, followed by a dry cycle in the 1970 and 1980s (Nicholson 1995). The difference between this century's cycle of rainfall and that of previous centuries is that this century's dry periods have occurred with a more pronounced overall trend towards desiccation in which for instance, the levels of lakes and discharges of rivers have fallen below 18th and 19th century values (Houghton et al. 1996:155; Amanor 1995:194). Periods of drought have been more frequent in the sub-region since the late 1960s (Davies 1996; Parry et al. 1988). Rainfall in the region from the late 1960s to 1993 was well below that received earlier in the century, and the amounts received in the last few decades were about half the amounts received in the 1950s (Houghton et al. 1996:155). Thus, the debate on the climate of West Africa is not whether there is a downward trend in rainfall, but whether human interaction with the environment has broken

the cycle of alternating dry periods and wet periods, so that there is now a persistent trend towards increased aridity.

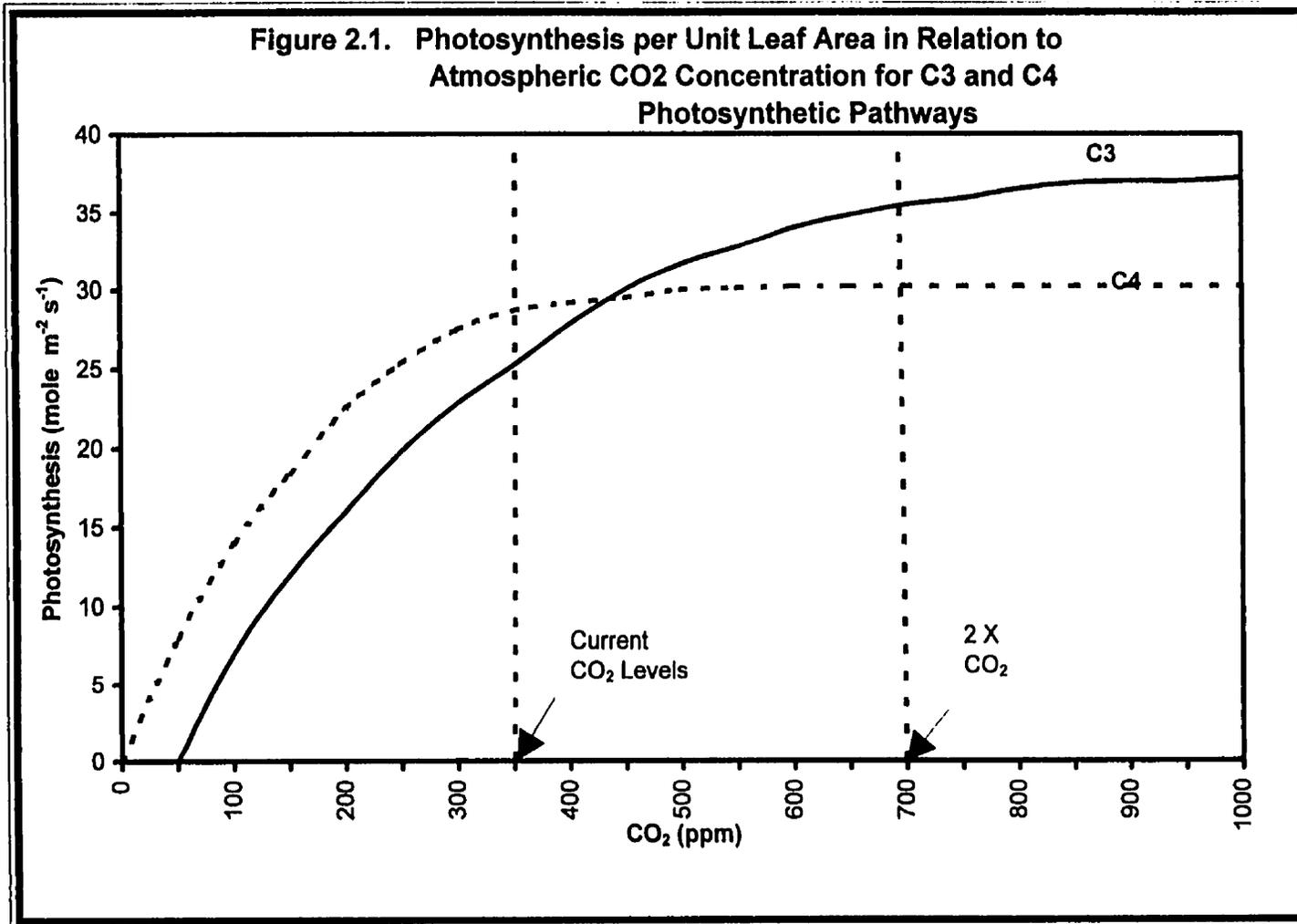
A number of factors have been suggested for the persistent trend towards desiccation in the West African sub-region. Some attribute the trend to the continued human disruption of the natural ecological balance (Ofori-Sarpong 1986; Section 2.1). Others explain the occurrence of droughts in the region in terms of the expansion of the circumpolar vortex which has pushed the subtropical high nearer the equator. The southward expansion of the circumpolar vortex checks the northward penetration of the Inter-tropical Discontinuity (ITD) which is responsible for rainfall in West Africa (Windstanley 1973; Lam 1966; Section 4.11). The warming of the equatorial East Pacific (El Niño), since the middle of this century, has also been suggested as the reason for rainfall decline and droughts in the West African sub-region and other tropical areas (Houghton et al 1996:153). Associated with the longitudinal circulation in the tropics, the El Niño events of 1972-1973 and 1982-1983 and more recent El Niño events have coincided with extreme summer droughts in West Africa. The present general decline in rainfall may, therefore, reflect the recent relatively frequent El Niño episodes. More recently, the scientific community has explained changes in rainfall patterns in the West African sub-region as part of the induced global climate change due to increased emission of carbon dioxide and other greenhouse gases (Houghton et al 1996).

The explanations offered above for rainfall decline in West Africa and the study area are theories. The exact reasons for the upward trend towards aridity in the sub-region are unknown. Some of these explanations are examples of how patterns of global resource use and natural factors outside the control of a locality can impinge upon and affect ecological processes within the locality. For a region where rainfall is the single most important factor determining agricultural production, decreasing rainfall and the possibility

of deficits of soil moisture are a matter of great concern because in this area the amount of water received and stored in the soil is more important than surface air temperature. Food production in West Africa is not likely to benefit much from the carbon dioxide-induced higher temperatures and the associated fertilizing effect because most common crops grown in the region, such as maize, millet, sorghum, sugarcane, and many pasture forage crops are C4, as opposed to C3 crops<sup>16</sup> (Figure 2.1). Since C4 crops do not do well in the tropics, emphasis on the few C3 crops, such as rice and soybeans, is one of the few ways the tropical regions can benefit from the carbon dioxide fertilizer effect. Studies on the projected climate changes in West Africa indicate that there could be a decline in food supply in the sub-region not only because most major crops are C4 but also because countries in the sub-region, as with other poor developing regions, cannot afford the technology and resources that can mitigate the effects of projected climate changes (Parry 1990; Rosenzweig and Iglesias 1994; Muchena 1994; Rosenzweig et al. 1993; Downing 1992; Wolfe and Erikson 1993; Parry et al. 1988, vol. 2).

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<sup>16</sup>The names C4 and C3 refer to whether the early products of photosynthesis in a plant are compounds with three or four carbons. C3 crops, such as soybeans, wheat, and rice tend to show significant gains in net photosynthesis from increased carbon dioxide because of photorespiration inhibition, a process by which the plant absorbs oxygen and releases carbon dioxide (Figure 2.1). On the other hand, C4 pathways of carbon fixation, which are common in tropical plants, show much less response to increased carbon dioxide due to their efficient carbon assimilation ability (Norman et al 1995:34-35; Wolfe and Erikson 1993; Parry 1990).



**Notes:**

The two lines represent typical curves for plants with C<sub>3</sub> and C<sub>4</sub> photosynthetic pathways. The exact photosynthetic values will vary from species to species, but generally, C<sub>3</sub> plants will show a greater relative benefit from a doubling of CO<sub>2</sub> compared to C<sub>4</sub> plants

Source: Wolfe and Erickson 1993:155

## 2.22 West Africa on the Losing Side

Some have argued that developed nations can sustain global food supply in a climate change situation by breeding novel strains of grain with higher yield and using other advanced agricultural technology to increase production. The regions with food surplus will then balance food deficit regions such as West Africa through global food trade (Rosenzweig et al. 1993; Kane et al. 1991). This suggestion, however, is a misrepresentation of the likely food situation in many areas in the event of predicted climate change. First, while climate change may not threaten the global food supply, it remains a serious threat to food-deficit regions such as West Africa. The optimism that international trade will be used to distribute global food production to deficit regions squares very badly with experiences from the recent past. For example, only about 15% of total world food production currently crosses national borders and this 15% food export has been to those countries which can pay and not to those which are in desperate need of food (Kane et al 1991; Fischer et al. 1990). Thus, though there is surplus food production in the world today, a nutritional gap of 965 calories per capita per day exists between the developed and developing countries (Tolba et al. 1992:282). The real picture of what could happen in the future food situation was echoed by the United States at the 1996 World Food Summit in Rome, when it stated, among other things, that achieving the right to adequate food was "a goal or aspiration" but not an international obligation of governments (Globe and Mail 1996:A10). The world-wide disparity in food supply has been created and aggravated by a combination of social, economic, environmental, and political factors. There are no indications that there will be any significant changes in these imbalances between rich and poor countries in the future to help countries that are subject to persistent hunger. Hence, there is the likelihood that these poor countries will continue to suffer a similar fate in the face of climatic change. This grim but real situation makes local access

to food far more important than global quantities, yet past attempts to ensure local food self-sufficiency have not been successful.

The Green Revolution package – based on new crop varieties, agro-chemical, and machinery – that transformed the tropics and subtropics, from the Indian subcontinent to South America, passed West Africa by. The package failed in West Africa mainly because the package demanded extensive irrigation and the application of liberal quantities of fertilizers and pesticides (McNamara 1973). The provision of these resources over-stress the West Africa economies and biophysical environments (Adams 1992; Lallement 1986). With its emphasis on cereals, the Green Revolution "has done little for all the multiple alternative ways in which smallholder farmers can extract a higher income from high value production on the small acreage farms typical of most farmers in the region" (Hunter 1978). The Green Revolution package was designed for neither the delicate agro-ecology of West Africa nor the economic conditions and the risk capacity of the smallholder farmers. Researchers have observed that the package was counterproductive since it aggravated rural poverty, undermined food security and damaged the biophysical environment not only in West Africa but also in Latin America (White 1993:106; Adams 1992; Biggs and Farrington 1991; Lallement 1986; Lipton and Longhurst 1989; Hunter 1978). Evidence from long-term trials conducted in Burkina Faso and Senegal shows that recommended fertilizer, tillage and crop rotation packages do not reverse the process of soil degradation, and may under certain circumstances even accelerate degradation (Lallement 1986). From the viewpoint of small-scale farmers in these countries, traditional cultivation practices still appear to be the best for the physical and economic environment of the West African farmer (Lallement 1986:114). Obviously, the appropriate choice of technology to increase crop production should be intimately related to the socio-economic and environmental conditions of a people. Western agricultural paradigms and technology, in this respect, are

not feasible economically, and are environmentally inappropriate for the tropical ecosystems (White 1993:106). For these reasons others oppose the technological modernization of traditional agriculture (Butzer 1990; Denevan 1989). They argue that the solution to present and future food problems is to be found in the smallholders' indigenous farming methods and in technologies that are based on the farmers' long experience of dealing with the agro-ecological environment.

### 2.23 Indigenous Technology and Farmer-First Agricultural Development.

Indigenous traditional knowledge (ITK) as opposed to modern scientific knowledge is variously referred to as peoples' science, ethnoscience, folk ecology, village science or indigenous technical knowledge (Bebbington 1996:89; Baker et al. 1977:2-3; IDS 1979). Two important advantages of indigenous management systems, as far as adaptation to environmental change is concerned, are the coherence with which people in this system understand, perceive and integrate interaction between different phenomena within their environment; and the system's ability to adapt to the changing environment in which it operates (Roach 1994). These factors provide a valuable foundation for improved techniques that are manageable by local people. A recurring theme is that the smallholder farmers' own technical knowledge is far more sophisticated than had been thought and that traditional technology does exist which enables farmers to adapt to environmental change to bring about substantial increases in yields on a sustainable basis (Barracclough 1994:18; Long and van der Ploeg 1994; Carr 1989; Geertz 1983). It has been demonstrated in other places, for example in Senegal, that small-scale, adaptable agricultural development can be extremely productive in agronomic terms (White 1990:157). In most West African countries, priorities in agricultural research have reflected biases against the traditional methods and crops that matter to the local farmers. The

readiness of small farmers to experiment and innovate on their own has been obscured by formal agricultural research, extension officers and communications which are carried out through official organizations. And yet, research shows that innovations which farmers make, often through personal trials, and which are developed with local farmers, are more acceptable, more effective, and more rapidly spread among farmers in the particular locality than the technologies which flow from the results of formal research (Roach 1995:9; Dias 1977:57; Hatch 1976:17).

This is not to agree with other activists who suggest that the appropriate way for an efficient rural development is to base the development *solely* on the local farmers' own techniques and innovation to the neglect of any *external technology* (Butzer 1990; Denevan 1989; Eckholm 1976). Rather, the emphasis on ITK is to show that local peoples' techniques, innovations and experience with the fragile ecosystems in which they operate have often been ignored by *experts* in favor of imported technologies which are unproductive in the special socio-economic and physical environments of the locality (Barracclough 1994:18; White 1993:107). For this reason, most of the pressures for the careless short-term use of soil and forest resources and the stagnating food production in the sub-region cannot be blamed so much on the inefficiencies of the traditional farming system or on the recent climatic changes. Most recent regional and local studies tend to situate agrarian and pastoral problems in developing regions within historical patterns of access to critical environmental resources (Peet and Watts 1996; Jarosz 1996:151-152; Fairhead and Leach 1994; Peters 1994; Bassett and Crummey 1993; Little 1992). More and more these studies attribute the failure of agriculture in poor developing countries to undue emphasis on export oriented agriculture, imported farming technologies and to the results of hostile agricultural policies of both colonial and independent governments.

However, there are others who are suspicious of the ability of traditional methods to meet the increasing food demands (Bebbington 1996; Grossman 1993). These have a more favorable view of modern imported technologies rather than ITK as the technology that can improve the food situation in food deficit regions. Bebbington (1996) has proposed that the indigenous technical solution to the food problem is “grounded in an exaggerated, over-generalized, and sometimes simplified critique of technological modernization”. He argues that while agrarian modernization has been counterproductive in some cultures, this need not necessarily always be so since the success of agrarian reform depends on how the farmers are able to incorporate and use modernization. Similarly, Grossman (1993) cautions against over-hasty generalization about export agriculture. In a report of his research in the Windward Islands, he shows that while export agriculture may have undermined peasant food security in some cases, this is not necessarily always the consequence. To the contrary, there are cases in which small farmer adoption of Green Revolution crops and varieties has increased food security, offsetting crises that would have occurred without the technological change (Goldman 1993; Turner et al. 1993; Rigg 1989).

The differing views on the potential of ITK to increase production arises from the fact that ITK is problematic conceptually as well as practically. Conceptually, ITK is often taken out of its socio-economic, political and cultural context (Scoones and Thompson 1994; Fairhead and Leach 1994; Fairhead 1992). The conception of ITK as a body of knowledge that is essential to increase agricultural production gives the impression that pre-modernized techniques are crucial to solving all agricultural problems and that agricultural technology is central to solving rural poverty. In addition, with emphasis on the farmer as the only one who knows and has the capacity to invent and create, the concept of ITK tends to remove the agent (farmer) from the political and socio-economic structures

that shape the farmer's actions (Long 1990, Giddens 1979). Thus, the emphasis on ITK and what the farmers already know about technology and ecology diverts attention from the myriad things the farmers do not know about or cannot control: markets, politics, and the machinations of the world beyond the farm gate (Bebbington 1996:91). And yet, the impacts of the wider social, political and economic processes on farm resources management are determined by these variables (Blaikie and Brookfield 1987).

Practically, it is a matter of genuine concern as to whether traditional methods can produce enough food to meet the needs of a rapidly growing population in the face of a changing climate and a degrading agro-ecosystem. For example, a study in Eastern Nigeria recorded the average yield of cassava (a common staple in West Africa that does well on relatively poor soils) as 10.8, 3.8 and 2.0 tons per hectare, relating to shortened fallow periods of 7, 4 and 2 years respectively (Lagemann 1977). This suggests that, with rapid population growth and increasing pressure on agricultural land, farmers cannot rely on the traditional fallow system of farming to sustain food production in the long run.

On the other hand, other studies show that where farmers make adaptations to the fallow system as a response to the changing agro-ecological environment, there have been positive results which can be exploited more systematically (Jules 1995; Lallement 1986; Dei 1984). In the words of Adams (1992:61), Africans have lived with "unpredictability for millennia and have developed a series of neat and more or less effective ways of ensuring themselves against the vagaries of climate, while exploiting the natural resources available to them". Campbell (1984:47-48) has also observed that when African societies are faced with challenging social, economic or environmental conditions, they develop adaptation mechanisms to reduce the impact and to meet their needs.

While these assertions and observations may be too optimistic and are not entirely supported by the facts, it has to be acknowledged that an adaptation of the traditional

agricultural practices to changing environmental conditions appears to be the only affordable option open to the West African farmer. Most countries in the sub-region do not have the economic muscle to provide the western agricultural technology which is, anyway, not suitable for the delicate agro-environment in the region. What is more, the technology has failed to improve the food situation. It is, therefore, necessary to revisit those traditional technology and farming practices that are productive, and to study how they could be adapted to the changing agro-ecological environment so as to respond to the increasing food demand.

The above discussion is not to say that traditional methods and modern or imported technologies of farming are mutually exclusive. On the contrary, they complement each other. Some experts now argue for the blending of traditional and modern methods of farming (Bebbington 1996:89; Warren et al. 1995, Chambers et al. 1989; Altiri 1989; Denevan 1989). However, they stress that viable agricultural development strategies must be based on indigenous people's knowledge of the environment since ITK is culturally appropriate, environmentally friendly and better adapted to the smallholder farmer's socio-economic conditions. Modern methods designed to help agricultural production should, therefore, be improved versions of the traditional methods rather than displacement of them.

The blending of ITK and modern agricultural technology is indispensable for the successful adaptation of the traditional farming systems to environmental change. In the special environmental and socio-economic conditions of the West African sub-region, the two complement each other in their strengths and weaknesses. Combined, they may achieve what neither would alone. The past attempts to introduce imported farming technologies into West Africa failed because policy makers tried to replace the traditional systems of farming with an imported system that was often not compatible with the

ecological and socio-economic conditions of the region (section 1.442). The policy makers did no research into how the two systems could be merged to make them more productive. Imported technology that is not compatible with the local conditions should not be encouraged just as traditional methods that are no longer relevant should be eliminated. Nonetheless, because the traditional system of farming is better suited to the environment, it is important that traditional methods, rather than imported technologies, should form the basis of the adaptation to environmental change. The appropriate mix of traditional and modern methods can be carried out within a framework combining interaction among the farming, the agro-ecological, and the socio-economic systems.

### 2.3. THE CONCEPT OF ADAPTATION

The response of the farming system to environmental change involves two broad families of strategies – mitigation and adaptation. Mitigating strategies are the strategies that moderate the shocks of environmental change or make them less intense. The Oxford dictionary defines adaptation as the "process of modifying, making fit or suitable to new conditions". With respect to climate change, adaptation may be defined as the "practical means of accommodating current climatic variability and extreme events as well as adjusting to longer term climatic change and of reducing or avoiding costs of climatic hazards in the short term" (Smit 1993:1). When we deal with the responses of human systems to climatic and environmental changes, adaptation may be defined as "a change in a system which maintains or improves the viability of that system under variable conditions" in the long and short term (Smit 1993:23). Adaptation is thus distinguished from "coping" which is a "short term response to an immediate inhabital decline" in the environment (Davies 1996:55). With reference to this research, adaptation is defined as "a

permanent change in the mix of ways in which food is acquired irrespective of the year in question" (Davies 1996:55). Adaptation may take one of many forms (Smit 1993):

- (a) *Preventative adaptations* are mechanisms put in place to reduce the vulnerability of sectors and regions to environmental changes. An example is technological innovation used to minimize the rate of the ozone depletion.
- (b) A second group of adaptations are those designed to *tolerate loss*. In this approach the system accepts loss, at least in the short term, because its absorptive capacity is not exceeded. This type of response, however, does not support the development of a sustainable adaptive system as it may reduce stability, resistance and flexibility and may actually cause increased vulnerability. An example of this response is insurance companies.
- (c) *Spreading/Sharing Loss* are another set of adaptive actions taken to distribute the burden of loss over a larger scale, spatial and social, beyond those directly affected by the perturbation.
- (d) *Changing location* is a response in which people choose to change their location instead of changing their activity. In some cases, interest in the preservation of an activity will outweigh the desire to remain in particular locations, and migrations will occur to areas which are more suitable.
- (e) *Changing use/Activity* are structural changes which are intended to assist human social systems in persisting in areas which are no longer suitable for the types of uses or economic activities which existed prior to the perturbation.

The last two responses, sometimes referred to as *intolerance* or *avoidance* mechanisms, represent the most efficient means of adapting to change in the long term, since they provide for the development of new opportunities and the avoidance of negative

consequences (Smit 1993). They support a more adaptive system by reducing *vulnerability* and increasing *flexibility* and *resilience*, though their implementation could be very costly in the short term.

Adaptive responses are *guided* when the responses are the result of carefully planned policies and programs in anticipation of both long and short term impacts. *Induced* responses, on the other hand, are *ad hoc* responses. These responses take place if and as the impacts occur (CAST 1992). A good adaptive system not only minimizes the adverse effects of the expected and unexpected, but also ensures that the system can benefit from change by maximizing opportunities (Holling 1978; Timmerman 1981). A system's ability to minimize adverse effects is dependent on its *resiliency* and *sensitivity* to changes or shocks (Davies 1996: 55; Smith 1993:24; Burton 1992; Timmerman 1981; Holling 1978).

*Resilience* is defined as a property that "allows a system to absorb and utilize or even benefit from change" (Blaikie and Brookfield 1987:10-11). It addresses the elasticity of a system in response to perturbation. *Sensitivity* or *vulnerability*, on the other hand, is "the degree to which a given land system undergoes changes due to shocks resulting from natural forces or human interference" (Blaikie and Brookfield 1987:10-11). When a disturbance does occur in a system with high resilience, the system recovers or nearly recovers its previous condition<sup>17</sup> in a *shorter time*. In a low resilience system, on the other

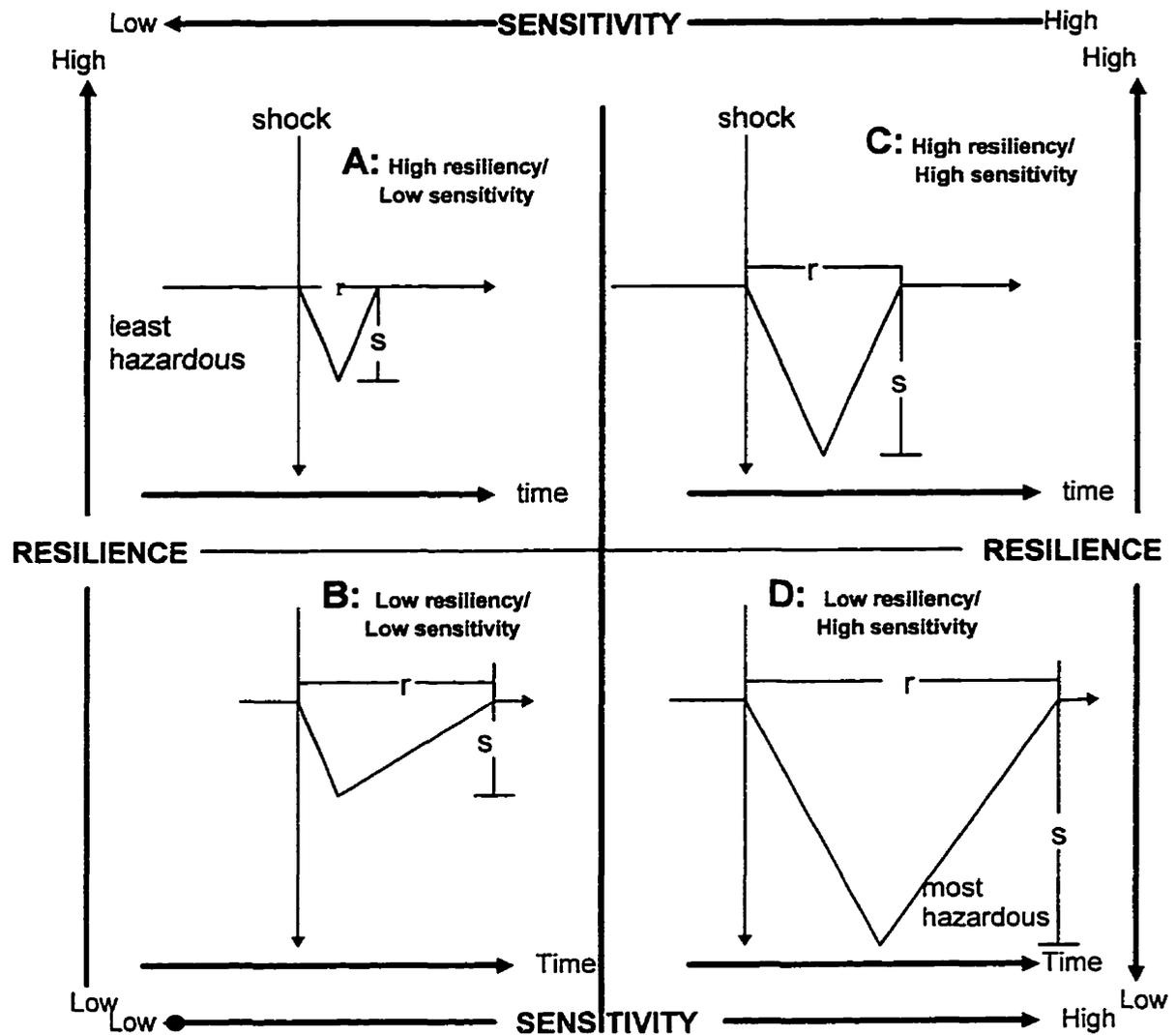
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<sup>17</sup> In this research the parameters for measuring the degree to which an agro-system has bounced back to or declined from its original/previous conditions is how much of its original/previous potentials it has been able to recover with respect to the system's ability to produce biomass, food, timber, fuel wood, and game as well as the system's ability to regenerate soil nutrient and to provide a safe cover for the soil, — things which are essential for the livelihood of the samllholder farmers and their activities. Original/previous conditions of a system refers to the state of the ecosystem, with respect to the its ability to provide these resources, relative to the system's capacity to provide the same resources after human interferences such as farming, and natural factors such as drought.

hand, the system takes a much longer *time* to return to its pre-shock conditions. A highly sensitive system reacts to minor changes in the natural and human activities that affect the system while a less sensitive system is not affected much even by major shocks. The distinction is shown in Figure 2.2, which shows that the least vulnerable or hazardous systems are those with properties of high resilience/low sensitivity, and the most vulnerable ones are those with low resilience/high sensitivity properties. Taken together, these two dimensions, resilience and sensitivity, show how agro-ecosystems, including the FSTZ agro-ecosystem, become vulnerable over time (Figure 2.2). An agro-ecosystem can become less resilient and more sensitive if the frequency and intensity of the shocks increase.

frequency of cropping and logging), and subsequently react adversely to even minor natural and human interference. Over the longer period the system follows the trend of Figure 2.3, which illustrates schematically the major periods of interference in the FSTZ agro-ecosystem in the twentieth century. An agro-ecosystem does not have to move from high resilience/low sensitivity to low resilience/high sensitivity since it can have different levels of degradation. While it may recover from some of the shocks to resume stability (Moretimore 1989), there is no guarantee that the system will return to the previous state (Davies 1996:27). Rather, it may become less resilient as a result of the magnitude of the shocks. For example, if a system cannot bounce back to its previous condition, and the magnitude of shocks do not further make it more vulnerable nor less resilient, then the system can be said have stabilized relative to the shocks.

**Figure 2.2. Sensitivity and Resiliency of FSTZ Environments and Farming Systems**



$r$  = resilience;  $s$  = sensitivity; shock = environmental change by natural and human causes

**A:** the environmental system is characterized by high resilience/low sensitivity. The system is least vulnerable to shocks ( $s$ ), and it recovers to its original condition within a short time ( $r$ ) after the shocks.

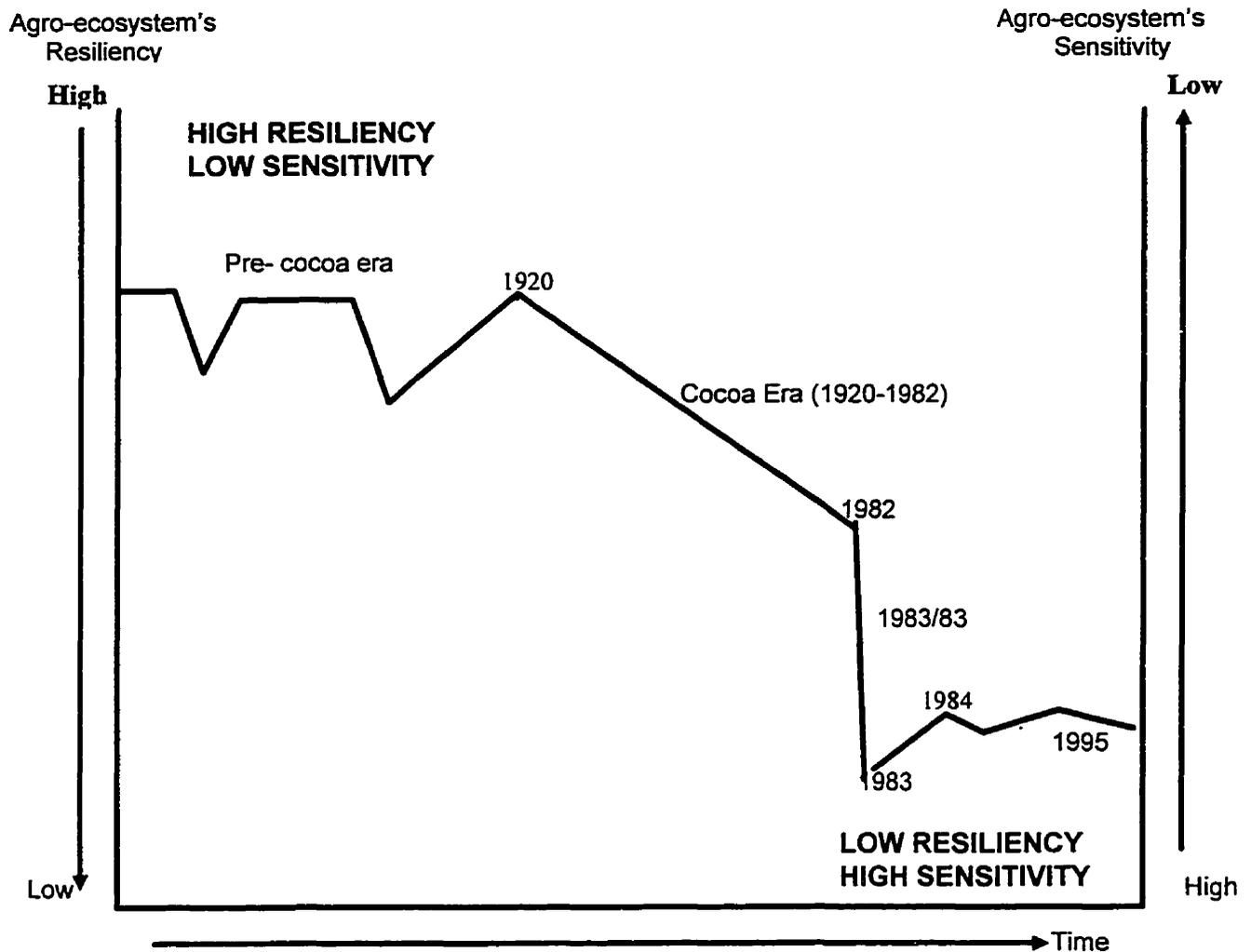
**B:** a low resilience /low sensitivity system. If the shocks continue in frequency and intensity, the system takes a longer time ( $r$ ) relative to A, to recover after the shocks have ceased, though the system is still least vulnerable ( $s$ ) to shocks.

**C:** high resilience /high sensitivity system. If the shocks persist, the system becomes more vulnerable to shocks ( $s$ ). In addition it takes a longer time to recover ( $r$ ). Relative to B, the system is less resilient and more sensitive to shocks, but relative to D, it is more resilient and less sensitive. The system can bounce back but it takes a longer time

**D:** low resilience/high sensitivity. The system, at this stage, is very vulnerable to shocks ( $s$ ) and it takes a very long time ( $r$ ) to recover from shocks. While it can recover some of its original conditions it may never bounce back to its previous position even after the shocks have ceased.

Source: Adapted from Davies 1996:27

**Figure 2.3. The Transition from a High Resiliency/Low Sensitivity Agro-Ecosystem to a Low Resiliency/High Sensitivity One in the FSTZ**



**Pre-cocoa era:** the ecosystem was highly resilient and less vulnerable to shocks. Because of the relatively low population density (National average density of 13 per sq. km) and because the economy was a subsistence one, fallow periods were long enough – over 25 years – for the ecosystem to bounce back to near its natural conditions.

**Cocoa era:** the forests were cleared for cocoa/coffee plantations. Many hectares were also cleared for food crops. Since a significant fraction of the land was under cocoa/coffee cultivation, and population had increased (section 1.431), fallow periods were shorter than they were in the pre-cocoa period. Vegetation and could not revert to previous conditions as a result. Shorter fallow periods meant more frequent shocks than before. The system became more sensitive and less resilient to shocks.

**1982-1983:** a period of drought and bushfires. These shocks, in addition to population pressure, declining rainfall and shorter fallow periods seriously affected the system's ability to make any significant rebound. The agro-ecosystem is now characterized by low resiliency and high sensitivity.

**1984-1995:** Farmers changed from tree crops to food crops. Land used for cocoa/coffee is available for food production. Even though rainfall is on the decline and population is increasing the pressure on the land is stabilized temporarily due to land availability. The ecosystem rebound beyond the 1983 conditions which were characterized by extreme drought, loss of most of the vegetation and wildlife due to bush fires

Even if a system cannot bounce back to its original condition— which is impossible with most systems once human interference starts – the system can maintain a high resilience/low sensitivity status if the shocks to the system, such as farming, logging, and grazing, are managed so that they do not exceed what the system can absorb.

The history of the FSTZ agro-ecosystem is represented by a movement from the top left hand to the bottom right hand quadrant of Figure 2.2. The starting point for analysis is that during the pre-cocoa era the low demand for food, due to a lower population density, put less pressure on the agro-ecosystem than now (section 1.431). Fallow periods were 25 or more years – the ideal fallow period needed to sustain soil and vegetation quality in the FSTZ (Dickson and Benneh 1988:81). In addition, rainfall was more abundant then than now (sections 4.12; 4.14), permitting the forest vegetation to dominate the area instead of the drought-resistant weeds as is now the case. With the increased production of cocoa between the 1920s and 1983, most of the original vegetation was cut down and replaced with cocoa and coffee plants. At the same time as the size of the population and the demand for food were increasing, a significant portion of the land was converted to cocoa and coffee plantations. The resulting pressure on the remaining land led to shorter fallow, degradation in the vegetation and exposure of the soil to the weather. Because the integration of food crops under and among the cocoa/coffee trees and shrubs closely mimicked the forest ecosystem, the effects of cocoa/coffee cultivation on the agro-ecosystem were gradual (section 1.514; Figure 2.3). These shocks, in addition to other pressures on the land such as logging, shortening fallow periods, more frequent tillage of the soil, unreliable rainfalls, and bushfires, all exerted a disturbing effect on the agro-ecosystem. The combined impact of these shocks were particularly significant in 1982 and 1983 (Figure 2.3). By 1983, the excessive pressures on the agro-ecosystem had made the system less resilient and more vulnerable to farming activities than the pre-cocoa era. The

persistent pressures on the system, in the form of shorter fallow periods, also meant that the system could not bounce back to the pre-cocoa era conditions. Some of the resources from the system, such as timber, herbal medicines, and wild game had declined seriously, and some had become extinct.

By 1983 the system had lost some of its resources and could not support tree crops any longer, though it was still suitable for food crops, among other things. To sustain food production, however, meant delicate dealings with the agro-environment to prevent further degradation. This stage in the FSTZ agro-ecosystem is represented by the wavy line between 1983 and 1995, indicating that the prevailing system is less vulnerable to shocks from food farming and is able to bounce back to the 1984 conditions and no further. This new equilibrium has been attained because land which was previously used for cocoa/coffee cultivation is now available for food crops. Since there is more land for food crops than during the cocoa/coffee era, the pressure on agricultural land has stabilized, at least temporarily. This balance in the ecosystem with respect to food production can be maintained if the agro-ecosystem is not degraded further. However, with the burgeoning population and the increasing demand for land, it is uncertain whether this equilibrium can be sustained for a longer time. While the system appears to be sustainable at the present, its potential uses are limited compared to its prior states. If further degradation occurs the system may still be useful for some other activities, but then its potential uses, compared to the current uses, will be more limited. For instance, previously the farmers could use the ecosystem for food crops and tree crops. Now it cannot support tree crops any longer. In a high resilience/low sensitivity ecosystem the options as to what the system can be used for are many. In a low resilience/high sensitivity system the options are limited. For a people who depend directly on the land for most of their needs, this difference is very significant,

since the transition from one condition to the other can have negative consequences for the very resources on which the people depend for survival.

The movement of the FSTZ agro-ecosystem from a prior state of high resilience/low sensitivity to the current one of low resilience/high sensitivity is central to understanding how the agro-ecosystem has evolved over time-frames that are longer than a single cycle of natural events or human activity. To sustain production in the prevailing ecosystem, farmers have to develop methods that reduce the sensitivity of the agro-ecosystem to shocks while enhancing its resiliency. Such on-farm innovations are products of the farmers' interaction with the agro-ecosystem in its gradual transition from a high resilience/low sensitivity agro-ecosystem to a high sensitivity/low resilience system over the years. At the same time, farmers can embark on off-farm activities such as education of children for off-farm jobs (a long-term solution), to ease the pressure on agricultural land. The question is whether the FSTZ farmers can maintain or increase production in the face of a rapidly population growth rate and a changing agro-ecological environment.

### 2.31 Population-Land Interaction, Intensification and Involution

Central to the changes in the quality, and sustainable use of the FSTZ agro-ecosystem, is the population-resource (land) interaction. Many studies conceive the population problem in rural Africa in terms of the relationship between the physical carrying capacity of an area and the agricultural subsistence needs of its population. Discussion focuses upon rural areas where rapid rates of population are seen as out-pacing the ability of crop production and animal husbandry to feed the people. Such a perspective is promoted by followers of Malthus such as Hardin (1974) and Ehrlich (1972, 1990). Boserup (1965) has challenged this view and has argued that population growth is a stimulus to agricultural production. Boserup based her observation on studies in rural areas which were sparsely populated.

The low population growth rate in these areas provided enough time for adaptations and innovations required to intensify production. In many areas in rural Africa, including the FSTZ, however, population growth rate are too fast to provide for adequate time for such experimentation and implementation of adaptations as in the case studies used by Boserup (Campbell and Olson 1991). These new realities have thrown into question the relevance of Boserup's thesis to the conditions in rural African communities and strengthened the case for the Malthusian theory in these areas.

A limitation of both the Boserup and Malthusian theses, however, relates to the spatial scale or unit of analysis. Both positions confine human-environmental interaction to agricultural, essentially subsistence societies in specific areas, which are relatively closed systems. The closed system imposes a limiting spatial unit of analysis and invites the Malthusian conclusion as it focuses on a narrowly conceived view of carrying capacity, that defined by subsistence production, in a limited area. If the closed system is opened up and the population-resource problem for an area is analyzed within a more open national or international socio-economic framework, then the solution to the population-environment problem is not limited to a specified geographical area under consideration, but should expand beyond primary subsistence to include activities such as secondary and tertiary activities, which do not depend directly on the land.

Closely related to the population-resource interaction and increased food production is the issue of intensification and involution. Intensification is the increased utilization of productivity of land currently under production (Kates et al 1991). Intensification is the theory that as population-land ratio increases, farmers are forced to employ greater labor and technical inputs to achieve greater production. Output per unit of area land grows as a result, though a reverse process (involution) is possible. Most of the growth in rural African agriculture, including the FSTZ, has come from extension of the area under cultivation. But

as population increases farmers tend to intensify the use of the same land. Consistent relationships between population density and agricultural intensity, measured through either the frequency of cultivation or output per unit or time, have been demonstrated for many parts of Africa, including the Jos Plateau of Nigeria and among the Matengo people in Tanzania (Turner et al. 1993; Ruthenberg 1980).

Though several studies indicate a positive relationship between population growth and agricultural intensification in African farming communities, intensification can lead to involution. The theory of involution proposed by Geertz in 1963, characterized the condition in which increasing demand is met by output intensification but at the costs of decreasing or small marginal and average returns to inputs. This situation erodes the long-term sustainability of agriculture through environmental deterioration, and leads to a diminution of socio-economic well-being of the people. This is the case for certain parts of Nigeria and Rwanda where population densities are high and have been so for a long time (Martin 1987). The declining returns in such conditions are due to the fact that usually more frequent cropping and less fallow reduce soil fertility and increase soil loss. These problems can be countered by the addition of procedural and technical inputs such as fertilizer—intensification. But Intensification can lead to real losses of economic well-being and a systematic differentiation based on social standing, gender, and economic means (Lipton 1989). These situations occur when the resources needed for intensification are not equally distributed because some segment of the population cannot afford them. Also associated with intensification are new social and economic risks of price fluctuation, the dependability of input supplies which comes with intensification, and the availability and price of purchased foods. Thus, in the event of intensification new dependencies and relationships are created that can be far beyond the ken and control of the farmers.

Although intensification has led to involution in a few places in Africa, there is ample evidence in different parts of Africa that shows that farmers have innovated changes in agriculture through intensification and other types of technological and institutional changes to increase production (Turner et al. 1993; Pingali et al. 1987). Different models of adaptations have been developed to explain the varied ways farmers may respond to environmental change, and the factors that influence these responses.

### 2.32. Models for Adaptation

Early analysis of environmental change shocks on agriculture tended to be based on a rather simplistic one-way non-interactive model which made environmental change solely responsible for all impacts (Parry 1986; 1990). Since this one-way non-interactive approach had no room for the formulation of systematic or holistic adaptive responses, it did not, for example, "consider the introduction of completely new crops, .... or changes in land use ....., or the many other productive uses of land... " that could reduce the effects of climatic and environmental changes (Mendelsohn et al. 1994:754). An improved approach to examining responses to the shocks is an interactive model which acknowledges that climate and environmental change effects are also influenced by interactions with other environmental and non-environmental factors. Such factors include the norms of the society, market forces, the availability of technology, the use of natural resources, and other numerous adaptive strategies available to farmers (Chiotti and Johnston 1995; Burton et al. 1993; Smit 1993; Smit 1991; Easterling et al. 1989; Garcia and Escudero 1981).

The neo-classical economic paradigm, for example, emphasizes that the invisible hand of the market place – forces of demand and supply – is what encourages or discourages various responses to environmental change (Chiotti and Johnston 1995; Crosson 1986). At the center of this adaptive process is the individual farmer who, when

given the proper incentives, will respond in a rational manner and, subsequently, successfully adapt farming practices and operations to suit a changing and variable environment (Crosson 1986).

The physical ecology framework, which attributes degradation of the agro-ecosystem to changes in natural factors such as climate, soils, environment and population growth, emphasizes the evolution of programs in soil conservation, family planning and resettlement as the appropriate responses to biophysical degradation (Bryant 1992; Watts 1989; Redclift 1987; Kanwar 1982; Myers n. d.). On the other hand, the political economy framework conceives environmental degradation as a function of social and political structures. This approach argues that local communities had devised agricultural systems which had evolved to provide food security through complex interactions between socio-economic institutions and environmental resources. Integration of rural communities into national and international economies has however, transformed the agricultural system upon which the local environment management strategies were based. Political ecologies therefore advocates changes in these structures as the means to alleviate degradation in the biophysical environment (Blaikie and Brookfield 1987; Bernstein 1982).

Each of the approaches to adaptation, standing on its own, reflects a narrow understanding of the interaction between economic forces, socio-political structures, and the physical environment on one hand, and the realities which these models seek to confront on the other. The realities of agro-ecosystem degradation and farmers' responses to the impact are more complex, having spatial, historical, ecological, socio-economic and temporal dimensions (Figure 2.4). Indeed, there are so many factors contributing to the degradation of the biophysical environment, and so many possible responses that it is difficult to judge to what extent one or more factor(s) may be primary, since the balance of their significance varies over time, by season, region, community, village, household, and

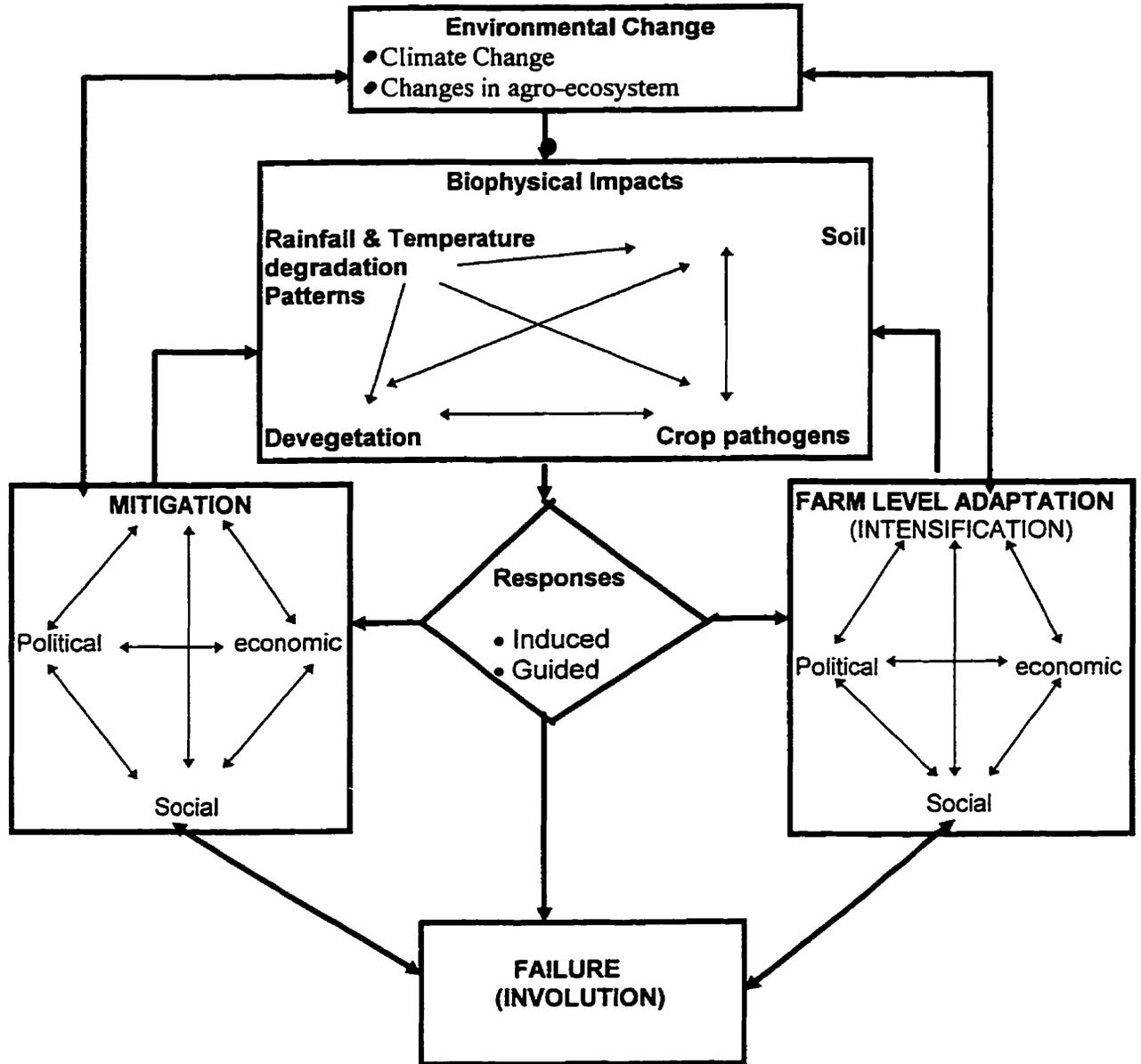
the individual (Moore 1996:126; Campbell and Olson 1991). In recent literature, there is a movement towards what Peets and Watts (1996) term *liberation ecologies*, and what others call a *pluralistic approach* to adaptation (Blaikie et al. 1994; Alexander 1993; Cutter 1993; Palm 1990; Chambers 1986).

### 2.33 A Pluralistic Framework for Analysis

Figure 2.4 represents a pluralistic model of farmer-agro-ecology interaction. The farmer response to the impact of environmental change is so complex; having ecological, social, economic, political, as well as on-farm dimensions. Consequently, the framework includes agro-ecological variables which directly influence farmers' activities on the farm. These ecological variables include climate, soil, and vegetation. Any change in each of these variables have repercussions for the others parameters.

The model also includes the economic, political and social factors which mediate farm-level adaptations to the effects of environmental change. Examples of elements of the economic variables are pricing, trade, marketing boards, markets, and commercial institutions. The socio-cultural variables include cultural and religious values, education, gender roles, family lineage, land tenure, distribution of power (authority) and indigenous

Figure 2.4. Farmer-Agro-Environment Interaction Model



knowledge. Included in the political elements that affect adaptation are farmer community organizations, international organizations, and national and local bureaucracies.

Farmers' responses (induced or guided) to environmental change impact are structured by the interactions between and among these variables. Agricultural production at the farm level, for example, is influenced by land tenure (social), soil quality (environment) and access to capital (economic). Farm level adaptations is also influenced by the exercise of power (political) in the community since the exercise of power determines the distribution of resources between and within societies. Power questions are also used to understand past interactions, such as who maintained control of what resources and how that pattern evolved. Similarly, social changes such as increased population growth affect farm-level adaptations such as intensification, just as intensification affects social, cultural and economic well-being (section 2.32). Off-farm policies (political and economic) affect how farmers respond to environmental changes at the farm-level. Socio-political policies, such as opening up economic opportunities beyond primary subsistence level, and emphasizing formal education, can ease the pressure on agricultural land, minimize land degradation and thus increase production. Similarly, the agro-ecological variables such as climatic rhythms, processes of soil formation and erosion, and vegetation growth and decay have natural rates of activity which may be accelerated or delayed by human intervention at the farm level through technology, which is a function of the socio-economic conditions of a people. All of the these interactions which occur at the village, national, regional and international scales overtime, have repercussions on adaptations at the farm-level. For examples, global food prices can affect, local food prices which in turn determines how much resources the farmer can invest in intensification. Thus, in addition to perceiving farmer-agro-ecosystem interaction in

a dynamic political and socio-economic framework, the pluralistic model also addresses how these interactions operate over space, and time.

The starting point of analysis is that farmer-environment interaction causes changes in the agro-ecological environment. In response to these changes, farmers embark on adaptive strategies such as intensification or mitigation at the farm level. These responses are, however, mediated by a complex socio-economic interaction. Some of the responses are successful while others fail. Both the successful and failed responses create new environmental and socio-economic conditions which initiate new responses to the new agro-ecological and socio-economic conditions.

The pluralistic model therefore integrates the theories of political economy, physical ecology, and social organization, into a unified methodological and theoretical framework that explains farmer-environment interaction. It recognizes multiple causes for changes in agro-ecological environment, multiple objectives, and multiple responses to the changes. It also stresses complexity and heterogeneity of the human-environment interactions and focuses greater attention on how political and socio-economic factors shape the relation between farmers and the ecosystem. In these ways the pluralistic approach allows a broader appreciation of the non-environmental forces that influence farmer-agro-ecological interaction. Since it places emphasis on the interaction between society and the environment, the model provides a solid basis from which to understand how socio-economic factors affect farmers' adaptations at the farm level; how environmental changes shape socio-economic structures; and how on-farm and socio-economic structures affect the biophysical environment.

### 2.34 CONCLUSION

From the preceding discussion, it could be said that current trends in the climate and the biophysical environment bode ill for West African agriculture. However, if farmer-environment interactions are situated within the broad socio-economic context, there are various options opened to the farmer which could be used to alleviate the impact of environmental change on production. While the literature on agricultural impacts of climate variability and land degradation has expanded dramatically, too little has been done to evaluate systematically the potential of local adaptations that might mitigate the impacts in the West African sub-region. This research uses farmers' responses to rainfall variability and land degradation in the FSTZ of Ghana to offer some suggestions on how food crop farmers in the sub-region could respond to the effects on agriculture of climatic and biophysical trends in the region. Responding to the environmental changes is most effective when it is based on local farming technologies. Hence, the next chapter examines the traditional farming systems in the FSTZ that will need to be adapted to the changing agro-environment.

### **3.0 FARMING SYSTEMS IN THE FOREST SAVANNA TRANSITIONAL ZONE**

" It took organized agricultural research decades to realize that what appeared primitive and unprogressive was complex and sophisticated. Small farmers are, after all, professionals" (Chambers 1986:87).

"After a long period of trial and error experts are now recommending multicropping and minimal tillage" (White 1993:106)

This chapter is an appraisal of the existing farming systems that are being adapted to the changing agro-ecological environment of the FSTZ. It examines the strengths and weaknesses of the systems with reference to their ability to meet the increasing food demand in the face of the changing biophysical environment. There are two main food farming systems in the FSTZ: the bush fallow and the permanent or continual farming systems.

#### **3.1 THE BUSH FALLOW SYSTEM**

In this system the farmer rotates crops, fields and bush. Geographical dispersion of the fields of one holding is very common. A piece of land is cleared at the beginning of the farming season (Table 1.2). Cutlasses (machetes) are used in clearing the bush and felling smaller trees, while axes and chain-saws are used to fell bigger trees. All trees of commercial importance such as oil palm trees, and trees that are too big to be felled are left standing. Since weeds in the cleared areas form a dense cover they are set on fire to ease access to the soil (Plate 3.1). Planting begins at the beginning of the rainy season (Table 1.2). The hoe is used for planting cocoyam, yams, plantain and cassava. For maize, millet, guinea corn and transplants, the cutlass or the dibble stick is used (Plates 3.2; 3.3). Tuber crops such as yams and cassava are often grown on mounds or ridges to encourage root and tuber development in the loose soil and to make harvesting easy. By hoeing topsoil on to the mound and adding organic matter, islands of higher fertility are created. Less demanding crops are grown in the intervening flat areas. Different crops,

**Plate 3.1**

A new field. Cleared weeds are burnt, ash serves as fertilizer and branches as fuelwood.

**Plate 3.2**

Farming tools. Two hoes and a cutlass. These rather than tractors are used for clearing and planting.



**Plate 3.3**

The farmer uses a dibble stick to plant some seeds. Gutters made between the ridges collect rain water which slowly seeps into the ridges to provide moisture for the crops



**Plate 3.4**

Mixed cropping. Many crops are cultivated on the same field. There are five different crops in this area.

such as cassava, maize, plantain, and cocoyam, are inter-planted in the same field (Plate 3.4). Weeding starts a few weeks after sowing. It is a very slow process because of the differing growing characteristics of the crops that are planted together in the same area. Hands and other simple tools such as the cutlass are used for clearing the weeds so that none of the crops are removed with the weeds. Some crops such as maize are harvested within two to three months, while perennial crops like plantain, cocoyam, cassava are harvested for the first time after almost a year, but are subsequently harvested several times without the necessity of replanting them annually. They keep bearing fruit even long after the farmer has abandoned the land to fallow.

There are problems with post-harvest storage. Yam is the only starch staple that can be stored for any considerable length of time. It can be stored in specially built yam barns or in heaps for a maximum of 6 months. But since moisture loss can reduce yam sizes by 30 - 50% of their volume after harvest, they are usually sold two to three months after harvest (Sarris and Shams 1991; Coursey 1967b). Cocoyam and cassava are harvested only when needed for food or for sale, since they are extremely perishable once they are harvested: they are good for only 5 to 8 days after they are harvested from the field. Cassava and cocoyam may remain in the ground for 6-24 months for storage. Cassava may even remain in the ground for 2-3 years as a famine reserve or for storage purposes. There is no way to store plantain when it matures, though it can be processed into chips and flour. The cereals – sorghum, millet, rice and maize – are stored in barns. They can be stored for more than 8 months; however, they are subject to attacks by rodents and insects while in the barns.

The farmers cultivate the same plot for two or three farming seasons, after which they abandon the plots to cultivate new ones. Regeneration of secondary bush takes place rapidly following the return of the plot to fallow, allowing the soil to gradually recover some

of its chemical properties. The soil is naturally replenished with nutrients from decomposing leaves, branches, fallen trees, and from the undergrowth. Traditional farmers have, by experience, associated some plants with the level of fertility that the soil has regained. For example, *Musanga cecropiodes* (Dwumma) and *Harungana madagascariensis* (Okosoa) are indicators of soils that have regained nutrients to levels very close to virgin soils; while *Corynanthe pachyceras* (Pamprama) and *Nesogordonia papaverifera* (Danta) indicate high forest, and therefore, good farming soil. Plants reported to be indicators of good soil include *Trema orientalis* (Sesea), *Momordica foetida* (Sopro) and *Momordica charantia* (Nyanya). The presence of *Paspalum conjugatum* (Asamoa Nkwanta) and *Hildegardia barteri* (Akyere) are associated with poor soils. The level of soil fertility that is regained is related to the fertilizing qualities of the vegetation cover and to the length of the fallow period, which in turn is a function of the amount of land available to the farmer.

Most food production is on relatively small plots of land, usually less than 4 hectares depending on available land, labor and financial resources. Both hired and family labor are used on farms. The actual percentage of hired labor, the main cost in traditional farming, varies from farmer to farmer with averages ranging from 30 - 50% (Sarris and Shams 1991:27). Generally hired labor is used for land clearance, preparation, and weeding, while family labor is used for planting, harvesting, and transport of harvest from farm to household or market.

### 3.11 Advantages of the Fallow System

In the peculiar environmental conditions of the tropics, the fallow system has several advantages. Mixed cropping, a major component of the fallow system, has been and remains widespread in small scale farming in the FSTZ. For many years, it was considered primitive, but mixed cropping and minimal tillage are some of the risk-reduction strategies

adopted by farmers in an environment of uncertain rainfall, poor soils, and a great variety of pests (White 1993:106). First, since the farmer uses simple tools like the cutlass, hoes and dibble sticks (Plates 3.2; 3.3), to plant and harvest the crops, there is minimal disturbance of the soil root-mat, and excessive erosion is prevented. Second, the farmer plants different crops on the same field. In this way, the farmer makes efficient use of the soil since the different rooting systems exploit the nutrients at different levels in the soil profile. Because there are varying species of crops growing together, crops with specific requirements or tolerances exploit the micro-environments created by the different crops and the cleared area (Norman et al., 1995:8). Thus, nitrogen fixing plants can fertilize non-nitrogenous fixing plants, shade-tolerant species are planted on shady margins of the plot, moisture-demanding species at the bottom of the sloping sites, and fertility-demanding species on localized ash concentrations or hoed-up mounds of topsoil. When they are planted among others, crops are less vulnerable to pest attacks than stands of single crops (Burden and Coursey 1977). In addition, labor requirements per crop are low in mixed crop farming, especially in reducing weeds. Also because the crops are planted and harvested at different times, labor peaks are spread out throughout the farming season.

Different crops on the farm have varying characteristics. For example, the melon grows by crawling on the ground; others such as maize grows straight up; some such as cocoyam and plantain have stems on which broad leaves grow at an angle from the vertical, others such as groundnut grow by spreading over the ground. The leaves of this crop mix provide a dense leaf cover that shields the soil from the torrential tropical rain, while the roots provide a dense spongy root mat that stores moisture in the soil and checks excessive erosion by holding the soil in place (Norman et al. 1995:2; Aina et al. 1979). Other benefits of mixed cropping are that the successive sowing of crop mixtures supplies a varied diet over an extended harvesting period, and spreads the farmers' income over the

year since the crops are harvested at different times in the year. Mixed cropping also reduces the risks of complete crop failure since if one or more of the crops fails, others may make up for some of the loss.

The cleared vegetation on new fields forms a thick leaf mat which makes it exceedingly difficult to work on the land. Burning the cleared weeds on new fields, therefore, saves time and labor during planting. The burnt weeds also release nutrients -- carbonates and phosphates -- which are washed into the soil with the first rains for crop uptake (Iremiren 1989; Plate 3.1). The simple tools used by farmers for preparing the land, planting, and weeding ensure minimal disturbance of the soil while protecting the forest seed bank. Apart from its soil regeneration capabilities, the vegetation on fallow land provides timber, fuelwood (Plate 3.1), medicines and wild fruits.

### 3.12 Shortcomings of the Bush Fallow System

In spite of the many advantages of the fallow system, it has some serious shortcomings, especially with increasing population and climate change. Generally, traditional agriculture does not use modern agricultural resources such as chemical fertilizers, herbicides, or tractor ploughing. By adopting a low input method of production, risks are reduced, especially in a year when the rains fail. But production per unit area is low, particularly in areas where shortening fallow periods have led to a decline in soil fertility.

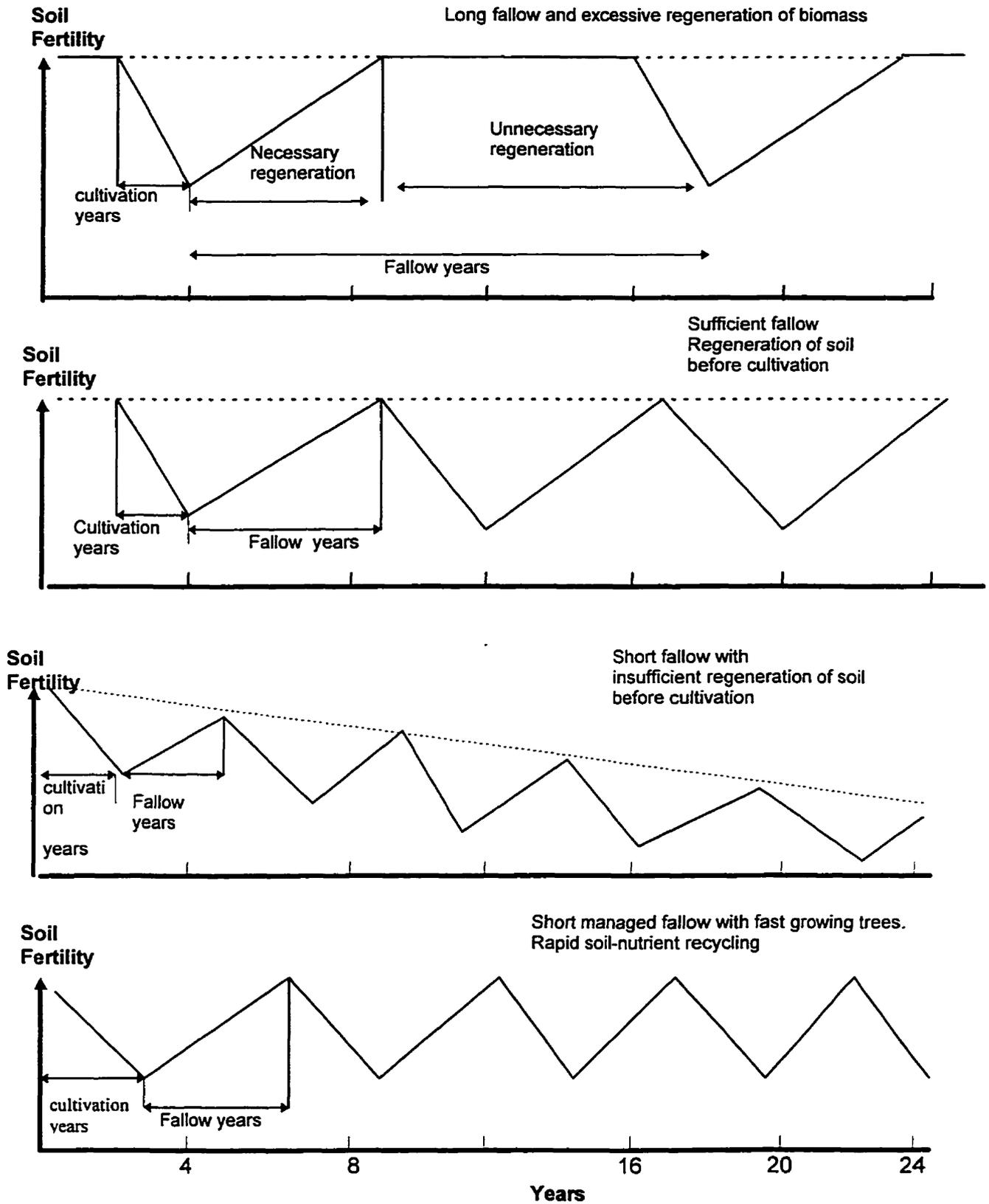
While the simple tools used in the traditional system of farming are gentle on the delicate soils, they cannot be used to clear large areas of land to increase production. Machines such as tractors can increase production by clearing larger areas and by harvesting the crops. However, problems of environmental degradation result from the use of methods such as tractor ploughing which adversely affect the soil by altering the soil structure, and impeding the soil's regenerative capacity (Amanor 1995).

Burning of litter reduces the amount of labor used in preparing the land and increases soil fertility, but it has been the cause of many bushfires and the destruction of food crop farms. Burning of the litter exposes the soil to the effects of sunshine and torrential rains until the first crops form an effective protective cover against the scorching heat of the tropical sun, and against soil erosion.

Another major weakness of the traditional methods is that they have not been the focus of serious scientific research for the purpose of improving the methods. Not only have researchers not sought to develop the fallow system but they have also discouraged it because they see it as primitive and as a waste of valuable agricultural land (Chambers 1983). Early geographic accounts of bush fallow in Ghana and elsewhere characterize it as "unplanned, aimless, unproductive, barbarous and deplorable, uneconomical in the utilization of land and labor, and destructive of the environment" (Whittlessey 1937). Early efforts to support agricultural development in the FSTZ and other areas in Ghana were, therefore, based on transferring technologies and management practices from Europe for the cultivation of a narrow range of exportable crops in areas with favorable soil and agro-climatic conditions (Nikos 1995:366). In the process, plant breeding focused on cash crops to the neglect of food crops, and soil nutrient replacement was dominated by mineral fertilizer instead of biological fertilizers. Similarly, the traditional mixed cropping and inter-planting practices with their high resilience to weather fluctuations and pest attacks were commonly discouraged and replaced by less favorable monocropping and row planting.

But perhaps the most outstanding disadvantage of the system is that it works best only in areas where there is either a small population or enough land that will allow exhausted soils to lie fallow for a considerable length of time to regain some of the lost

**Figure 3.1. Hypothetical Relationships between Soil Recuperation and Fallowing Systems**



Source: Amanor 1995:170

fertility. When the soil regeneration period is significantly shortened, it triggers a chain reaction that degrades both vegetation and soil over time. Some studies show, however, that shortening of fallow periods does not necessarily imply that the content of soil nutrients has diminished since sometimes farmers purposely shorten the period to minimize the cost of clearing unnecessary vegetation (Norman 1995:6; Nye and Greenland 1960; Figure 3.1). Increasing competition with weeds and invasion of the cultivated field by pests are other factors that make the farmer abandon the field long before it is exhausted of all its potential nutrients (Nye and Greenland 1960). Further, fallow beyond a certain number of years does not ensure a significant increase in soil fertility, nor is there a conclusive linear association between the fertility of topsoil and the number of years it has been left to fallow (Amanor 1995:190; Figure 3.1). For example, research shows that soil fertility in tropical forest *ochrosols* improves considerably in the first two to four years and then levels off with longer periods (Amanor 1995:190). The implication of these observations is that when rates of nutrient accumulation are assessed in relation to returns to labor in clearing biomass, the utilization of fallow periods, of as little as five years, may be more cost-effective than fallow substantially longer than five years. Another factor is that patterns of land degradation are complex in bush-fallow systems.

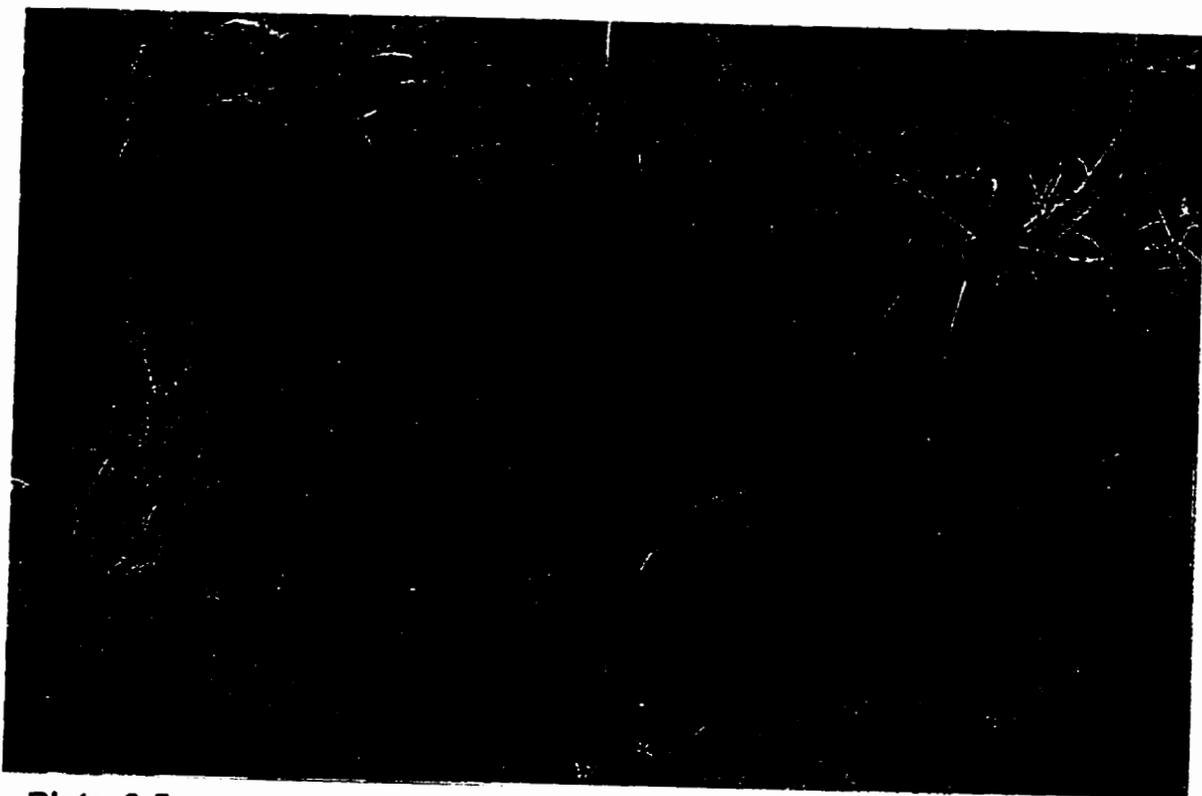
While a shorter fallow period does not necessarily imply declining soil fertility, the fact remains that there are very large areas in the FSTZ and other parts of Ghana where there is no possibility of extended fallow periods, since virtually all land is cultivated each year due to population pressure. In many areas, non-irrigated cultivation is becoming increasingly dominated by permanent agriculture— a continuous arable cropping system with only short fallow periods or none at all. It is in these areas that the problems of maintaining the soil in good condition are the most acute and where the farmers has to be more creative their farming methods.

### 3.2 PERMANENT OR CONTINUOUS CROPPING SYSTEMS

There are other versions of continuous farming in the FSTZ that are not the result of population pressure. The two most important versions of these are the mechanized and the tree-crop farming systems.

#### 3.21 The Mechanized Farming System

The mechanized system of farming is common in the FSTZ, especially in the northern sections of the study area around Wenchi, where fallow periods have shortened considerably (Figure 1.9). In this area tree density is relatively low, and the undergrowth is predominantly grass. These conditions allow for easy mechanized farming. The farms in this area are mechanized in varying degrees. On most farms, tractors are used for clearing and preparing the land since it is exceedingly difficult to manually clear the elephant grass which now dominates the vegetation. However, tractor ploughing is suited only to a few crops such as rice, maize, peanuts, and soybeans. Other resources such as fertilizers, herbicides, pesticides and mechanized harvesters are common on medium and larger-scale holdings where these crops are cultivated. On the other hand, crops such as cassava, plantain, cocoyam and yam are not suited to mechanized farming. Plantain and cocoyam are typical forest crops that need the protective shade of trees, but such trees do not allow tractor ploughing. Even though cassava and yam do well in both forest and savanna environments, the farmers have observed that these crops do not do well on soils that have been ploughed.



**Plate 3.5**

Tractor ploughing. It cuts too deep into soil and buries topsoil.  
Note the thin layer of topsoil.



**Plate 3.6**

Bullock ploughing. It is gentle on the soil

Despite the tractor-based land preparation and the higher levels of fertilizers applied in mechanized farming, production from these farms is often disappointing owing to poor management. As with the traditional methods of farming, most of these mechanized farms depend on rainfall for crop growth. In the event of rain failure, mechanized farmers lose more since they invest more resources than the farmers using the traditional methods. Mechanized farming makes it possible for many hectares of land to be cleared but tractor ploughing, unlike bullock ploughing, disturbs the shallow soils and increases the danger of soil erosion (Plates 3.5; 3.6).

There is also the problem of cost. Most of the agricultural machinery that is imported is not designed for tropical conditions. Because it deteriorates very quickly under these conditions and breaks down very often, the maintenance cost is high, much more so since all spare parts have to be imported. These and other factors, such as the lack of expertise in the maintenance of machinery and the lack of regular supply of inputs such as fertilizers do not make mechanized farming a viable alternative for solving the problems of food supply in the country, at least not in the near future.

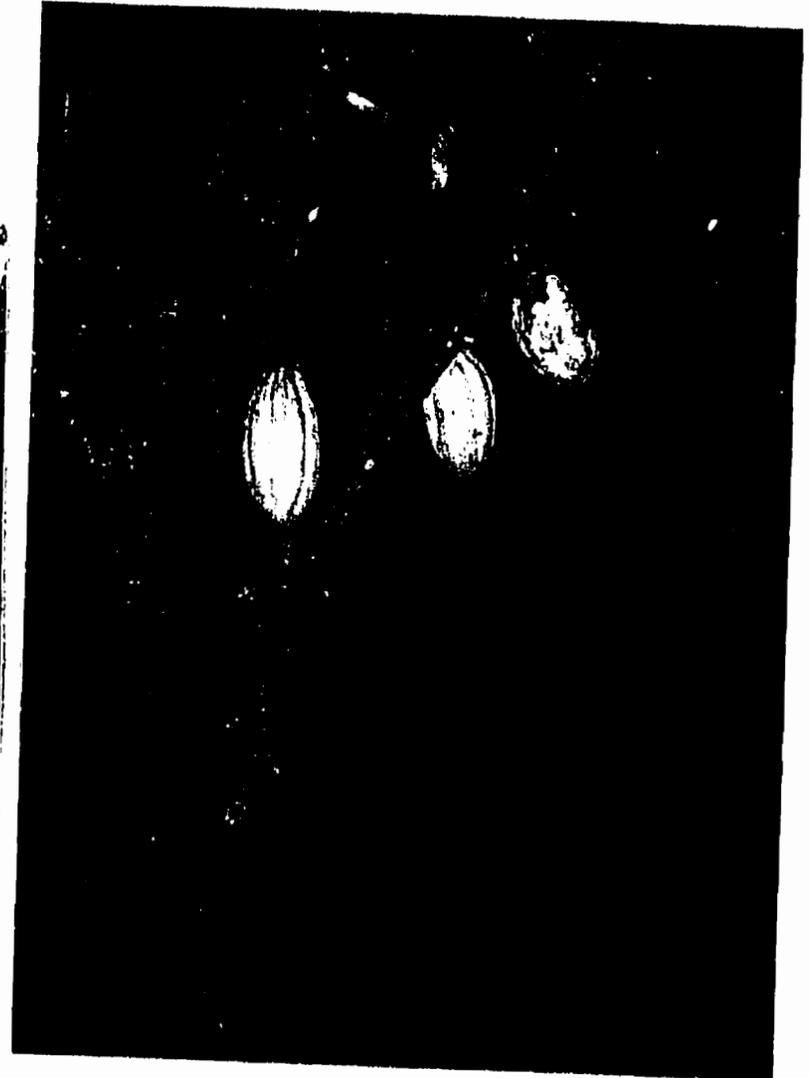
### 3.22 The Tree Crop Farming System

A version of continual farming with far reaching consequences in the FSTZ is tree crop farming. In this version of continual farming the land is cleared, and planted with food crops and young tree crops such as cocoa or coffee seedlings. The food crops serve the dual purpose of providing food and serving as shade for young tree crops. In the meantime the farmer nurtures special trees known to be good shade trees for matured tree crops (Plate 3.7). In about four to five years the food crops, even the perennial ones such as plantain and cassava, are overshadowed by the tree crops so that only the tree crops and the shade trees remain on the plantation. Cocoa and coffee start bearing fruit in



**Plate 3.7**

A two year old cocoa farm. Plantain gives shade to the young plants. The nurtured trees will provide shade to the cocoa trees later.



**Plate 3.8**

*Theobroma cacao*. A cocoa tree fructing for the first time

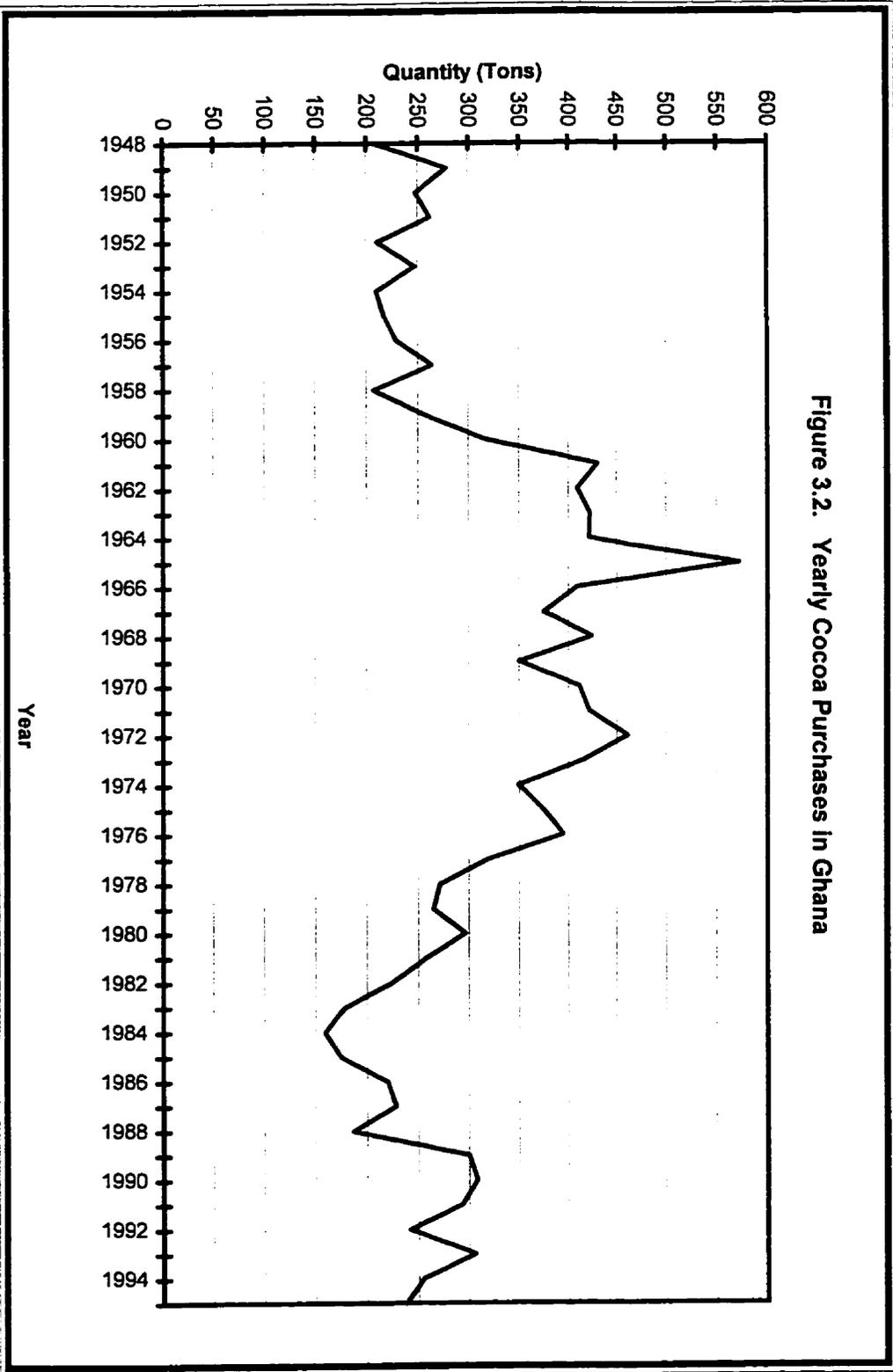
the first 3 to 5 years, and continue bearing fruit every year for 30 to 50 years (Plate 3.8).

Until 1983 when the bushfires destroyed most cocoa and coffee crops, every cocoa farmer also had a foodcrop farm (s) in addition to the tree crop farm(s). While tree crop farming provided income for the family, the food crop farm provided food.

### 3.221 Impact of tree crop farming

The characteristics of the cocoa economy and forest farming in the FSTZ have been determined by a process of pioneer frontier settlement – the movement of people into new areas untouched by farming. Frontier farming began in the FSTZ around the sixteenth century, long before cocoa and coffee were introduced in Ghana at the end of the nineteenth century (Amanor 1995). Frontier farming was mainly subsistence farming and was most often associated with shifting cultivation based upon the development of extensive farming systems which aimed at establishing ownership over the land and of conquering the wilderness at a faster rate (Richards 1985; Grandstaff 1981; Greenland 1975). As land became scarce, a re-orientation of the farming strategies shifted from the maximization of the cultivated areas towards both the intensification of farming and the rehabilitation and conservation of land. At the end of the nineteenth century cocoa became the major crop influencing the development of the frontier (Hill 1963). The desire of farmers to harvest more cocoa increased the competition for more land. Because cocoa cultivation was given direct support by the government, the industry lured many farmers to put emphasis on cocoa production to the neglect of food production (section 1.441). Ghana emerged as the major world cocoa producer in the early twentieth century and has sustained cocoa as the main export crop of the forest and transitional zone. However, in the 1970s and 1980s, cocoa production declined both locally and relative to the world market (Figure 3.2). Since then the government has been trying desperately to revive the

Figure 3.2. Yearly Cocoa Purchases in Ghana



Note:

The apparent sustainable production since 1989 is a result of the massive cocoa rehabilitation program started by the government in 1983. Most of the increase came from new cocoa farms started on virgin soils in the Western Region of Ghana, program began in 1984/85 (ISSER 1993:81) rather than from the rehabilitation of cocoa farms destroyed by fire (Manor 1996)

Source: Based on data from the Produce Buying Division, Accra 1996

ailing cocoa industry against a formidable combination of odds which were responsible for the decline. These obstacles include environmental factors such as degraded soils, declining rainfall, bushfires, and socio-economic factors such as declining prices on the international and home markets, inadequate producer prices from the Ghana Cocoa Marketing Board (section 1.4441), and increasing competition with food crops for land.

Usually the decline in cocoa production in any area is associated with environmental stress, especially of land degradation (Amanor 1996:34). Under conditions of land degradation and diminished rainfall, farmers in the FSTZ moved out of cocoa production into food crop farming. But the change is anathema to the government since taxes on cocoa production is the government's principal source of revenue. While the government has little or no control over the internal marketing of food crops, the government collects 45% - 50% of all cocoa production as tax (Personal communication with Ben T. Manor; Marketing Research Manager of the National Office of the Produce Buying Company, Accra). For this reason state policies indirectly discourage food production in areas defined as lying within the cocoa belt (Figure 1.10) but provide incentives to farmers to rehabilitate and maintain their cocoa farms in the region (Konings, 1986). The government exceeded its target of 300,000 metric tones of cocoa in 1992/1993 mainly because of the incentives (in the form of loans and seedlings) it gave to farmers to rehabilitate aging and burnt cocoa farms, and to start new cocoa farms (ISSER 1993:81; Figure 3.2). Most of the increase, however, is from new farms in the south-western part of Ghana rather than from the few old farms that were resuscitated (ISSER 1993).

If the farmers in the study area opt for cocoa rehabilitation, they will receive financial and material assistance from the government, but then they will disregard the lessons learned from their own experiences of dealing with the changing biophysical environment in which they operate, their own adaptive traditions, and their intellectual autonomy. The

farmers know, for example, that the area has become too dry for cocoa, that the erratic rainfall makes survival of young cocoa trees very difficult, and that the many new weed species pose serious weeding problems for the young cocoa plants. In addition, frequent bushfires in the region make it risky to embark on any tree crop cultivation, especially cocoa and coffee which are highly susceptible to fires.

What's more, most farmers are unwilling to go back to cocoa farming because the cocoa era did not favor most farmers. In the natural agro-environmental conditions, tree crop agriculture is undoubtedly more profitable (in financial terms) in the FSTZ, but these do not supply the basic dietary requirements of carbohydrates. Several studies of the cocoa sector reveal great inequalities in land holdings and in tonnage of cocoa produced (Amanor 1996:46; Beckman 1976; Hill 1956; Beckket 1944). During the scramble for land for cocoa, family heads and influential people in the communities used their positions to have more than their fair share of the family land. As a result 10% of all farmers produced up to 50% of all sales in several instances, while a much greater percentage of farmers had small holdings of under just three hectares. These inequalities in production reflect the manner in which tree crop farming restricted access to land to a few large-scale farmers, as opposed to the pre-cocoa era when all members of the family had access to the family land.

### 3.3 CONCLUSION

The experience with mechanized farming in the FSTZ is not very encouraging. In cocoa/coffee farming, the farmers' knowledge of agro-ecosystems was subjugated to the dictates of the colonial and world commodity interests in monocultural production. With the emphasis on cash crop production, the farmers failed to devote enough of their agro-ecological knowledge to the enhancement of the traditional farming to increase food

production. Nevertheless, these methods have sustained food production and the agro-ecological environment, even if imperfectly, at a time when population was low. The real test, however, is what agricultural revolution, if any, will occur in the traditional farming systems now that the fallow system is breaking down under the pressure of a rapidly growing population, and the associated environmental degradation. With the failure of the cocoa industry, due mainly to environmental factors, and the gradual break-down of the fallow system, farmers in the region are adapting their farming methods to the new realities such as soil degradation, bushfires, decreased fallow periods, changes in biota, and unreliable rainfall, that now characterize their environment. The trends in these variables, which shape the agro-ecological environment in the FSTZ are the subject of the next chapter.

## **4.0 ENVIRONMENTAL CHANGE IN THE FOREST SAVANNA TRANSITIONAL ZONE**

Evolving environmental problems affecting agricultural productivity in the FSTZ are a result of the inter-play of a complex of socio-economic and biophysical factors. This chapter examines the changes in the main biophysical factors – climate, vegetation and soil – that are evoking a response from farmers in the region. Despite their inter-relatedness, these variables are treated separately for the sake of order.

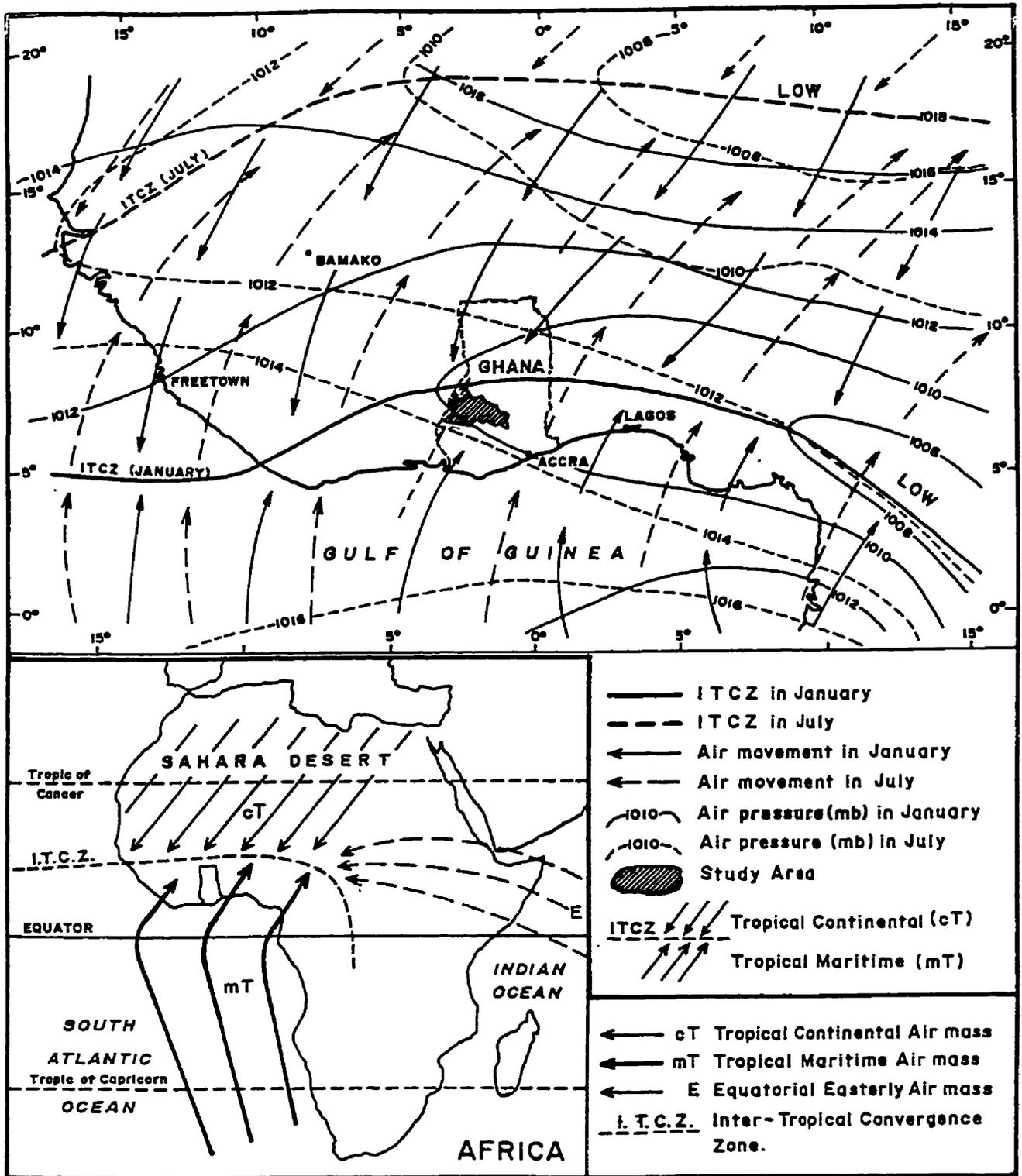
### **4.1 RAINFALL AND TEMPERATURE TRENDS IN THE FSTZ**

#### **4.11 Rainfall and Temperature Dynamics in the FSTZ**

The Tropical Continental (cT) and the Tropical Maritime (mT) air masses are the most important factors controlling the rainfall pattern in the FSTZ. The former originates from the Sahara desert and the latter from the South Atlantic Ocean (Figure 4.1). With its source in the heart of the Sahara-Arabian Desert, the cT air mass, or the north-east Trade winds or the Harmattan, dominates most parts of Ghana from November to February. It is dry, dusty and hot. The virtual absence of clouds associated with its presence raises temperatures to about 40° C during the day, but it brings a cooler-feeling of about 20° C in the night. The diurnal temperature ranges can thus be as much as 15-20° C during this period.

On the other hand, the mT or the monsoon air mass has the South Atlantic Ocean as its origin (Figure 4.1). Because it originates and moves over the warm ocean in the tropics, it contains a great deal of moisture. It dominates the country from March to October but it is not until August that the northernmost parts of the country come under its full influence. Air temperatures during the day (25° C) are lower than those associated with

Figure 4.1 Air Movement and Pressure Systems in West Africa



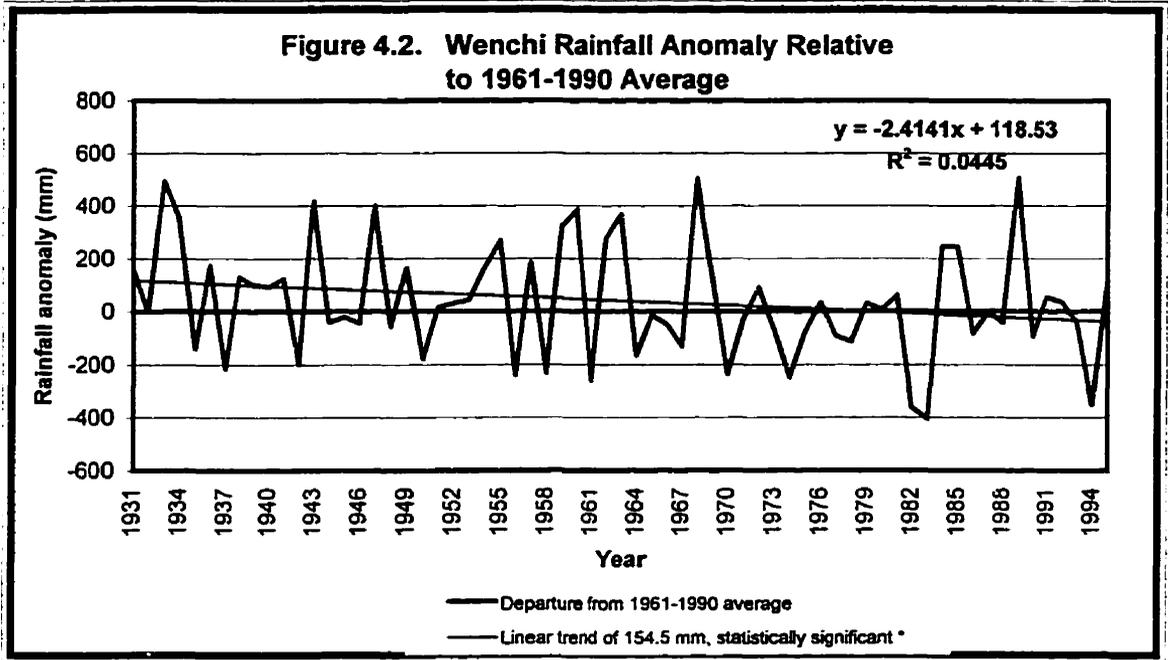
Source: Produced by the Cartographic Office, Department of Geography and Resource Development, University of Ghana

the cT day temperatures, though they are higher than cT air temperatures in the night. Clouds and rain are common in areas under the influence of the mT. The effects of a third air mass, the Equatorial air mass or the E air mass, which brings rain in September, have been identified in Ghana. Its source region is uncertain but it is generally believed to originate in the Indian Ocean (Dickson and Benneh 1988:26; Figure 4.1).

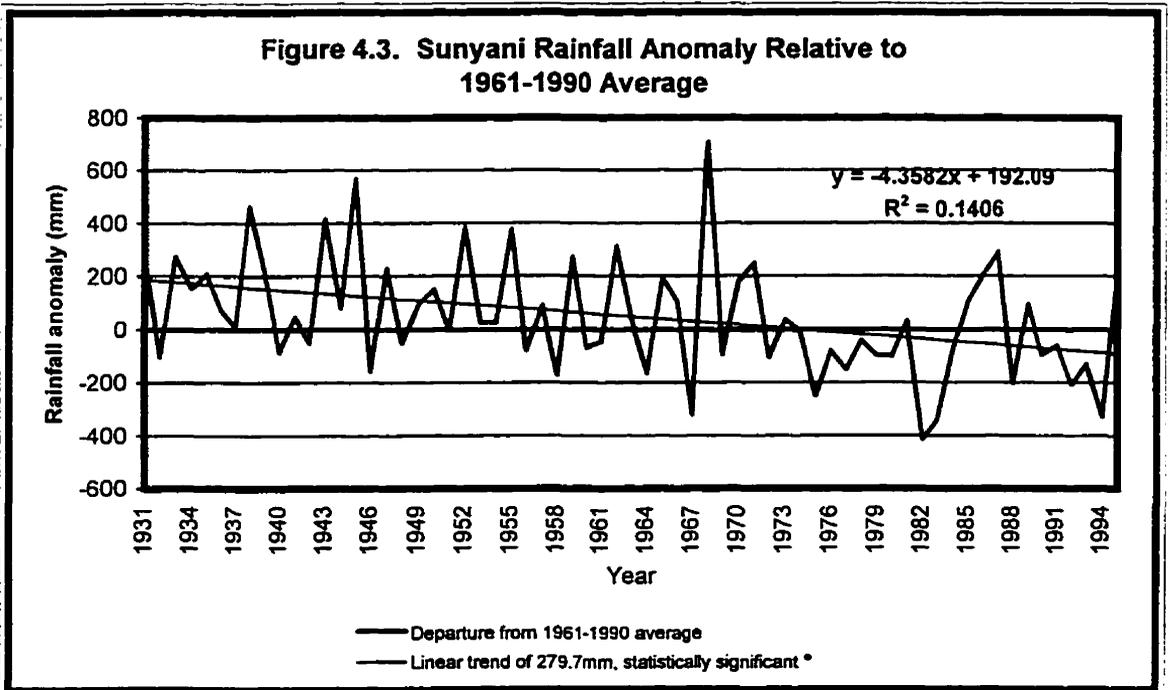
The meeting point of the cT and mT air masses is called the Inter Tropical Convergence Zone (ITCZ) or the Inter Tropical Discontinuity Zone (ITD). This zone swings from north to south in response to pressure systems on the equator (Figure 4.1). Weather conditions prevailing in any part of the country at any time are determined by the location of the ITD because its location determines which area of the country is under the influence of which of the air masses. In January most parts of the country come under the influence of the dry and dusty Harmattan winds because around this time the ITD fluctuates between latitude 5° N - 7° N (Figure 4.1). This positioning of the ITD allows the cT air mass to invade the entire country right to the sea. Hence, in January all parts of the country experience the driest and hottest days in the year. In September, the ITD is at latitude 20° N and the whole country comes under the influence of the moist southwesterly monsoon winds which bring rainfall to all parts of the country (Figure 4.1). Though the dynamics of rainfall in Ghana remain the same, climatic records point to a trend towards decreased rainfall in the region (Appendix 4).

#### 4.12 Precipitation Trends

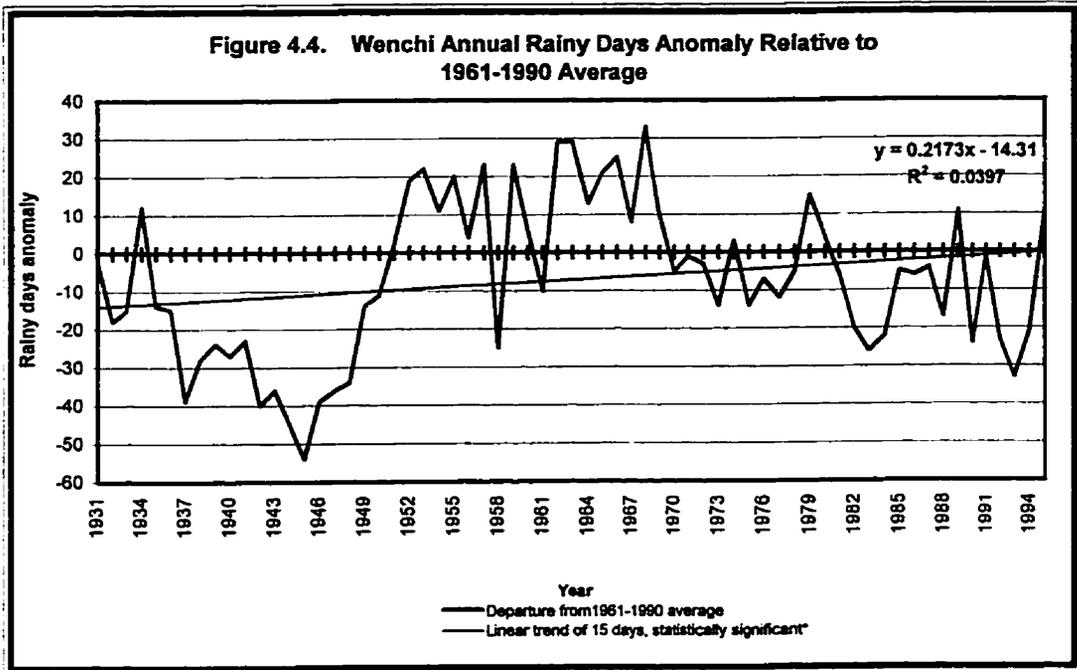
Figures 4.2 and 4.3 show annual rainfall anomalies for Sunyani and Wenchi from 1931 to 1995 relative to the 1961-1990 mean rainfall (section 1.6511). The downward trends of the regression lines in both figures point to decreasing amounts of rainfall at the stations. Average annual rainfall in Wenchi between 1931 and 1990 was 1291.1 mm. The average



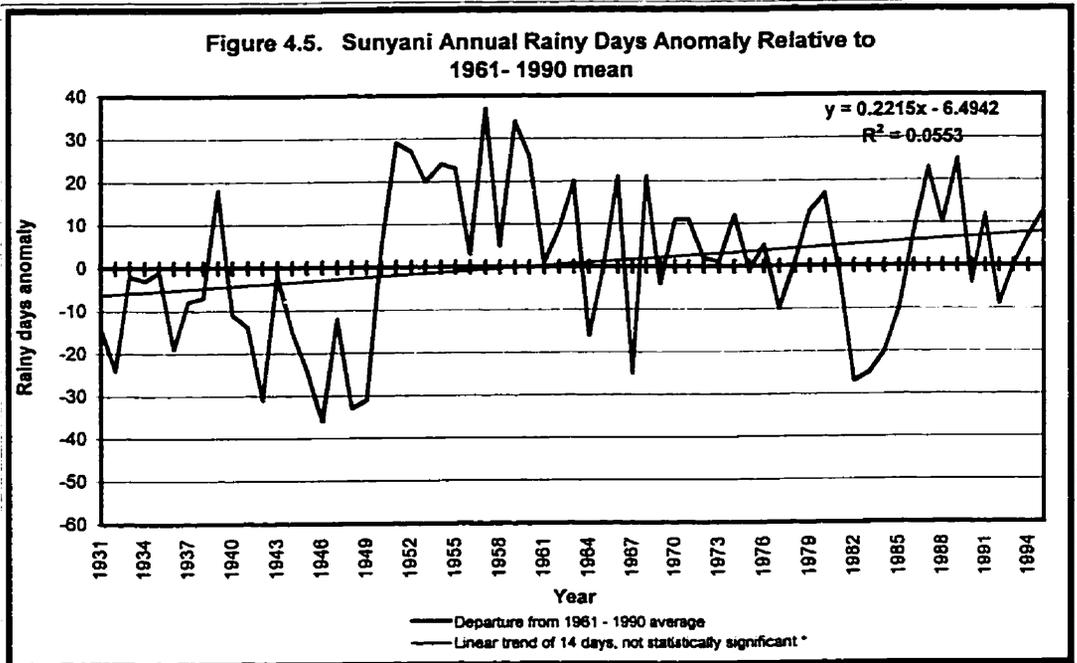
Note: \* t-observed value, 4.7985 > 2.086, value of  $t_{0.025}$  for 20 df. Therefore reject  $H_0$  (section 1.6511)  
Source: Based on data from Ghana Meteorological Services Department, Accra, 1996.



Note: \* t-observed value, 29.4763 > 2.086, value of  $t_{0.025}$  for 20 df. Therefore reject  $H_0$  (section 1.6511)  
Source: Based on data from Ghana Meteorological Services Department, Accra, 1996.



Note: \* t-observed value, 4.8405 > 2.086, value of  $t_{0.025}$  for 20 df. Therefore reject  $H_0$  (section 1.6511)  
Source: Based on data from Ghana Meteorological Services Department, Accra, 1996.

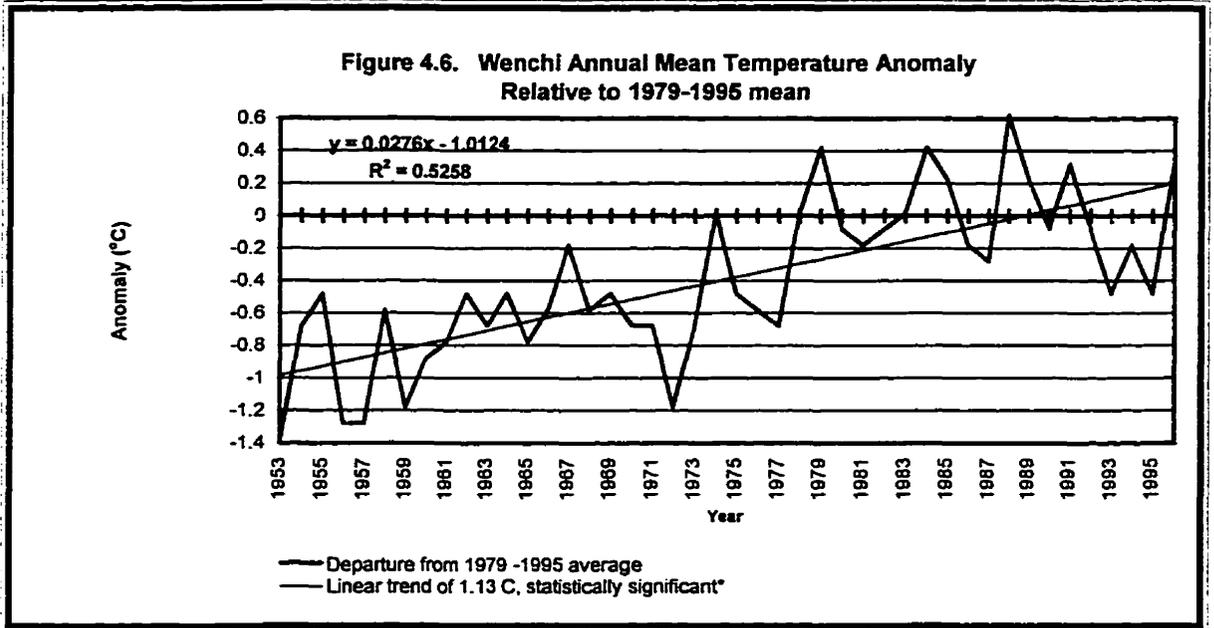


Note: \* t-observed value, 0.07 < 2.086, value of  $t_{0.025}$  for 20 df. Therefore accept  $H_0$  (section 1.6511)  
Source: Based on data from Ghana Meteorological Services Department, Accra, 1996.

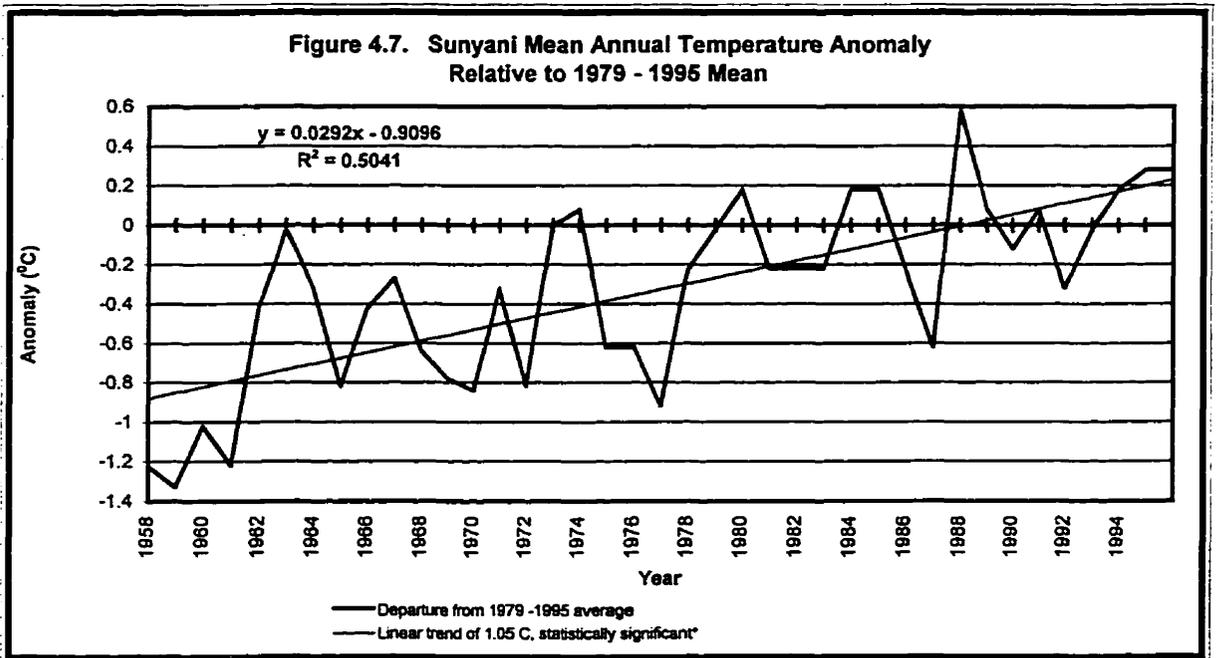
annual rainfall for 1931-1960 (1341.7 mm), was above the average for 1931-1990, while the corresponding figure for 1961-1990 (1252.8 mm) was below the average for 1931-1990. The drop of 88.9 mm in the annual average for 1961-1990 relative to 1931-1990 represents a decrease of 6.6% in average annual rainfall amounts between the two climatic periods. This trend towards aridity is demonstrated by the linear trend in Figure 4.2 which shows an overall rainfall decline of 154.5 mm, at an annual average of 2.6 mm since 1931.

In Sunyani, there is a similar tendency towards aridity. Between 1931 and 1990, the average annual rainfall amount was 1258.14 mm. Average annual rainfall amount decreased from 1332.2 mm in 1931-1960 to 1209.9 mm in 1961-1990, representing a decrease of 122.3 mm (9.2%) from the 1931-1960 annual average. The linear trend shows a decrease of 279.2 mm of rainfall at an average annual rate of 4.2 mm between 1931 and 1995 (Figure 4.3). While Figures 4.2 and 4.3 show trends towards aridity in both Wenchi and Sunyani, the decrease in absolute rainfall amount is greater in Sunyani (279.2 mm) than in Wenchi (154.5 mm). Also the annual rate of decrease is higher in Sunyani (4.2%) than in Wenchi (2.6%), for no obvious reasons.

Though the analysis of records for both stations points to overall decreasing rainfall amounts in the regions, the number of rainy days per year increased in both stations in the period (Figures 4.4; 4.5). The yearly average of rainy days in Wenchi between 1931 and 1960 was 101, while the corresponding figure for 1961-1990 was 114. The difference represents an increase of 13% (13 days) over the 1931-1961 period. In Sunyani the yearly average of rainy days between 1931 to 1960 was 100, while the corresponding figure for 1961-1990 was 102, a modest increase of 2% over the 1931-1990 average. That the amount of rainfall is decreasing while the number of rainy days is increasing indicates a decline in the amount of rainfall on any rainy day.



Note: \* t- observed value, 4.14 > 2.16, value of  $t_{\alpha, 0.25}$  for 13df. Therefore reject  $H_0$  (section 1.6512)  
Source: Based on data from Ghana Meteorological Services Department, Accra, 1996.



Note: \* t- observed value, 30.8 > 2.16, value of  $t_{\alpha, 0.25}$  for 13df. Therefore reject  $H_0$  (section 1.6512)  
Source: Based on data from Ghana Meteorological Services Department, Accra, 1996.

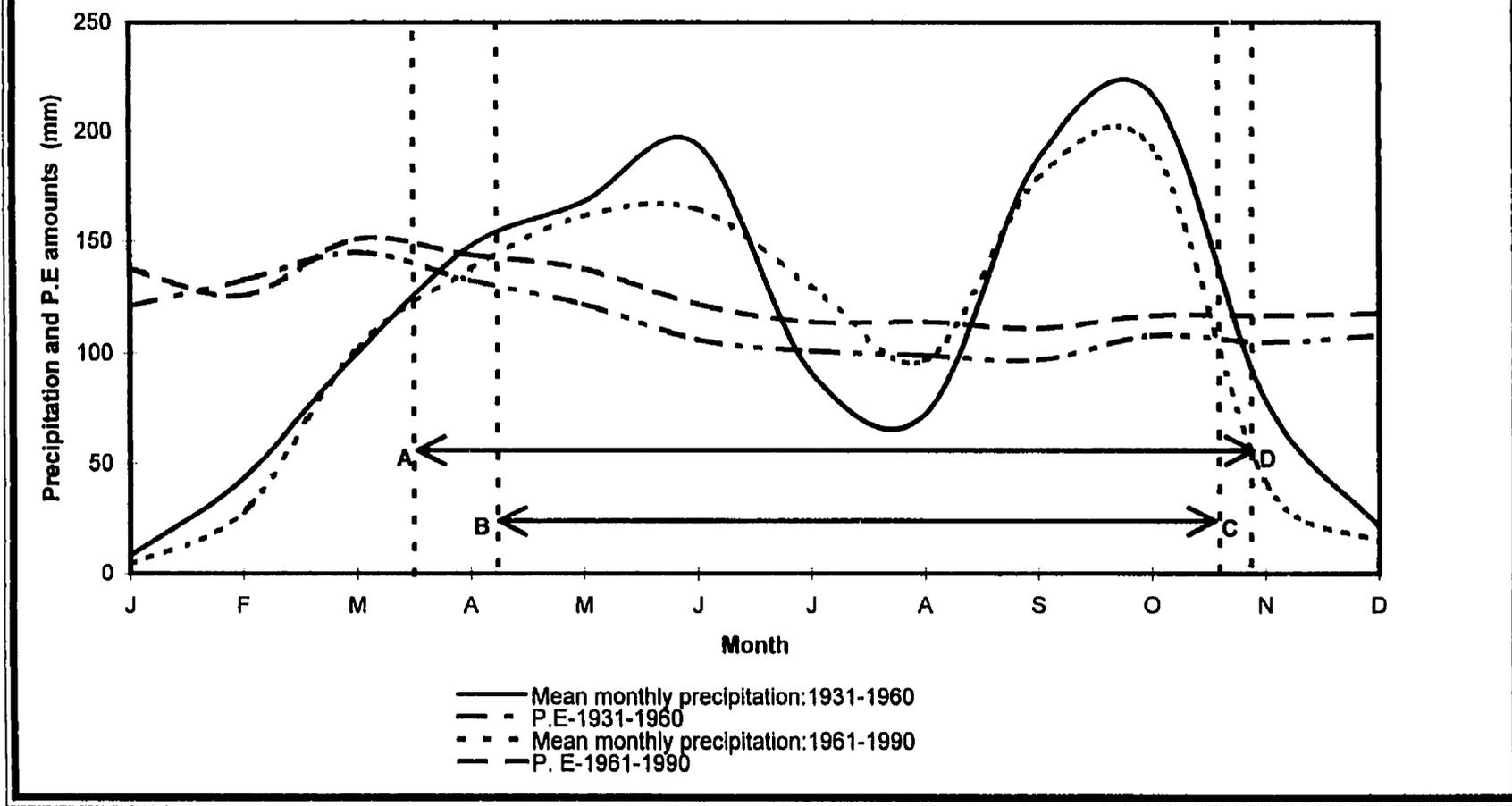
#### 4.13 Temperature Trends

Figures 4.6 and 4.7 show annual temperature anomalies for Wenchi between 1952 and 1995, and for Sunyani between 1957 and 1995 (section 1.6514; Appendix 4). Mean surface temperatures in Wenchi and Sunyani increased by  $1.13^{\circ}\text{C}$  and  $1.05^{\circ}\text{C}$ , respectively, in the corresponding periods. These figures are significantly higher than the global mean temperature increase of  $0.2$  to  $0.3^{\circ}\text{C}$  in the last 40 years (Houghton et al. 1996). The temperature increase in both stations is the result of a rise in maximum and minimum temperatures which warmed by  $0.7^{\circ}\text{C}$  and  $0.4^{\circ}\text{C}$ , respectively, in the period. There is a very weak negative correlation,  $-0.11$  and  $-0.12$ , between temperature and rainfall amount in Wenchi and Sunyani, respectively. The combined impact of increasing temperatures and declining rainfall on agriculture is better demonstrated in the effects these trends have on water balance in the farming season.

#### 4.14 Water Balance in Wenchi

Figure 4.8 compares the monthly water balance for Wenchi from 1931 to 1960 with the water balance from 1961 to 1990 (section 1.6513; Appendix 5). Mean yearly potential evapotranspiration (P. E) for both periods was  $1378\text{ mm}$  and  $1252\text{ mm}$ , respectively. The net yearly water balance for both periods was  $-3.6\text{ mm}$  and  $-7.9$ , respectively. Though yearly moisture indices (MI) for both periods were negative, the net MI in the corresponding farming seasons—March to October—were  $29.2\text{ mm}$  and  $15\text{ mm}$  respectively. While the MI was positive in the farming seasons in both periods the soil moisture in the 1961-1990 farming season was only 52% of the 1931-1960 soil moisture, indicating a decrease of soil moisture in the 1961-1990 period.

Figure 4.8. Water Balance for Wenchi: 1931-1960 and 1961-1990



Notes:

- (a) Line AD indicates the average length of farming and rainy seasons for the 1931- 1960 period.
- (b) Line BC indicates the average length of farming and rainy seasons for the 1961 -1990 period.
- (c) Calculation of Potential Evapotranspiration from crop and soil follows net radiation:  $P.E = R_N/L$ : where P.E is potential evapotranspiration ( $kg\ m^{-2}$ ),  $R_N$  net radiation ( $MJ\ m^{-2}$ ) and L is latent heat of evaporation of water ( $2.453\ MJ\ Kg^{-1}$  at  $20\ ^\circ C$ )

Source: Based on Climatic Data from Ghana Meteorological Services Department, Accra, 1996.

Though evapotranspiration was higher between July and August relative to 1931-1990 values for the same months, the increased rain in these months made the relatively drier period become less dry in the 1960-1990 period than in the 1931-1960 period (Figure 4.8).

Likewise, there has been a shift in the timing of when the MI becomes positive from "A" in 1931-1960, to "B" in 1961-1990 (Figure 4.8). This shift implies that the beginning of the planting season has moved from the middle of March ("A") to early April ("B"), given that farmers begin planting their crops when the MI becomes positive (section 1.6513). The two cropping seasons have become shorter. While the beginning of the major cropping season has shifted from the middle of March to early April, the end of the season, which also marks the beginning of the minor cropping season, remains unchanged; it is still marked by the relatively dry season in August (Figure 4.8; section 1.514). Net water balance at the end of the minor season turns negative earlier than before – around the middle of October ("C") instead of late October ("D") - hence shortening the minor crop season. Since the water balance for the year becomes negative earlier than before and does not become positive until early April, the over-all farming season in the 1961-1990 period (*line BC*) has become shorter relative to the 1931-1960 period (*line AD*). Assuming that the dry season is the period in which the MI is negative, the dry season has become drier and longer in the years 1961-1990 – from late October to early April – than in 1931-1960 – from late October to middle of March (Figure 4.8). The lengthening of the dry season and the shortening of the farming season have adverse effects on agricultural activities in the FSTZ (section 4.17).

#### 4.15 Precipitation concentration index (PCI)

PCI is a measure of the nature of rainfall distribution in the year, that is, whether rainfall tends to be more concentrated in some months of the year or whether it is evenly distributed throughout the year (section 1.6512). PCI values of less than 10 suggest

uniform distribution; values between 11 and 20 denote a tendency towards seasonal distribution; and an index above 20 represents marked seasonal differentiation with increasing monthly concentration (Oliver 1980). Rainfall records in the FSTZ show a tendency toward a uniform annual rainfall distribution. The PCI values in 1931-1990 and 1961-1990 were 11.43 and 9.5 for Sunyani and Wenchi stations respectively. Thus, although there was a trend towards increased aridity in the 1961-1991 period, there was a tendency towards more uniform rainfall distribution in the period. On the other hand, in the 1931-1960 period there was more rainfall but there was also a greater variation in seasonal distribution.

Nevertheless, the tendency towards a more uniform annual distribution of rainfall has little agricultural benefit, especially if the rains in the farming season are not sufficient for crops to complete their growth. Conversely, if the uniform distribution in the year is accompanied by increased rainfall, it could extend the farming season and allow farming throughout the year. The PCI in both stations shows that there is a trend toward decreased rainfall and a uniform rainfall distribution. This situation bodes ill for agriculture in the region (section 4.17).

#### 4.16 Indirect Measures of Rainfall

Some indirect measures of rainfall also point to desiccation in the study area. Farmers testified, for example, that until 1983 most of the streams had water for the greater part of the year. But now for most of the year, stream beds are dry and choked with weeds, while rivers which had water all year round have isolated pools dotting the river beds. That the four wells in Wamanafo had dried up since 1985 points to a lowering of the water table, which is consistent with declining rainfall. These wells were dug in 1967 but they started drying up in 1977. The 1980-1983 drought completely deprived the wells of any water. Originally 13 m (45 ft) deep, they were deepened to 16 m (52.5 ft) in 1981 but they dried up

again in 1985 and have been without water since. Deeper bore-holes now serve the community. According to the women interviewed at the site of the bore-holes, water yield has declined from about nine liters per minute in the 1970s to only 2.4 liters per minute at the present. Similarly, the natural spring which has served the community since its foundation in the late 1860s now flows only in trickles.

The lowering of the water table could also be attributed to over-pumping due to population increase from 2 723 in 1960 to about 6 500 in 1995. While the interplay of both factors, over-pumping and decreased rainfall, may be responsible for the falling water table, the effects of significant decrease in rainfall amount on the water table in the area cannot be overemphasized (Figures 4.2 and 4.3). Increasing temperatures and decreasing rainfall and the associated desiccation in the study area may be explained by the general climatic change in the West African sub-region as well as by the continued human disruption of the natural ecological balance discussed in section 2.21.

#### 4.17 Implications of Temperature and Rainfall Trends for FSTZ Agriculture.

The rainfall and temperature trends discussed above have consequences for agriculture in the FSTZ. The increasing temperature trends are a matter of great concern in the study area since there is a strong negative correlation between temperature and humus formation (Harrison 1979a; b). Some research shows that in regions with average maximum temperatures 20° C and below, humus forms faster than it is broken down making the soil better for agriculture because it is enriched with nutrients, and the soil structure is enhanced (Tisdale et al 1993: 127; Harrison 1979a and b). On the other hand, in areas that have average maximum temperatures above 20 °C, soil fertility is difficult to sustain because the rate of bacterial activity is faster (three to six times the rate in the temperate zones) than the supply of organic matter (Chang 1957). In addition, the higher temperatures of soil water in the tropics increases the quantities of dissolved substances

that can be held in a solution at saturation (Young 1976:65), thereby increasing the rate of nutrient removal in the solution. It is estimated, for example, that for a given moisture condition, higher temperatures increase the rates of leaching by a factor of about three in the tropics as compared with temperate latitudes. (Young 1976:65). Accordingly, the increasing temperatures would make the already poor soils in the FSTZ even poorer.

The increased rainfall in July and August interferes with the ripening, harvesting and drying of some of the crops from major the farming season (Figure 4.8). Cereal crops, such as maize, are allowed to dry on the stalk before they are harvested. Excessive rainfall at the time of their harvest, therefore, delays the ripening and drying process, and makes the seed rot on the stalks. The increased rainfall in July and August also impedes preparation of the land for the minor season crops since the raining makes it difficult to burn the cleared weeds. Because of the delay in the start of the first rainy season, the major season crops are planted later than before (Figure 4.8). The harvesting of the crops therefore coincides with the beginning of the minor farming season. This coincidence stresses human resources as the farmers harvest the major season crops at the same time as they are preparing the land for the minor season crops. Besides, the minor farming season is also getting shorter as the period of adequate moisture shortens (Figure 4.8). A shortening of both farming seasons implies that longer gestation crops such as yams and plantain, which need both farming seasons to mature, will be difficult to cultivate (Figure 4.8; Table 5.2). Furthermore, the trend towards drier conditions in the dry season can result in imbalances in the MI, causing water stress in the perennial crops, and creating conditions for more frequent bushfires. Another possible outcome of the shortening of both farming seasons is that a single cropping system may replace the double cropping system. The shortening of one of the two cropping seasons can have adverse affects on the yearly food production since farmers will not have the opportunity of a second harvest.

With more rains in August, the rainfall trend portends a late single maxima rainfall pattern peaking in September but having a very long dry season. Such rainfall patterns are typical of the savanna zone to the north of the study area. If these rainfall trends persist, they may transform the forest-savanna vegetation into savanna vegetation, given that it is the length of the dry season more than anything else that creates savanna from forest vegetation (Amanor 1994:193; Houghton et al. 1995:142).

#### 4.2 CHANGES IN VEGETATION COVER

The nature and type of vegetation cover are important in the bush fallow system because of the crucial role they play in soil regeneration (Dennis 1995; Goudie 1994:29). Pressure from farming and bushfires has decimated the original vegetation, while logging has stripped the remaining forest reserves of most of the trees of known commercial value. In structure and biodiversity, there is a remarkable difference between the vegetation on fallow lands and the original vegetation in the FSTZ (Plates 4.1; 4.2). Unlike the fully developed secondary forest vegetation, a typical fallow in the area is dominated by *Chromolaena odorata* (Plate 4.3) and/or *Panicum maximum* weeds, with isolated remnants of the indigenous tree species, such as *Ceiba petandra*, towering over the mostly derived bush species (Plates 4.1; 4.2). Most indigenous undergrowth is dwarfed by the more aggressive new weeds, which thrive vigorously in relatively poor marginal soils and on scant rainfall. Their life cycles are generally very short but they regenerate easily from their seeds, stolons, or other vegetative parts. Their ease of dispersal accounts for the rapid

**Plate 4.1**

Upper canopy of a fully developed secondary forest in the FSTZ  
The trees are over 45 meters tall.

**Plate 4.2**

Now the average vegetation in the FSTZ looks like this one which  
has the undergrowth dominated by *Panicum maximum* with  
smaller isolated trees towering over it..

**Plate 4.3**

*Chromolaena odorata* plant. It grows aggressively and dominates all other plants.

**Plate 4.4**

A termite mound. Active termite mounds are signs of degeneration in vegetation and soil quality. Abandoned termite mounds are signs of regeneration of vegetation and soil quality

manner in which they spread and establish themselves, and the relative difficulty in eliminating them. Among the dominant weeds newly introduced into the region, the *Chromolaena odorata* is the most aggressive and most widespread.

#### 4.21 Invasion by the *Chromolaena Odorata* Weed

Locally called the "*Acheampong weed*" or "*Busia Weed*", *C. odorata* is originally a native of the West Indies and Continental America (Abbiw 1990:244). It was first introduced into the University of Ghana Botanical Gardens in 1969 for scientific research (Abbiw 1990:244). Since then, it has spread to all the forest and forest-savanna regions of Ghana. It is an annual composite growing to a height of 2 meters and may assume a climbing stance (Plate 4.3). It is a threat to biodiversity and slows regeneration since it spreads vigorously throughout the fallow land. In the process it dominates the undergrowth, replaces woody vegetation and other climbers, and prevents the germination of the forest seed bank, thus excluding other species. Farmers have observed that many forest undergrowth species have completely disappeared since the introduction of the *C. odorata* weed. Its massive, inflammable foliage increases the risk of bushfires, which are a threat to perennial food and tree crops in the dry season. In the field, they grow faster than the newly planted crops, and may climb to cover up perennial crops. It is particularly troublesome in oil palm and cassava farms and demands constant weeding to give the shorter gestation and perennial crops a chance of survival. If they are not pruned regularly they can cause complete crop failure. At the same time, farmers say the weed makes it possible for large acres of land to be cleared, since the weed is easy to clear and to burn when preparing the land for farming. Others intimated that the weed has some fertiizing effect, a claim which will be revisited later in this chapter.

#### 4.22 Intrusion of the Savanna Vegetation

Other weeds with far-reaching adverse consequences for soil fertility and biodiversity in the region are the varied grass species that are persistently invading the indigenous vegetation. The increasing dominance of the grass or savanna vegetation over the forest vegetation is a function of a complex set of factors such as soil degradation, frequent bushfires, logging, farming, grazing, decreased rainfall and dispersal of grass seeds through road construction (Goudie 1994:51-53). The savanna vegetation is made up of herbaceous plants, especially grass species such as *Panicum maximum* (Hwede) and *Pennisetum purpureum* (Sre). These herbaceous plants form the undergrowth for the few tall and isolated remnant trees in the fallow (Plate 4.2). Once the savanna vegetation has established itself, it initiates a chain of natural and human processes with dire consequences for agricultural productivity.

#### 4.23 Implications of Vegetation Change for Agriculture

The conscious and unconscious introduction of "ecological pollutants", such as *C. odorata*, and the spread of the savanna, diminish the regeneration potential of the forest-savanna ecosystem since these weeds aggressively and effectively compete with the forest species for dominance. Since tree crops do not thrive in savanna vegetation but in a forest and savanna-forest setting, the increasing grass component in the vegetation cover may explain why tree crops such as cocoa and coffee do not fare as well as before in the FSTZ.

Besides, the annual fires associated with the savanna vegetation destroy the forest seed bank, inhibit the regenerative ability of the forest species, and reduce the build-up of leaf litter and humus in the top soil. Young (1976:45) and Ahn (1970) have observed that annual bushfires account for savanna soils being poorer with lower organic matter, poorer nutrient reserves and poorer soil-storage properties than their forest counterparts. Even in the absence of fire, savanna soils are low-humus variants of their forest counterparts on

the same soil series, and have a higher carbon:nitrogen ratio (Young 1976:45). The carbon:nitrogen ratio in moist savannas is sometimes 15 or above, compared with 10 in adjacent forested sites (Young 1976:44), indicating some form of inhibition in the action of nitrifying bacteria (Nye and Greenland 1960; section 4.322).

Grass species are so aggressive that a thorough cultivation of soils is necessary to clear the grass species to minimize their competition with the newly planted crops. But the thorough tillage of the land destroys the soil-root mat of the forest trees and shrubs, disturbs the soil structure, and reduces the status of the soil nutrients, reducing the constitution of the soil to that of a savanna soil (Nye and Greenland 1960). This is in contrast to the minimum tillage methods used in the forest and semi-forest vegetation zones to preserve the soil root-mat of the trees and shrubs. Excessive cultivation of the soil also tends to slow down the regeneration of the evergreen and deciduous forest plant species, supplanting them with grass and more drought resistant savanna species. The rigorous methods of weeding associated with savanna vegetation also increase expenditures for labor on the farm. But perhaps the most remarkable result of the changes in vegetation for farming is the proliferation of the fauna that are associated with the new weed species.

According to farmers, rodents, insects and other pests which have the savanna as their habitat have increased in number in recent times. This sudden increase may be attributed to the introduction of the new weeds and the increasing grass component of the vegetation. Among the pests now common in the area are caterpillars, ants, termites, and the varied species of grasshoppers. Grasshoppers and termites were mentioned as the most destructive of all the pests. In the dry season grasshoppers eat the leaves and stems of even perennial crops such as cassava, plantain, and cocoyam. Termites eat the bark and roots of crops, especially if the rains fail for a considerable length of time.

Grasshoppers and termites are testaments to ecological changes. The results of some research in Nigeria show that decreasing rainfall and the introduction of *Chromolaena odorata* are the main factors responsible for the growth and spread of the grasshopper. While the *C. odorata* provides an ideal place for the eggs of the hopper, the dry conditions are favorable for the hatching of the eggs (Baker et al. 1977).

Another indicator of land degradation and change in vegetation is the presence of termites (Plate 4.4). Mainly a savanna species, termites colonize forest areas that have degraded to savanna standards (Lee and Wood 1971; Howse 1970). When increased rainfall results in moister conditions that produce less dry biomass, and when the land starts regenerating into its original woody vegetation, the termites move out, leaving their mounds as “monuments of their colonization and centers of regeneration” (Amanor 1995:205; Plate 4.4). The presence of active termite mounds on some fields in the study area is, therefore, an indication of a change in the vegetation and soil into more degraded ones. Surprisingly, only one of the five farms that I visited in Wenchi -- a predominantly grassland area -- had a termite mound on it. On the other hand, five of the fifteen farms that I visited in Wamanafo had termites mounds of varying sizes on them. The average number of mounds per hectare was two with a range of one to six mounds. The differences in the number of mounds in the two areas may be explained by the more frequent use of the tractor ploughs in Wenchi, which destroy the mounds, as compared to Wamanafo where tractor ploughing is not part of the farming practices. The relationship between the presence of termites and soil quality may explain why farmers who complained of increasing frequency of termite mounds on their farms also complained of loss of soil fertility. Hence, the changes in vegetation have led to the deterioration in the agro-ecosystem, loss of biodiversity, decrease in the number of crops that can be cultivated and impoverishment of the soil.

### 4.3 CHANGES IN SOILS QUALITY

#### 4.31 Dynamics of Soil Regeneration

The nutrient content of the FSTZ soil, as with the tropical rain forest soils, is very much more concentrated in the complex and luxuriant vegetation that protects the soil from the pounding power of the torrential rainfall (Norman et al. 1995:6-7). Nutrients are taken up by the vegetation, and are returned to the surface soil as litter. Most of organic matter and other plant nutrients are therefore largely held within the top 20 cm of mineral soil. The nutrients, accumulated in the above ground vegetation, are made available to subsequent crops when the vegetation is cut down and burned (section 3.11). However, a few years of continuous cultivation lead to a rapid decline in soil nutrients, and the soil has to be left to fallow to regain some of its lost nutrients (Cunningham 1963). Years of alternating farming with insufficient fallow can lead to a disturbance of the soil-root mat, which may in turn destroy the delicate ecological relationship between the plants and the soil (section 3.12). Maintenance of the FSTZ soil in a steady state requires a cycle of 2–3 years of cultivation followed by 15–16 years of fallow (Nye and Greenland 1960). With pressure on the land increasing due to the increase in the population, it is becoming impossible to maintain this fallow period in the FSTZ. It is, therefore, expected that the soil quality is declining in the region.

#### 4.32 Status of Soil Quality in Wamanafo

Physical soil erosion, a common problem for soils in the tropics (Hudson 1971), is insignificant on farms in the study area. The low physical erosion is a credit to the protection offered by mixed cropping, the dense soil-root mat and the vegetation cover which protects the soil during cultivation and the fallow period. Population pressure has forced subdivision of farmlands into smaller parcels among family members (section 1.434) leading to shorter fallow periods with adverse effects on soil quality. To determine the state

of soil fertility in the area, an analysis of the physical and chemical properties of nine *composite* soil samples was conducted (section 1.6531; Table 1.3).

#### 4.321 Physical properties of soils

Table 4.2 shows some of the physical properties of the samples examined. The soils belong to the *forest ochrosol* group of soils (section 1.513). Generally, the texture of the soils is typical of forest-savanna soils, which are high in clay content right into the topsoil (Young 1976:82; 89). In the virgin, and plantain-cassava soils, the shallow loamy topsoils pass into clay loam and sandy clay loam in the 2-20 and 20-40 cm depths respectively. The *C. odorata* soil is dominated by clay up to the topsoil. The dark brown color of the topsoils gives way to a dark reddish brown in the 2-20 and 20-40 cm layers. Up to 40 cm, the soils are porous, well drained and loamy enough to allow root penetration and crop growth.

**Table 4.1 Physical Properties of Soils under Different Vegetation Cover at Sample Points Along the Same Contour.**

Nature of Soil Cover	Depth (cm)	Particle Size Analysis			Texture
		Sand % %	Silt %	Clay %	
Virgin Forest	0 - 2	50.5	30.1	19.5	Loam
	2 - 20	44.5	31.1	24.4	Loam
	20- 40	41.5	24.0	34.5	Clay loam
Fallow under <i>C. dorata</i>	0 - 2	37.5	30.0	32.5	Clay loam
	2 - 20	35.5	30.5	34.0	Clay loam
	20- 40	27.5	22.5	50.0	Clay
Soil under Plantain and Cassava intercrop	0 - 2	40.1	36.9	23.0	Loam
	2 - 20	49.5	21.0	29.5	Sandy clay loam
	20- 40	38.5	26.5	35.0	Clay loam

Source: Results of soil analysis at Soil Research Institute, Kumasi, 1996

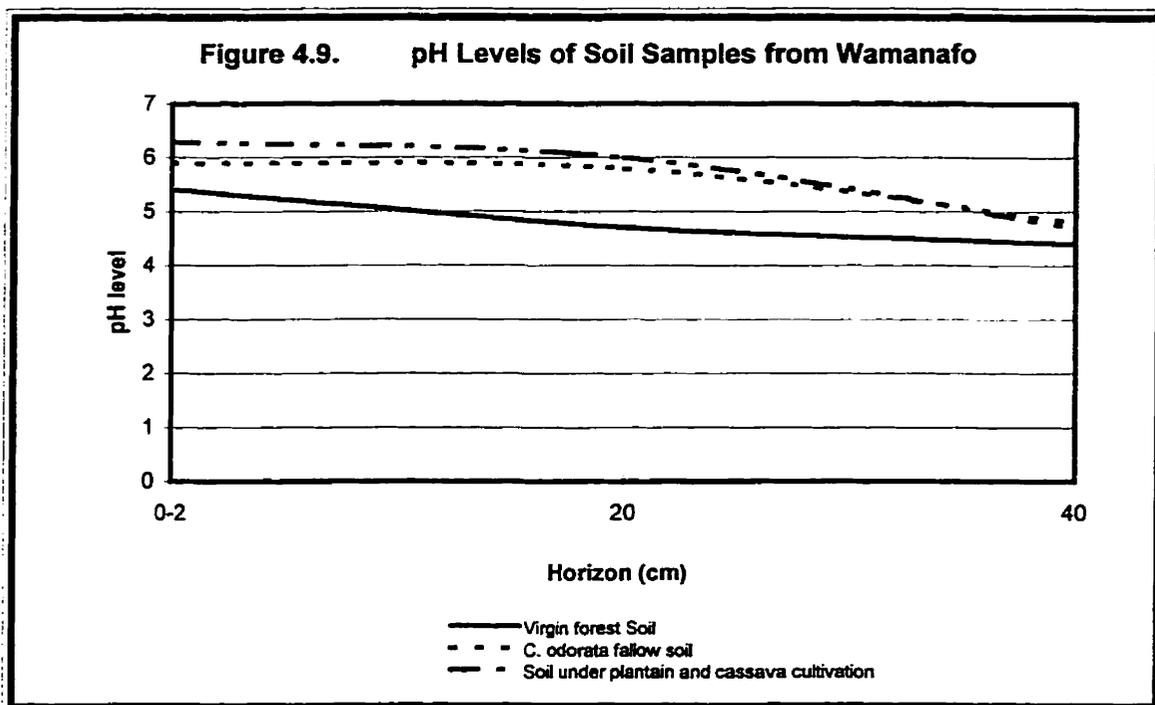
#### 4.322 Chemical properties of soils.

Figures 4.9 - 4.12 show the mean values of some chemical properties of the soil samples (Appendix 6). The mean nutrient values of the soil under fallow and the soil under cultivation are compared with the mean nutrient values of the virgin soil (the control) to determine the extent of degradation due to farming activities (section 1.653). The term *relative nutrient status* is used in this sense. It is defined as the ratio, expressed as a percentage, between the existing nutrient content of a soil and its estimated content under natural (climax) vegetation (Young 1976:285). Relative pH, relative CEC, relative organic matter, relative nitrogen, relative carbon:nitrogen ratio etc., are similarly defined. Since composite samples were analyzed, it was impossible to estimate the statistical significance of the increase, or decrease in soil properties relative to the virgin soils (section 1.653). Where appropriate, variations in nutrient status among the samples are estimated by the applicable standardized measurement used by soil scientists to differentiate soils.

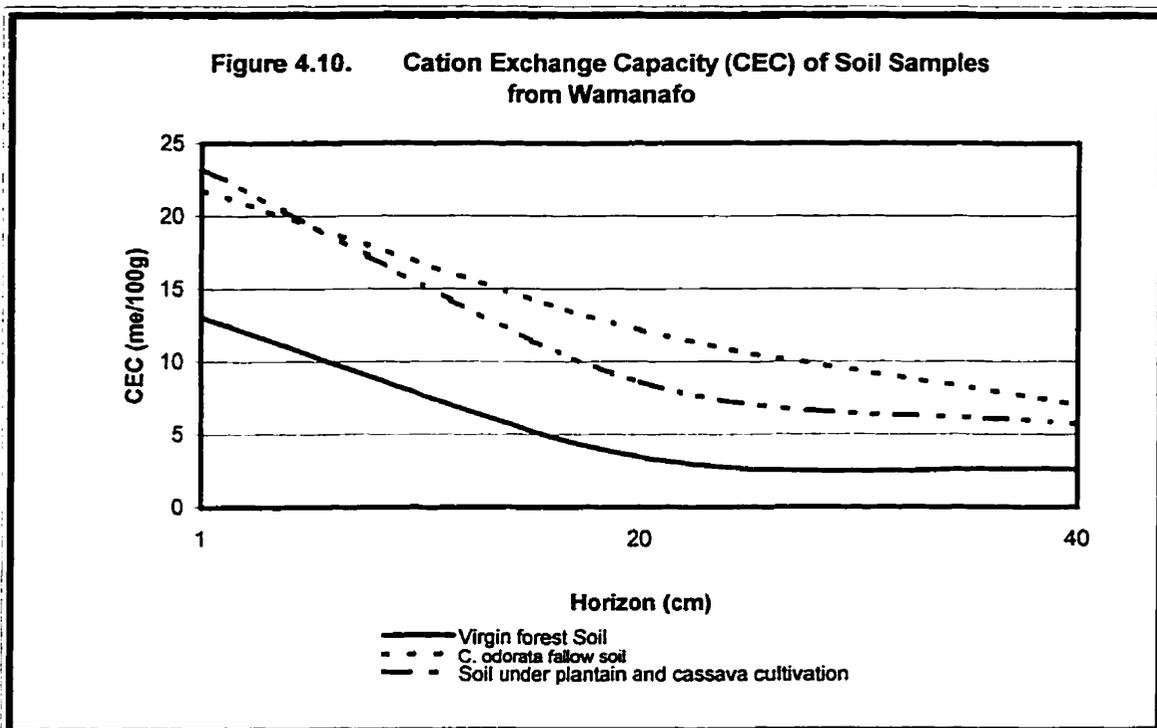
##### 4.3221 Soil pH

Figure 4.9 shows the mean pH levels of the soil samples (Appendix 6). pH is a measure of soil acidity or basicity. Typically, pH values range from 0 to 14.7. The following ranges are generally used for the verbal description of the significant pH levels (Young 1976:94):

pH	<4.0	very strongly acid
	4.0–5.0	strongly acidic
	5.0–6.0	moderately acidic
	6.0–7.0	weakly acid
c.	6.5–7.5	'neutral'
	7.0–8.0	weakly alkaline
	8.0–9.0	moderately alkaline
	>9.0	strongly alkaline



**Note:** All the soils become more acidic with depth. The decline in acidity with depth is a consequence of the greater leaching and take up of bases by roots from the lower horizons than in the topsoils.  
**Source:** Results of soil analysis conducted at Soil Research Institute, Kumasi, 1996.



**Note:** The CEC at the different horizons for each soil reflects the varying clay and organic matter content in the soil at the respective horizons

**Source:** Results of soil analysis conducted at Soil Research Institute, Kumasi, 1996.

Numbers lower than neutrality signify increasing acidity, while the higher values point to increasing basicity. Whereas in temperate latitudes strong acidity is indicative of low soil fertility, this is not so in the tropics, where a high proportion of freely-drained soils are strongly acidic (Young 1976:94). Values ranging from pH 4 - pH 7 are normally good for the common crops grown in the area since these crops have adapted to the acid conditions (section 5.21; Dennis 1995; Young 1976:299).

All the soils are acidic (Figure 4.9). The virgin and *C. odorata* topsoils are *moderately acidic*, with pH values of 5.4 and 5.9, respectively, while the plantain-cassava topsoils are *weakly acidic* (pH value of 6.3). The decline in pH levels in *C. odorata* and plantain-cassava topsoils relative to virgin soils is consistent with the findings of previous studies which show that soils in the humid tropics generally experience a decrease in pH levels when under cultivation (Gyasi et al., 1995; Cunningham 1963: 334-345). This is true of soils in the humid tropics which tend to be generally less acidic than the next horizon, a consequence of exchangeable calcium removed from the lower horizons by roots and deposited on the surface as plant litter (section 4.31; Young 1976:94; Ahn 1970:202-8; Brammer 1962).

#### 4.3222 Cation exchange capacity (CEC)

CEC is a measure of the negatively-charged sites on the surfaces of clay-humus molecules (Tisdale et al 1993:86-87; Young 1976:95). CEC is one of the most important properties of soils strongly influencing nutrient availability (Tisdale et al. 1993:86). It is expressed in terms of milliequivalents (m.e) of negative charge per 100 g of oven-dried soil (me/100 g) (Young 1976:96). The more weathered the soil is, the higher its CEC. Consequently, soils with large amounts of highly weathered material such as clay, and soils with high organic matter tend to have higher exchange capacities than sandy soils that are low in clay and

organic matter (Tisdale et al 1993:89). Values of CEC of a soil as a whole, the analytical figure usually given, reflect clay content as much as clay mineral type (Young 1976:96).

Figure 4.10 shows the CEC of the soil samples at different layers. The CEC values for the topsoil of the virgin soil, *C. odorata* and plantain-cassava soils are 13.2, 21.3, 23.3 m.e./100 g clay respectively. The mean CEC in the *C. odorata* soil is 161% of the mean value in the virgin topsoil, while the corresponding value for plantain-cassava soil is 176.5%. The lower mean CEC in the virgin topsoil compared to the *C. odorata* and plantain-cassava topsoils is partly the result of a lower clay content in the virgin topsoil than in the other two soils (Table 4.1). The CEC values at the different layers of each soil reflect the varying clay and organic matter content in the soil at the respective layers (Table 4.1; Figure 4.10; Appendix 6).

#### 4.3223. *Total exchangeable bases (TEB) and Base Saturation*

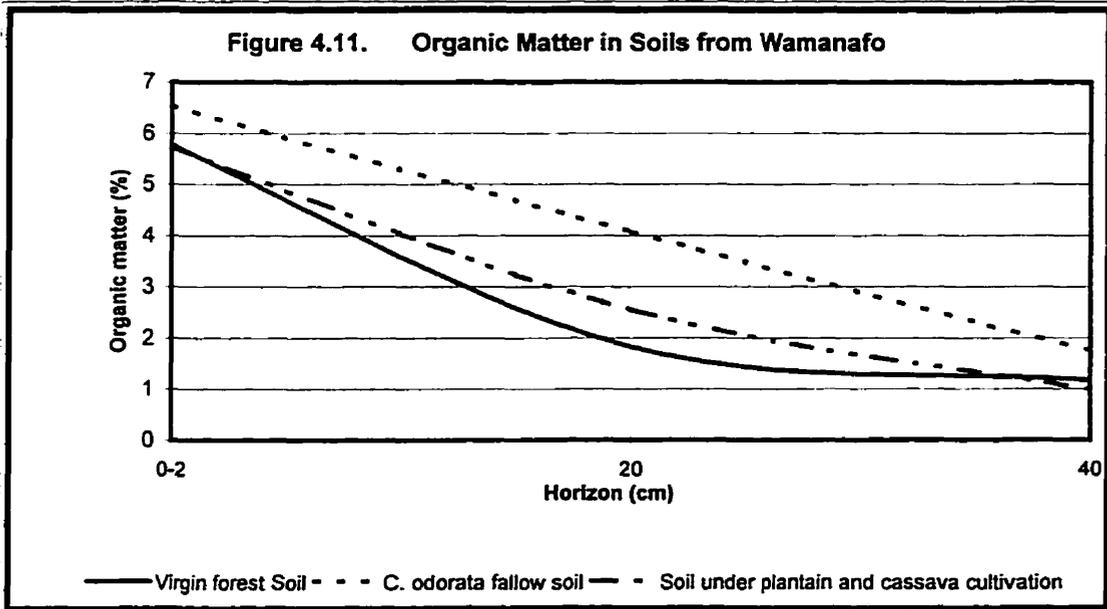
*Total exchangeable bases (TEB)* is the sum of exchangeable calcium ( $\text{Ca}^{2+}$ ), Magnesium ( $\text{Mg}^{2+}$ ), Sodium ( $\text{Na}^+$ ), and Potassium ( $\text{K}^+$ ) ions adsorbed onto clay-humus molecules (Young 1976:95). These exchangeable bases are highly soluble and are therefore readily lost under moderate leaching (Young 1976:71). The *base saturation* is the total exchangeable bases divided by the CEC, expressed as a percentage (Appendix 6). It indicates the intensity of present-day leaching in the soil. The analysis shows that all the topsoils have a base saturation of 98%. This indicates that present day leaching in the area is of only moderate intensity (Appendix 6).

#### 4.3224. *Organic matter (OM)*

The agricultural significance of *organic matter (OM)* in tropical soils is greater than any other property with the exception of moisture (Young 1976:101). OM improves the soil structure, root penetration, and erosion resistance. It also augments CEC, and acts as a

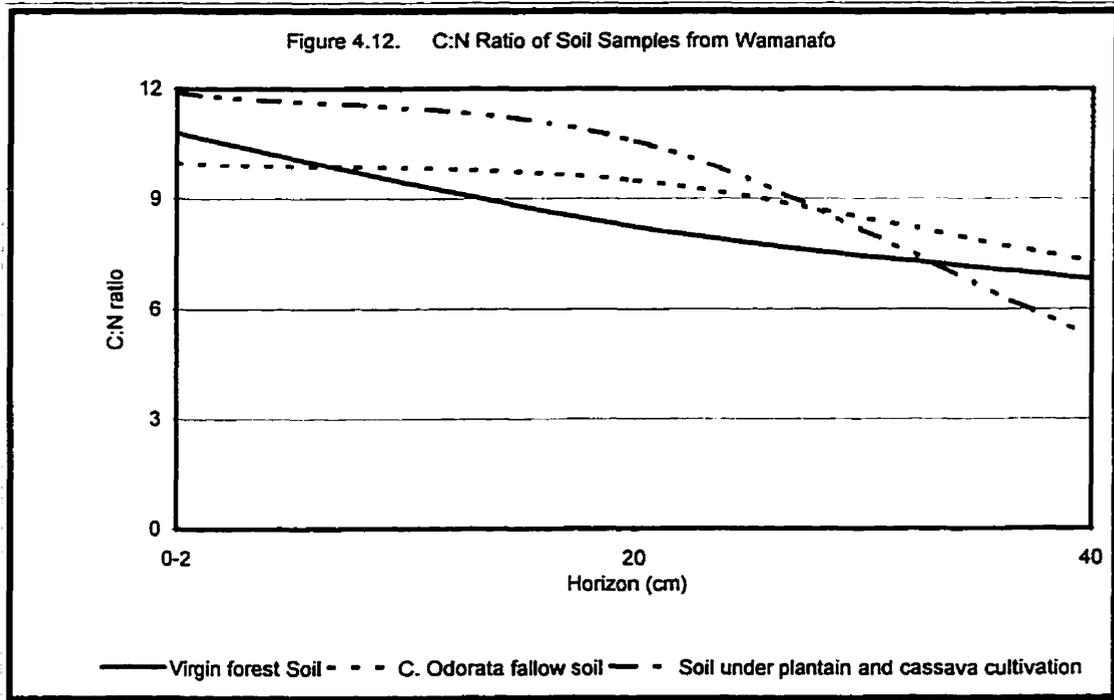
storer of nutrients (Gyasi et al 1995:361). The amount of organic matter in a soil sample is expressed as a percentage of the total soil volume (Young 1976:105). As a general rule, topsoil OM is considered 'low' if it falls below 3.0% in heavy textured soils such as *sandy clay* and *clay*. In sandy, sandy clay loam and sandy loam soils, OM is considered *low* if it falls below 2.0% of total soil volume (Young 1976:300). The OM content in a soil, expressed as a percentage of the organic matter content in the corresponding virgin soil, gives an indication of the soil's OM status relative to the virgin. Typical OM values for tropical soils that have been under cultivation for two years or more are 30-60% of the values of the corresponding virgin soils (Young 1976:105).

The OM values at different layers in the soil samples analyzed are illustrated in Figure 4.11. With mean OM values of 5.8%, 6.5%, and 5.7% for the virgin, *C. odorata* and plantain-cassava topsoils respectively, all the soils have satisfactory OM content; that is their OM levels are not *low* (Appendix 6). OM values in *C. odorata*, and plantain-cassava soils, relative to the virgin soil, are 113% and 99% respectively. These represent an increase of 13% for *C. odorata* soil, and a drop of 1% for plantain-cassava soil. Relative to the plantain-cassava soil, the *C odorata* soil increased its organic matter content by 14.1% over three years. The lower OM in the plantain-cassava topsoils relative to the virgin soils and *C odorata* soils is explained by the continuous cultivation of the plantain-cassava soils for three years. Another reason is that though *the decomposition constant* (the rate of soil carbon increase) in soils under cultivation is considerably higher (4.5 % per annum) than



**Notes:** The organic matter content in virgin soil is unexpectedly low especially in the 2-20 cm horizon. This is attributed to the leaching and storage of organic compounds in the vegetation. C. Odorata soils have higher organic matter content because it drops much litter every year, significant portions of which are retained in the topsoil.

Source: Results of Soil Analysis Conducted at Soil Research Institute, Kumasi, 1996.



Source: Results of Soil Analysis Conducted at Soil Research Institute, Kumasi, 1996.

Table 4.2. Chemical Properties of Litter on 1 m <sup>2</sup> of Land Under Different Vegetation Cover in Wamanafo								
	N %	P %	K %	Ca %	Mg %	Moisture %	Dry Matter %	Ash (% of Dry Matter)
Litter under virgin forest	1.65	0.015	0.028	0.021	0.012	55.7	45.3	54
Litter under <i>C. odorata</i>	1.69	0.023	0.042	0.024	0.01	72.4	27.6	56
Litter under plantain and cassava fallow	1.27	0.015	0.038	0.016	0.004	71.6	28.4	44

Source: Results of analysis of litter samples at Soil Research Institute, Kumasi, 1996.

soil under fallow (0.9% per annum), the annual organic nutrient uptake from the soil under cultivation is higher than the amount that is gained annually (Nye and Greenland 1960). Hence, there is a deficit in organic nutrients in the soil for every year that it is under cultivation. The soil under cultivation has higher organic matter than the virgin soils in the 2 - 20 cm layer because the bulk of the available nutrients in the virgin sub-soil is taken up again and stored in the vegetation (Norman et al 1995:7). The higher OM in *C. odorata* topsoil relative to the virgin topsoil results because *C. odorata* drops large amounts of litter every year, in addition to root decomposition. Consequently, a significant proportion of the OM from the decomposed litter is retained in the topsoil.

On the other hand, the luxuriant vegetation on the virgin soil takes up organic carbon in the topsoil and stores most of it in the vegetation. Therefore, at any time, most of the organic carbon is not in the virgin soil but in the vegetation (section 4.31). The fact that *C. odorata* fallow could regenerate soil OM to levels higher than the virgin forest soil within three years, goes to buttress farmers' claim that the weed has some fertilizing effect. In a study by Gyasi et al. (1995:362), three out of the six sets of composite samples analyzed show that organic carbon content, which constitutes approximately half of soil OM (Nye and Greenland 1960), is higher in *C. odorata* soils than in virgin soils. Also chemical analysis of litter collected on a square meter of soil under the different vegetation covers during this research shows that *C. odorata* litter has a higher content of vital plant nutrients than virgin forest litter (Table 4.2). This may explain why soils under this weed appear to recover plant nutrients within a relatively short time.

Below the 20 cm layer, the OM content level in virgin soil is relatively steady while the content in *C. odorata* and plantain-cassava soils decline with increasing depth (Figure 4.11). The differences in OM amounts below 20 cm is because, unlike the virgin topsoil, the topsoil under *C. odorata* and plantain-cassava is cultivated periodically. Therefore, not

much of the nutrients in organic matter is left in the topsoil to be leached into the lower layers of the soil.

#### 4.3225. Carbon - nitrogen ratio (C:N)

The *carbon - nitrogen ratio (C:N)* defines the relative quantities of carbon (C) and nitrogen (N) (%C to %N) in soil organic matter (Tisdale et al. 1993:124). The ratio is used as an index of soil fertility (Nye and Greenland 1964; Cunningham 1963; Gyasi et al. 1995). The lower the ratio the better the soil. The C:N of an undisturbed virgin soil is between 10 and 12 (Tisdale et al. 1993:124). This ratio range indicates satisfactory mineralization of nitrogen, while C:N values over 12 indicate that nitrification is inhibited (Tisdale et al. 1993:124). Whether N is *mineralized* (conversion of organic N to inorganic N) or *immobilized* (conversion of inorganic N to organic N) depends on the C:N ratio of the organic matter being decomposed by soil microorganisms (Karam 1993:464; Stevenson 1982; Young 1976:294). For instance, if fresh plant matter has a C:N ratio exceeding 20, when large amounts of this type of fresh matter are incorporated into a soil, it results in net immobilization of nitrogen.

Figure 4.12 illustrates the C:N ratio for the various soil samples at different layers (Appendix 6). The mean C:N values for virgin, *C. odorata*, and plantain-cassava topsoils are 10.8, 9.97 and 11.89 respectively, indicating a satisfactory mineralization of nitrogen in all the topsoils. The differences in mineralization of nitrogen in *C. odorata* soils and virgin soils could be due to the fact that woody forest vegetation takes a longer time to decompose than the *C. odorata* litter. Consequently, the virgin soil has higher content of undecomposed matter than *C. odorata* soils. The difference between the C:N value for virgin soil and the plantain-cassava soil may be explained by the relatively stable microbial activity that characterizes uncultivated soil (Tisdale et al. 1993:127). Generally, an uncultivated soil has a relatively stable soil microbial population and a low rate of N

mineralization (*decomposition constant* of 0.9% per annum) which result in a relatively constant amount of plant residue returning to the soil (Tisdale et al. 1993:127). On the other hand, if a soil is under cultivation, there is an immediate and rapid increase in N mineralization activity (*decomposition constant* of 4.5 % per annum). Continued cultivation without the return of adequate crop residues will ultimately lead to a decline in the C content of the soil relative to the N content.

#### 4.33 Implications of Soil Analysis Results for Agriculture

The conditions of soils under cultivation and fallow are not much different from the virgin soils. If it is assumed that the virgin soil is a reflection of the ideal soil conditions in the area then soils in the study area have not degraded much from their original conditions (section 1.67). Soil pHs are within the 4-7 pH levels which are satisfactory for the acid tolerant food crops grown in the area; C:Ns of the soils are within the satisfactory range of 10 – 12; OM content of all topsoil samples are more than 3% of their volumes – values commonly taken as the limit below which remedial measures are necessary for the soil (Young 1976:105). In fact, the inability of the agricultural system to support tree crops may be due to factors other than soil quality since the soil quality is similar to the original conditions which supported cocoa/coffee crops.

Compared to the virgin soils, soils under *C. odorata* have higher levels of exchangeable cations, pH, organic carbon, total nitrogen and phosphorous (Appendix 6). Since the sampled *C. odorata* soils were left to fallow after three years of cultivation, it could be reasonably inferred that their nutrient status at the time they were left to fallow was similar to the nutrient status of the soil under plantain and cassava cultivation for three years. On the basis of this inference, the C:N ratio for *C. odorata* soils improved from 12 to 10 within three years (Figure 4.12). Since the dominant weed, *the C. odorata*, could make soils recover their lost fertility from a C:N ratio of 12 to a C:N ratio of 10 (Figure 4.12), that

is, to levels similar to the virgin forest, in three years, it appears that the fallow system could sustain production if farmers were to maintain a two- to four-year fallow period under this dominant plant.

Though *C. odorata* promotes rapid early nutrient recycling, and achieves some astonishing results in regenerating soil fertility within a very limited time, it inhibits the regeneration of other plant species. In addition, it prevents the growth of indigenous plant species which also achieve a higher level of nutrient recycling, but much more gradually. Others have observed that while *C. odorata* may achieve rapid gains in soil fertility, it can prevent a further build-up of nutrients, and so stabilize the soil-nutrient cycle at sub-optimal levels (Amanor 1995:190). But whatever its shortcomings, *C. odorata* should be studied further for its possible exploitation as a potential organic fertilizer for farmers in the region.

While the soils have not degraded much from their original conditions, the shortening fallows are indications that to sustained the present levels of soil quality there is need for external sources of nutrients, such as biological or chemical fertilizers, to regenerate soil fertility. Sustained crop yields without the use of fertilizers would require that farmers maintain a minimum fallow of three years and to use measures that enhance early soil regeneration. With the increasing pressure on agricultural land due to population pressure it seems more likely there will continuous cropping in the area with agricultural intensive methods that enhances production (section 2.31).

#### 4.4 CONCLUSION

It could be inferred from the foregoing discussion that in the study area rainfall is decreasing, while temperature is on the increase. The combined effects of these variables have shortened the farming season as indicated by the *water balance* in Wenchi. Similarly, the vegetation cover is under invasion by more aggressive weed species. While some of these weeds, such as the *C. odorata*, have some alleged fertilizing properties, most of

them, such as the various grass species, have fewer agricultural benefits than the indigenous vegetation. A range of crops that are indigenous to the FSTZ can no longer be cultivated in the region due to the changes. While the soil quality in the area has not changed much from its original condition and is satisfactory for food crop agriculture at the moment, it is much more difficult to maintain its quality now by fallow methods because of population pressure on the land. The combined effects of the trends in climate, vegetation and soil on agriculture require that the farmers develop strategies to alleviate these effects. The next chapter, therefore, identifies the patterns of innovation, and the regenerative technologies already used by the smallholder farmers in the FSTZ to respond to these trends.

## **5.0 FARMER RESPONSE TO ENVIRONMENTAL CHANGE**

"It is likely that over the years farmers will find ways of adapting to the changing weather patterns and will adjust their cropping systems" (Amanor 1995:194; 198).

"Historically, farmers have tuned their agricultural practices to the natural variations of local climate" (Taylor and MacCracken 1990:1).

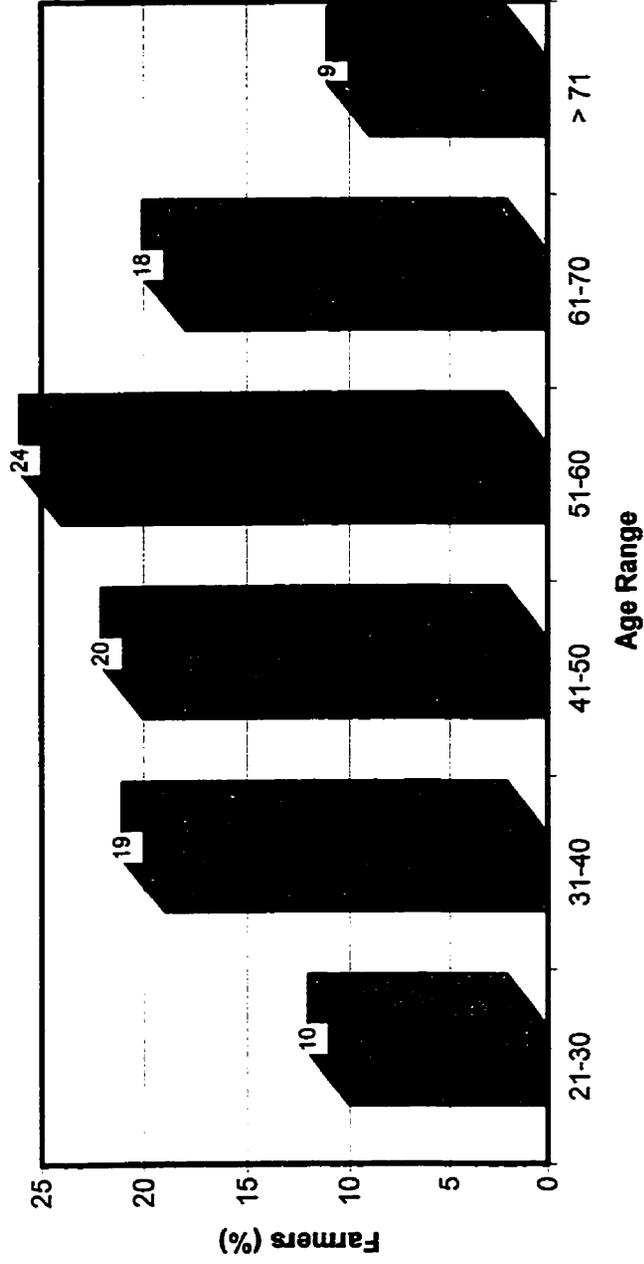
This chapter describes farmers' adaptation strategies in response to the agro-ecological changes discussed in the previous chapter. The various farming methods were identified during group discussions with farmers, from field observations, and from the results of a questionnaire administered to 100 farmers in Wamanafo (sections 1.642 and 1.643).

### **5.1 RESPONDENTS' BACKGROUNDS**

The average farming experience for the respondents is 27.8 years. Respondents' ages range from 21 to 77 years, with an average age of 51 years (Figure 5.1). The high average age and the fact that only 5 % of farmers are between the ages of 21 and 30 is an indication of an aging farming population. Younger people may be avoiding farming because it is not as economically rewarding as they want and because there are no opportunities for them on the land. Also, many young people have formal education, unlike their parents, and tend to get off-farm jobs. Therefore, more and more young people are moving to the urban centers in search of "green pastures" (section 5.47). The high average age also reflects the bias towards the heads of families during the interviews (section 1.642). Since heads of families tend to be oldest members of the family, the preference for heads of families during the interviews can be the reason for the high average age of respondents.

Only 33% of respondents are males. The ratio of two females to one male in the farming sector is a reflection of discrimination against female education, especially in the

**Figure 5.1. Respondent's Age**



Notes:

Average age of respondents = 51.

Average farming experience = 27.8.

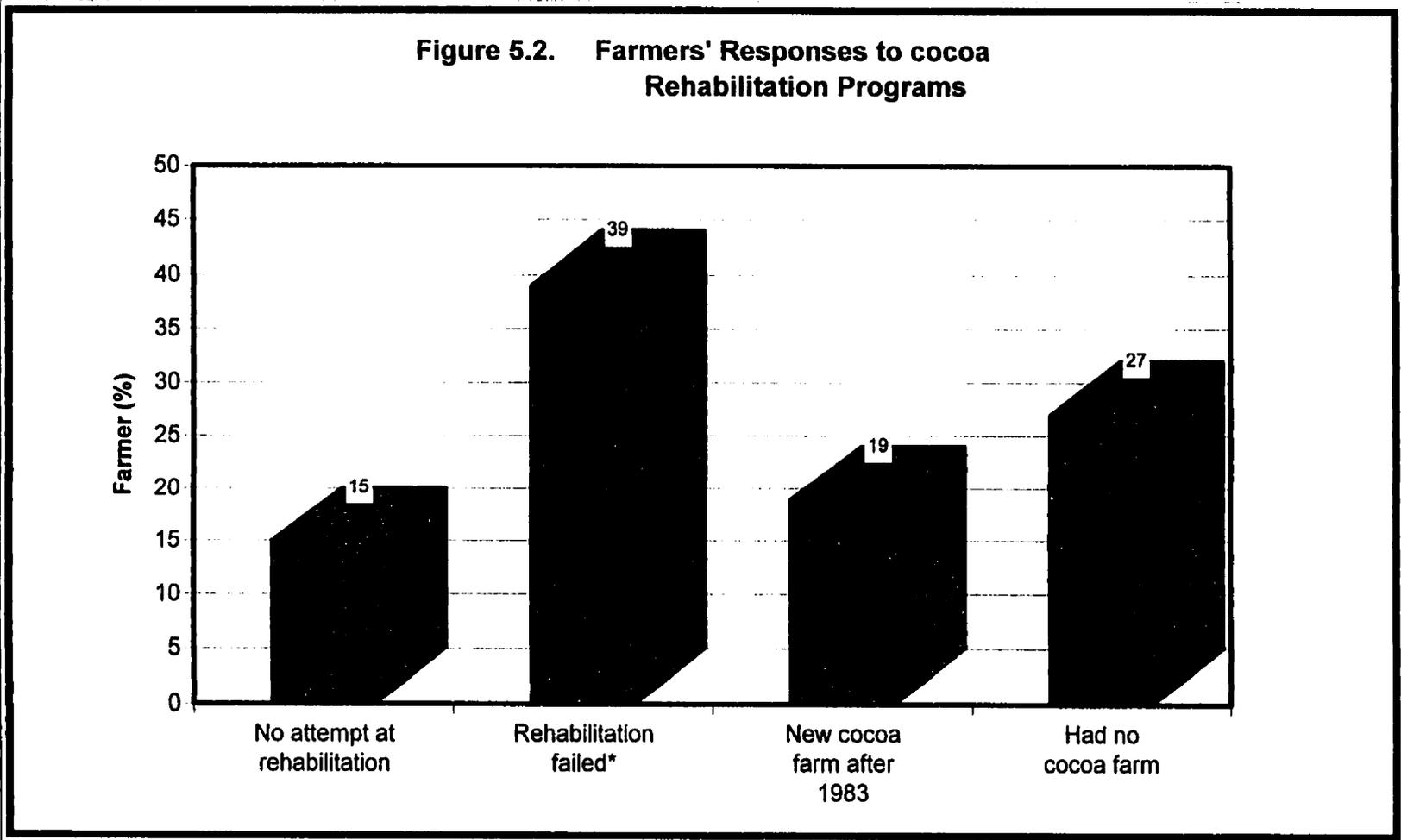
Source: Author's Survey, 1996

rural areas of Ghana. As in all areas in Ghana, more young men than young women in the study area tend to have higher education and to learn more trades. As a result, more young men have off-farm jobs while most young women do not complete elementary school because of the traditional role women are expected to play, especially the bearing of children. More women than men, therefore, end up in farming because farming has no entry requirements.

Only 46% of respondents have had any formal education but the highest level of education attained is elementary school education. Of these respondents, 41% are males. The low level of education is not surprising since people with secondary education and beyond will normally have off-farm jobs, thus making farming a job for those who have minimum or no formal education. Most of the farmers (93%) own and manage their own farms. Three of the seven farmers who farmed on a sharecropping basis are immigrant farmers who do not belong to any land-owning family in the settlement. The other four farmers own and manage their own farms, but they also do sharecropping since they do not have enough land to meet all their farming needs.

Only 23% of the respondents now own cocoa farms compared with 73% in 1983. A significant number of farmers, 38%, had attempted to rehabilitate their cocoa farms but they failed because of bush fires, insufficient rainfall, and degraded soils. Of those who owned cocoa farms, 19% are relatively young farmers who started their farms after the 1983 bush fires in spite of the odds. The interest in cocoa cultivation arises because cocoa serves as an *insurance* in times of sickness and old age.

**Figure 5.2. Farmers' Responses to cocoa Rehabilitation Programs**



Note:

\* 13 of the farmers attributed failure to insufficient rain; 9 farmers said the plants were doing well but were destroyed by bushfires; while 16 complained that the soil was not good for the crop.

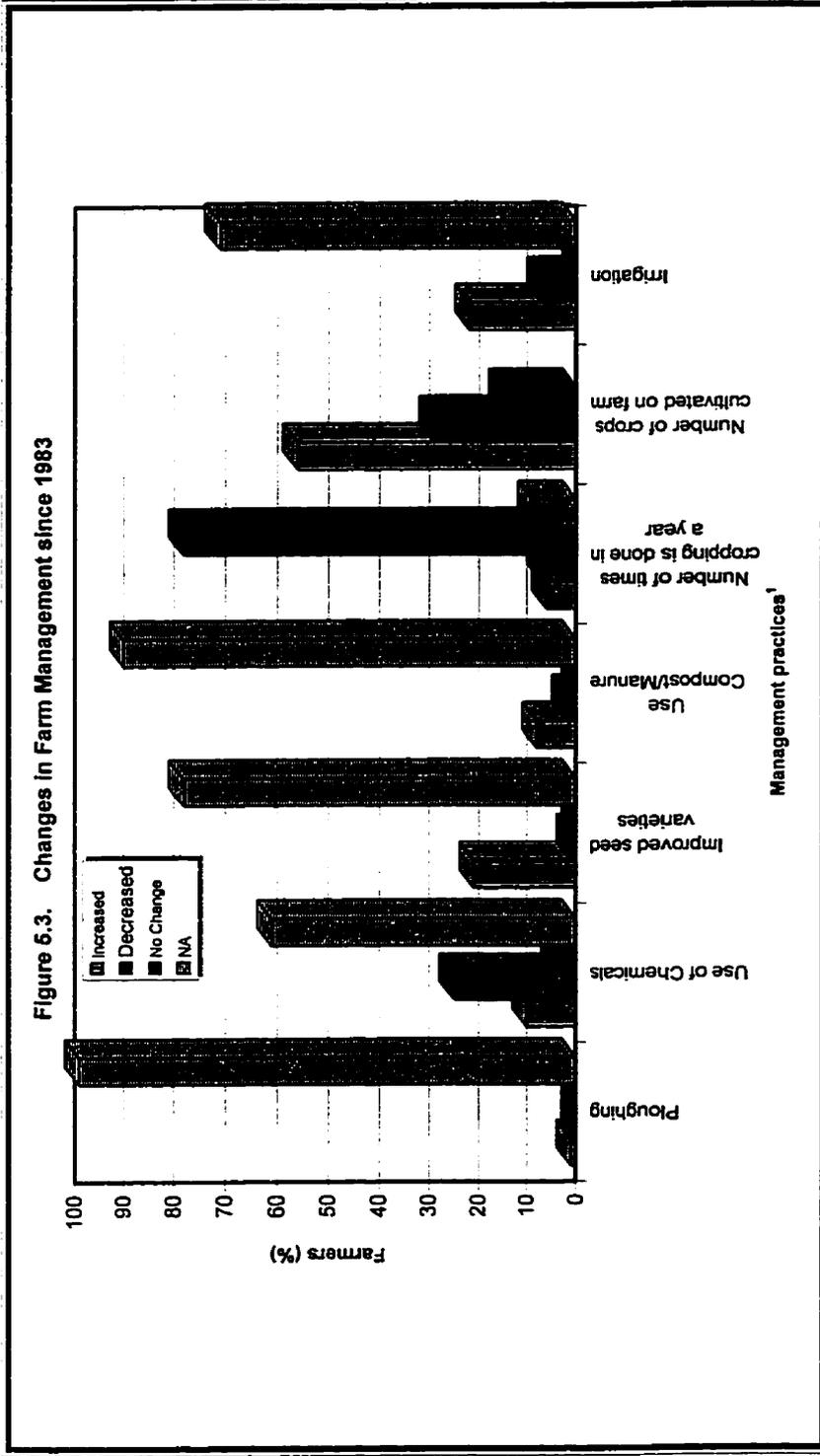
Source: Author's Survey, 1996

When asked why he was interested in cocoa cultivation in spite of the risks one young man responded;

“Now that I am strong I can work in the fields every year and get money from the sale of food crops. But what about when I am old and cannot grow food crops every year? The cocoa farm will offer me an assured yearly income in my old age and when my health fails me”.

Apart from the fact that cocoa/coffee was a cash crop, the reason given by the young man was a major reason why cocoa/coffee was popular among farmers in a poor country where there are neither insurance policies nor retirement or pension benefits for farmers. In spite of the advantages of cocoa cultivation, most farmers failed to respond to the government-initiated program of cocoa rehabilitation for various reasons (Figure 5.2; section 3.221).

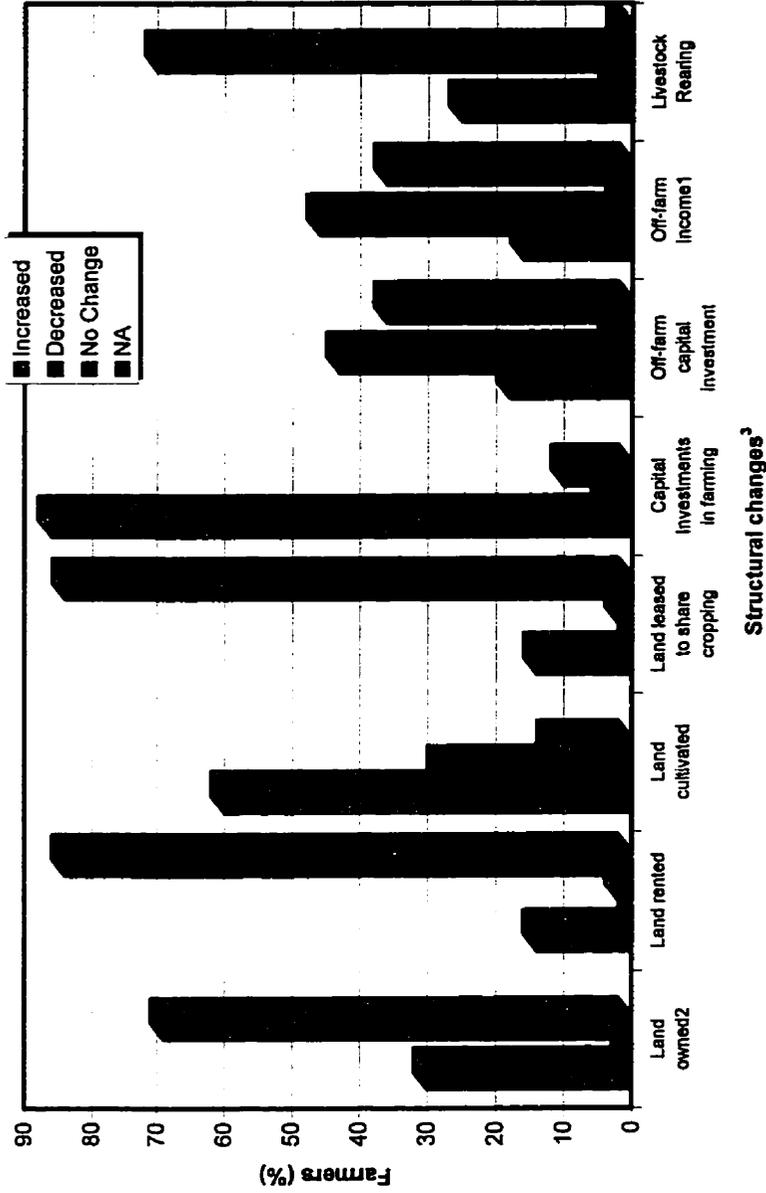
Faced with a fast-changing agro-ecological environment, farmers are changing their land-use patterns and are adopting new farm management practices that reduce the vulnerability and enhance the resiliency of the agro-ecosystem. Most of these responses belong to the “changing use/activity” category of adaptation (section 2.3) and can be grouped into two main categories: farm management strategies and structural changes on the farms (Figures 5.3; 5.4). The former involves specific farming techniques aimed at alleviating specific effects of the changing agro-ecosystem, while the latter are changes in farm infrastructure such as the amount of land owned, capital investments in farming activities, and the introduction of other forms of agriculture such as animal rearing. Very few farmers (about 21%) use some modern methods of farming consistently. The increased capital investment on the farms are the result of increased cost of land preparation and weeding rather than the use of modern tools on the farms (section 5.341).



NA (Not Applicable): Refers to farmers who have never tried the corresponding management practices before  
 1. The management practices are not mutually exclusive. That is, some farmers are using more than one of these management practices.

Source: Author's Survey 1996

Figure 5.4. Structural Changes on Farms Since 1983



Notes:

- NA (Not Applicable): Indicates that the farmer has not made the corresponding structural change(s) on his farm.
- 1 Off-farm income has decreased because farmers who worked on cocoa plantations as laborers lost their jobs with the destruction of cocoa farms. Others who were working for the government as laborers lost their jobs with the Government's Structural Adjustment Programs which began in 1983
- 2 Land owned has decreased for these farmers because some of their land has been leased on long term bases.
- 3 The structural changes are not mutually exclusive. That is, some farmers are making more than one adjustment on the farm.

Source: Author's Survey 1996

Figure 5.4 shows that apart from structural changes on farms to enhance food crops, farmers are considering other farming options such as animal rearing and alternative off-farm sources of income. A combination of the managerial and structural strategies defines the way farmers are responding to trends in the biophysical variables that affect food crop farming.

## 5.2 RESPONSE TO RAINFALL AND TEMPERATURE TRENDS

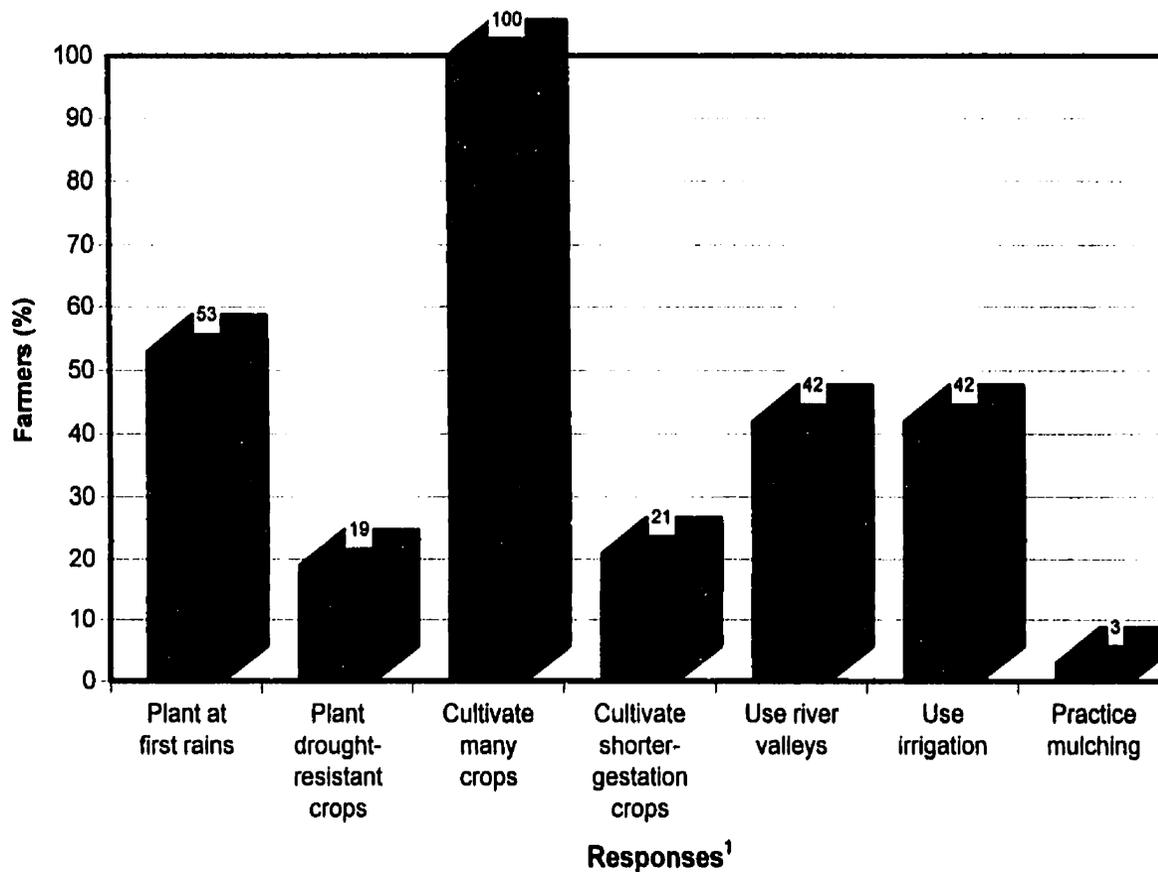
Figure 5.5 indicates the methods farmers are using to mitigate the impact of climatic change on agriculture. The effects of temperature on plant growth are negligible, since temperature is high enough to permit growth throughout the year (Figure 4.8). Farmers' responses to climate change are, therefore, aimed directly at the alleviation of the effects of unpredictable and insufficient rainfall and only indirectly at temperature, much as the increasing temperatures affect soil moisture content by increasing evapotranspiration.

Insufficient rainfall was frequently mentioned by all farmers as a cause of the agricultural crisis. So important is rainfall that many of the farming communities say special prayers at the beginning of each farming season to ask the gods for plentiful rain. However, response to the rainfall problem is not limited to prayers, as farmers have adopted a series of strategies to moderate the effects of decreasing rainfall trends.

### 5.2.1 Emphasis on Drought-Tolerant Crops

There is more emphasis on relatively drought-resistant crops while cultivation of water-demanding crops such as cocoa and coffee has declined significantly (section 5.1). Only 12% of the respondents have cocoa as their main crop compared to 88% who cultivate relatively drought-resistant food crops as their main crops. Among the crops selected for

Figure 5.5. Farmer Response to Decreasing Rainfall

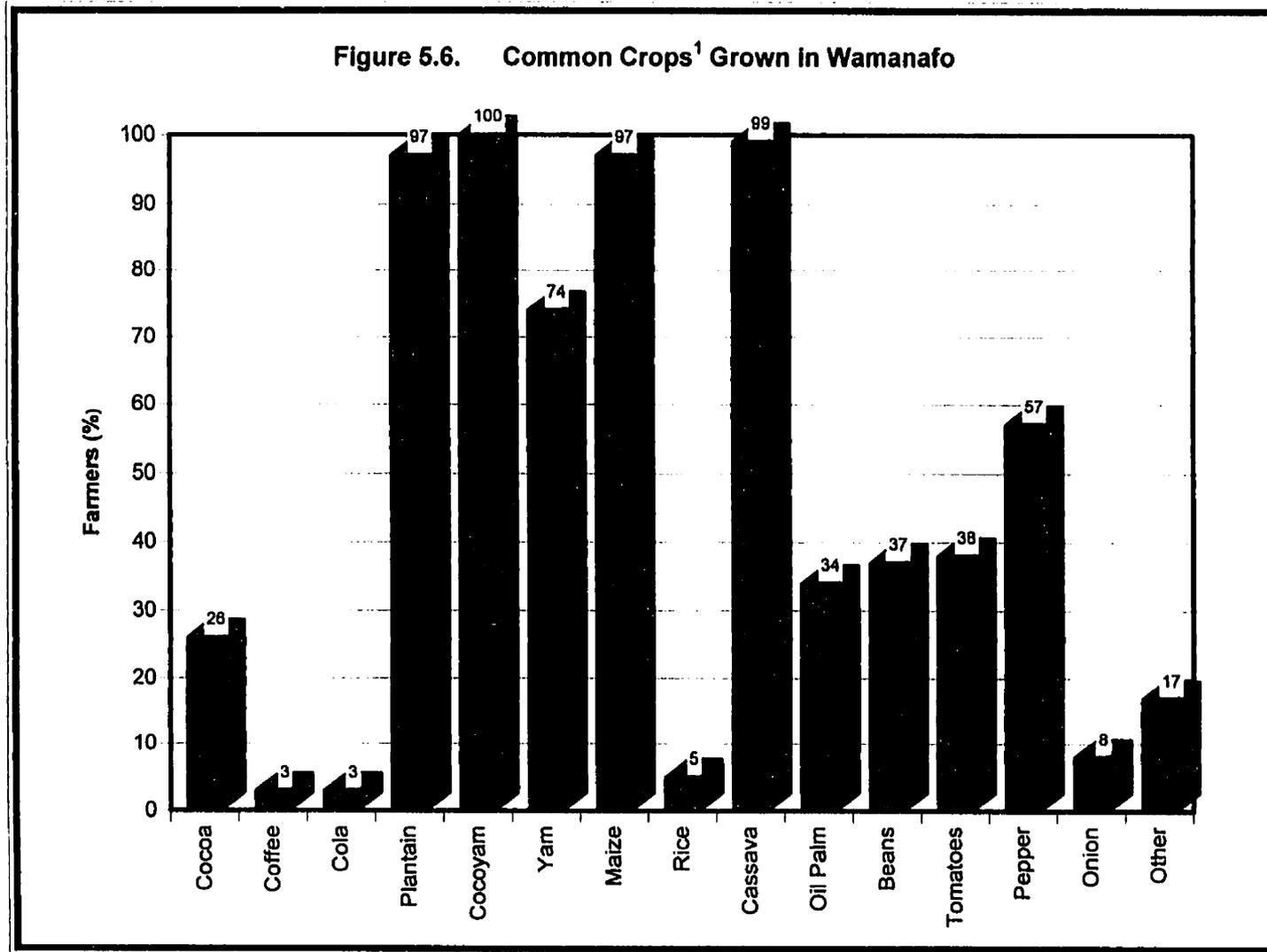


Note:

1 Farmers use a mix of these responses according to the biophysical conditions on the field

Source: Authors Survey, 1996

Figure 5.6. Common Crops<sup>1</sup> Grown in Wamanafo



Note:

1 Each farmer cultivates an average of 8 different crops on a field.

Source: Author's Survey, 1996

**Table 5.1. Gestation Periods of Some Common Crops in the FSTZ**

Crop	Minimum Gestation (months)	Life Span
Cocoyam	6	3 - 4 years.
Cassava	6	4 years.
Yam	6	6 months
Plantain	10 - 12	3 - 4 years
Oil Palm Tree	36	20 - 40 years
Maize	3 - 4	3 - 4 months
rice	3	3 months
Millet	4 - 5	4 months
Sorghum	4 - 5	4 months
Cocoa/coffee	36	30 - 50 years

Source: Author's Survey 1996

their resiliency to decreased rainfall are cocoyam, yam, cassava, plantain, and palm oil trees (Figure 5.6)

#### 5.211 Cocoyam (*Xanthosoma mafaffa*)

Though cocoyam is a native of tropical America, Africa now accounts for well over 75% of the world production, most of which comes from West Africa (Abbiw 1990). Nigeria, Côte d'Ivoire, and Ghana are the important producing countries in the sub-region.

There are about four varieties based on the color of the cormels<sup>1</sup>. They are eaten, boiled, roasted, or fried. Cocoyam leaves (Kontomire), are consumed as spinach when young and tender (Plate 5.1). The cormels are ground or milled into flour which can be used for biscuits and pastries (Plate 5.2). To plant cocoyam the farmers cut the fleshy, succulent corm<sup>2</sup> into small pieces and cover them with soil. Because they are succulent and fleshy the planted corms are able to withstand long periods of drought. They stay dormant in the soil when there is no rain but they sprout only a few days after the rain. On a newly cleared land, cocoyams germinate from remnant corms left on fallow land (Plate 5.3). Thus, the farmers do not buy or plant cocoyam seeds every year, since some of the corms left in the soil from previous farming on the same site serve as seeds for the new farm. It takes five to six months for cocoyam to mature (Table 5.1). Even though cocoyam is drought resistant, it needs good rains to get a good harvest. When there is insufficient rain the tubers get smaller but the farmer gets some harvest. After harvest the farmer cuts part

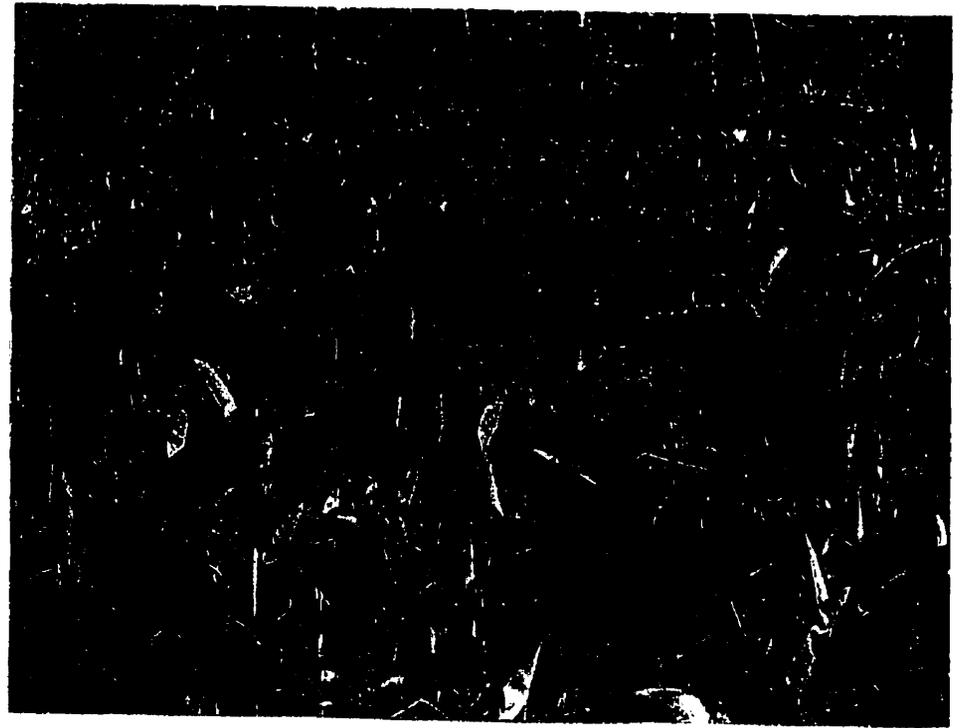
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<sup>1</sup> Cormels are tubers that grow underground on the stem of the cocoyam plant. They are harvested for food (Plate 5.1). Cormels also function as an organ of vegetative reproduction when they are left in the ground (Plate 5.2).

<sup>2</sup> The corm is the underground storage organ of the cocoyam plant (and similar plant species) formed from a swollen stem base, bearing adventitious roots and scale leaves. The corm functions as an organ of vegetative reproduction (Plate 5.2)



**Plate 5.1**  
*Xanthosoma mafaffa*. A matured cocoyam plant. The leaves are edible



**Plate 5.3**  
Young cocoyam plants germinating on a newly cleared fallow land.



**Plate 5.2**  
Harvested cormels of cocoyam in basket

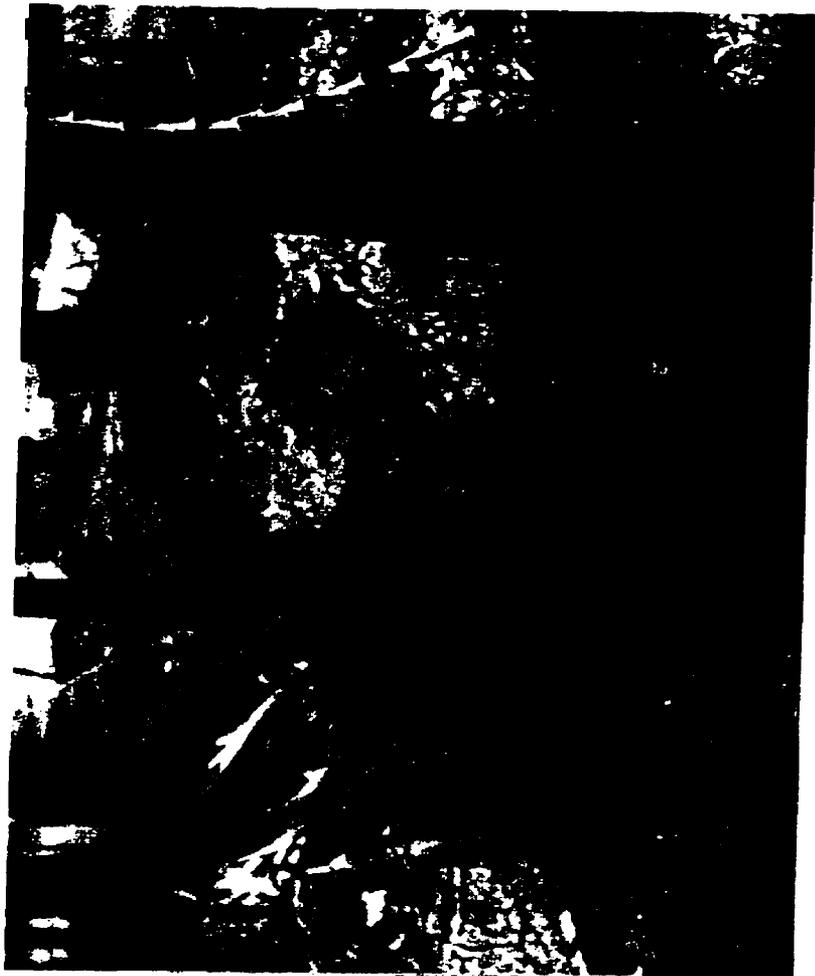
of the corm and plants it on the spot where it was harvested. When the land planted with cocoyam is left to fallow, the corms still grow cormels which farmers harvest in times of famine. All respondents cultivate cocoyam because they are certain of a harvest even in a very bad year when the rains fail (Figure 5.6).

#### 5.212 Plantain (*Musa paradisiaca*)

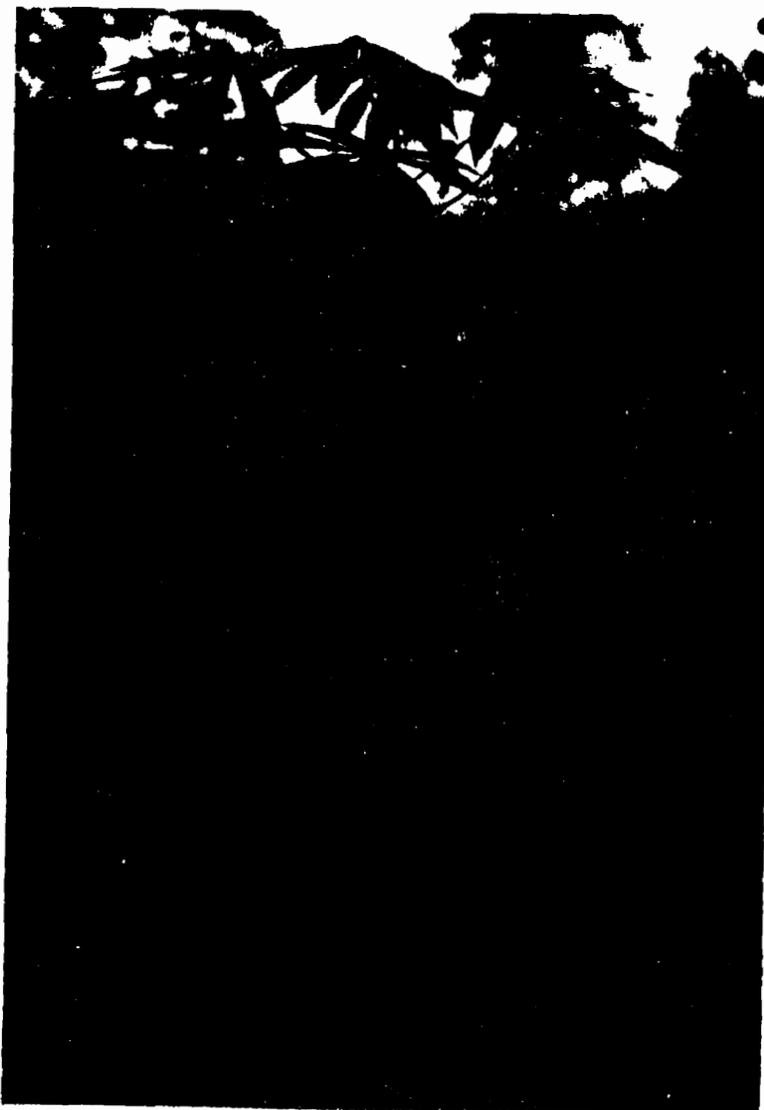
As many as 97% of all respondents cultivate plantain (Figure 5.6). Though it is indigenous to Tropical Asia, it thrives in the forest-savanna region of West Africa as a staple (Plate 5.4). Farmers plant young suckers removed from a parent plant (Plate 5.5). The young sucker in turn develops many suckers, each of which bears fruit within eight to twelve months (Table 5.1). The fruit is boiled, fried, or eaten ripe or unripe. According to the farmers, the plantain plant survives long periods of drought because of its great water-storing ability, although it is not as drought-resistant as cocoyam. As does cocoyam, it needs a considerable amount of rain to produce a very good harvest. In a year when there is insufficient rain, the harvest is poor but there is never a complete crop failure. Each parent plant grows an average of four to six suckers a year, each of which bears fruit within a year. The suckers may be harvested several times at different times in the year, ensuring food supply throughout the year for three to four years. Since there is no efficient technology for the storage of plantains, they are harvested only when needed for food or for sale (section 3.1).



**Plate 5.4**  
*Musa paradisiaca*. A mature plantain ready to be harvested



**late 5.5**  
Young plantain suckers removed from parent. They will be planted on a new field.



**Plate 5.6**

*Manihot esculenta*. Cassava plant growing from the stem which was originally planted. Note the grasshoppers getting ready to attack the plant.



**Plate 5.7**

Harvested cassava tubers.

### 5.213 Cassava (*Manihot esculenta*)

A native of South America, cassava is increasingly cultivated in the forest and savanna areas of Ghana (Plate 5.6). It is the basic food for the poor and the middle class since it is the cheapest of all the root tubers. It may be eaten roasted, boiled, or fried. Farmers cut the pithy stem into small pieces and plant them in the soil. Because of drought and soil compaction, most farmers plant the stem in small mounds to ease the growth of tubers. Once planted, the stem stays dormant in the soil and buds at the first rain. It grows very fast when there is rain. If the rains cease for a long time it sheds its leaves but does not die. It quickly grows leaves and resumes growth any time the rains come. It grows tubers within six months (Table 5.1; Plate 5.7). After harvest, the farmer plants a piece of the stem in the soil where it was harvested. The replanted stem grows tubers within four to six months. The short gestation period for some cassava species makes it possible to have two harvests in a year.

All but 1% of the respondents cultivate cassava on their farms (Figure 5.6). It is a very popular crop among farmers because it is very drought-resistant, does well on marginal soils and can be planted any time in the year regardless of when the rains begin or end. Its pithy and succulent stems may explain its extraordinary ability to withstand drought, even when it has not yet developed roots. Other advantages of cassava include the alleged fertilizing effects of its leaves, and its ability to control *C. odorata* weeds. It is known that cassava tubers in a fallow land decompose and fertilize the soil, but the claim that cassava leaves have a fertilizing effect is yet to be confirmed by research. As with cocoyam and plantain, cassava needs a good deal of rain to produce the best tubers. However, farmers are content that with cassava there can be no complete crop failure even in a year when the rains fail. One farmer summed it all up when she said:

"We would all be dead of hunger had it not been for cassava. It is a generous mother who provides enough to feed all her children at all times".

#### 5.214 Yam (*Disoscorea species*)

Yam is cultivated by 74% of the farmers. There are various species of yams. The most commonly planted species are the Water Yam (*D. alata*), Winged Yam, Ten-month Yam, Guinea Yam (*D. cayenensis*), Lesser Yam (*D. esculenta*), White Yam (*D. rotundata*), and Potato Yam (*D. bulbifera*). Yam tubers are cut into small pieces and planted in mounds between January and March in anticipation of the first rains (Plates 5.8; 5.9). Meanwhile, the farmer covers the mounds with weeds to serve as mulch to keep the interior of the mounds cool. Even though they are planted in the dry season, most yam cuttings sprout before the first rains in March and April. According to farmers, yams do not need water to germinate because the planted tubers are sappy and contain enough water for them to germinate and survive for a long time even if the first rains are delayed in coming. In this way the yam cuttings take advantage of whatever little rain there may be in the farming season to grow new tubers. That yams are drought-resistant and do well with very limited rains, which makes their cultivation popular among farmers, at a time of decreasing and unreliable rainfall.

#### 5.215 Maize (*Zea mays*)

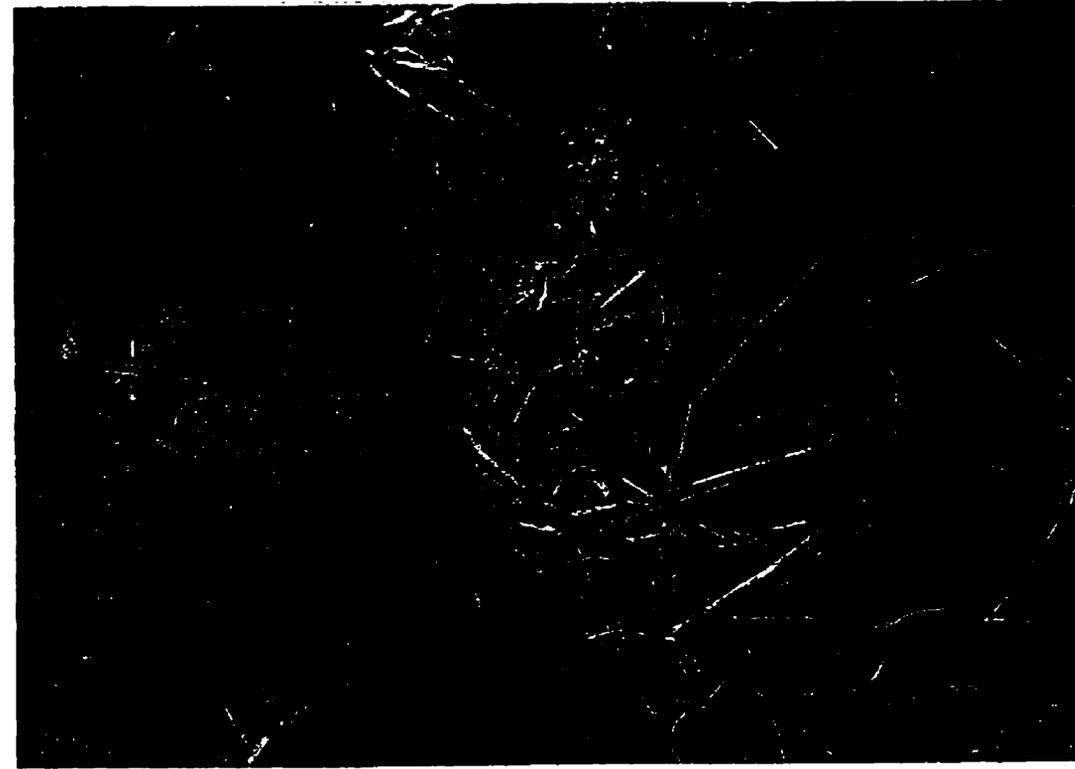
Maize is the only crop which, though not drought-resistant, is cultivated by as many as 97% of the respondents (Figure 5.6). A good harvest of maize depends on abundant and continuous rainfall throughout its 60-120 day growing period, depending on the varieties of maize (Table 5.1). In spite of its high water requirement, maize is popular among farmers. Because it has a relatively short gestation period, it can be cultivated and harvested three times in one farming season, if there is a fairly uniform rainfall distribution in the farming season. In addition, its short gestation period gives the farmer another chance to re-plant maize, as happens often in the region, if the first or the second maize plants are fatally

damaged by insufficient rain (Plate 5.10). Thus the short gestation period reduces the risks of complete crop failure within any farming season, a characteristic which makes maize cultivation popular among farmers in spite of decreasing rainfall in the region.

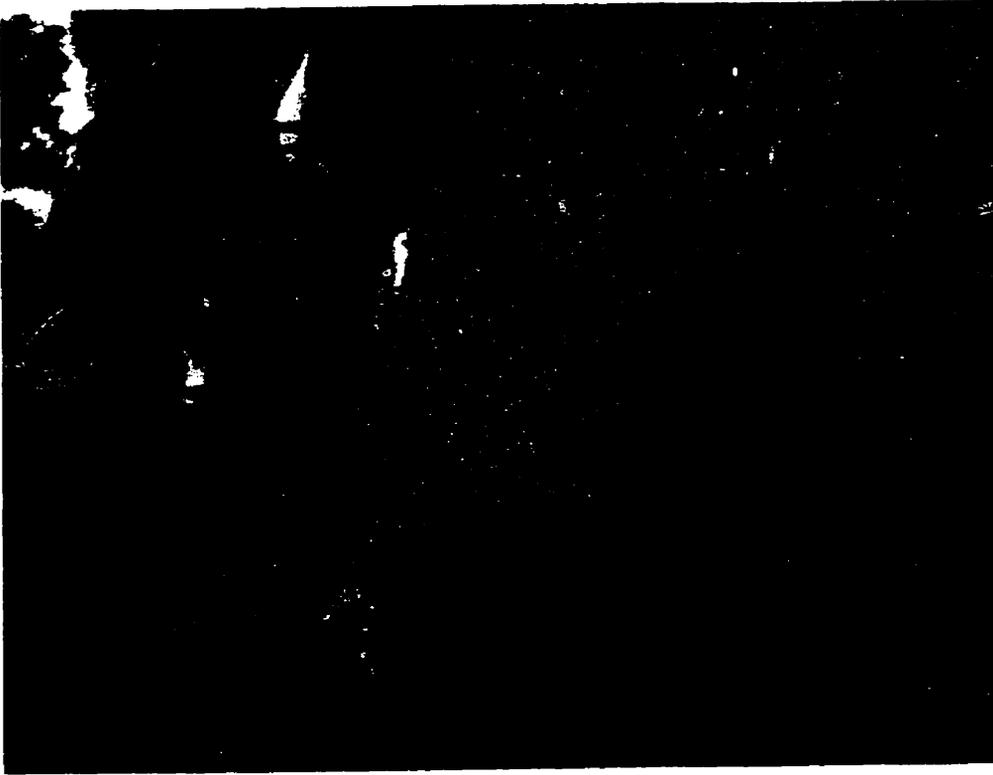
Few respondents (3%) said that they had given up maize cultivation because, apart from its extreme dependence on rainfall, maize cultivation degrades the land faster than other crops. Since maize plants need lots of sunshine to grow, most trees on the farm are felled, thus exposing the soil to erosion. To increase production, large tracts of land are cleared annually. Because most farmers lack the financial and human resources to intercrop maize with other crops such as cassava, plantain and cocoyam as a means of controlling weeds on the farm, *C. odorata* weed quickly dominates the land after the harvest of the maize. The colonization of the fallow by *C. odorata* hinders the survival of other tree species that could provide shade for food crops like plantain and cocoyam when the land is cleared the next time to grow these food crops. Moreover, clearing large tracts of land annually also means faster land rotation, which does not allow much time for the soil to recover some of its lost nutrients.

#### 5.216. Oil Palm (*Elaeis guineensis*)

Oil Palm was originally popular only in the southern section of Ghana, but it is gaining grounds in the study area (Plate 5.11). Compared with 12 % of the respondents in 1983, 34% of the farmers were in oil palm cultivation in 1996. The increased attraction of oil palm cultivation is due to the increased demand for palm oil in and outside Ghana.



**Plate 5.8** *Discorea* species. A young yam plant growing from a mound. The mound retains moisture for the yam seed and protects it from excessive heat.



**Plate 5.9** Harvested yam tubers.



**Plate 5.10**  
*Zea mays*. Maize plants wilting for lack of rain



**Plate 5.11**  
*Elaeis guineensis*. Oil palm trees in stiff competition with *C. odorata* weeds.



**Plate 5.12**

*Sorghum bicolor*. Harvested Sorghum.



**Plate 5.13**

*Mangifera indica*. A mango tree with fruit. It blooms where other trees do not survive.

Oil palm grows very well on marginal lands that are not good for most other food crops in the region. Farmers therefore use for the cultivation of oil palm, degraded lands which otherwise would be left idle. Though the crop is extremely drought- and fire-resistant, its yield can be affected adversely by prolonged dry seasons and annual bushfires.

#### 5.217 Millet and Sorghum (*Pennisetum americanum* and *Sorghum bicolor*).

Millet and Sorghum are cultivated mainly in the savanna areas and in the northern sections of the FSTZ (Plate 5.12). Though they do very well with very limited rain, only one farmer cultivates millet and sorghum in Wamanafo on a large-scale. Most farmers said that they did not know how to cultivate the crop. However, it would appear that the real reason for the lack of interest in these crops is because the farmers are satisfied with the performance of the crops they are cultivating. In addition, the more woody vegetation in Wamanafo, compared to Wenchi, does not provide an ideal environment for the cultivation of sorghum and millet, which thrive in savanna environments. In Wenchi, where the vegetation is mainly grass, millet and sorghum are becoming important crops even though rainfall is still high.

#### 5.218 Mangoes (*Mangifera indica*)

*Mangifera Indica* is a drought- and fire-resistant evergreen tree crop that has been woefully ignored by farmers (Plate 5.13). It grows on highly degraded soils and in the driest areas in the country where they are used as shade trees (Plate 5.12). Because it grows so easily in the wild by seed dispersal and because there is an abundant supply, it did not have a market until recently. Now, food processing factories such as the Nsawam Canneries and Tomaccan process the fruit into juice. With increasing demand for the fruit, mango cultivation can be considered for cultivation as a cash crop. It is one of the few tree crops

that can survive in the study area as rainfall continues its downward trend.

#### 5.22 Increase in Number of Crops Cultivated

Apart from the selective cultivation of drought tolerant crops, farmers are also increasing the number of crops cultivated in their field as part of the response to the climate change in the area. Within the same farming season farmers cultivate, on the same plot, a wide variety of crops as a strategy against unreliable rainfall (Plate 3.4). Since the FSTZ supports both forest and savanna crops, the farmers are able to experiment with a wide variety of forest crops, which have high water requirements, and with savanna crops which tend to have relatively lower water requirements.

All farmers responded that they cultivate many and different crops to counteract unreliable rains (Figure 5.5). The average number of crops on a farming plot was eight, though some farmers cultivated as many as twelve and others as few as four. Since 1983, 72% of respondents have increased the number of crops on their farms (Figure 5.3). Because the crops have different water requirements, some of them, such as cassava, cocoyam and plantain, do relatively well even in a year when the rains are scanty, while others, such as maize, bear fruit only when the rains are normal (section 5.21). Since the crops are planted at different times of the farming season (yam seeds are planted before the first rains, maize and plantain are planted at the first rains, while some crops such as cassava and cocoyam can be planted at any time within the farming season), some of them will benefit from the rain irrespective of when the rains come. Cultivating different crops in the same farming season as a security against failure of one or more crops on the same plot is not new to farmers in the region (section 3.11). What is new is that the unpredictability of rainfall in a region whose agriculture is rain-fed has made the cultivation of many crops in one season a necessity for ensuring some harvest, and no longer a

practice of convenience as it was in the past (Chapter 3).

### 5.23 Cultivation of Improved Crop Varieties

Another strategy that farmers have adopted to combat the effects of decreasing rainfall is to cultivate improved crop varieties. Twenty-one percent of the respondents use one or more improved crop varieties on a consistent basis. The Crops Research Institute (CRI) assists farmers with improved seed varieties that are adapted to the different ecological conditions and rainfall patterns in the country. Unlike the perennial crops such as cassava and plantain, these crops are not drought resistant. However, some of them such as maize have shorter-gestation periods, which allows them to mature within a short period in the rainy season, and to be harvested twice in a farming season. In the words of one farmer;

"The *obaatanpa* (literally "good mother") and the hardier six months' variety of cassava bring faster food since they mature within a short time. The old ones took too long to mature"

The Grains and Legumes Development Board (GLDB) has also ventured into the production of early maturing varieties of plantain, yams and cocoyam to further enhance the advantages of these crops (ISSER 1992) but these are not yet available to the farmers.

## 5.3 RESPONSE TO CHANGING VEGETATION

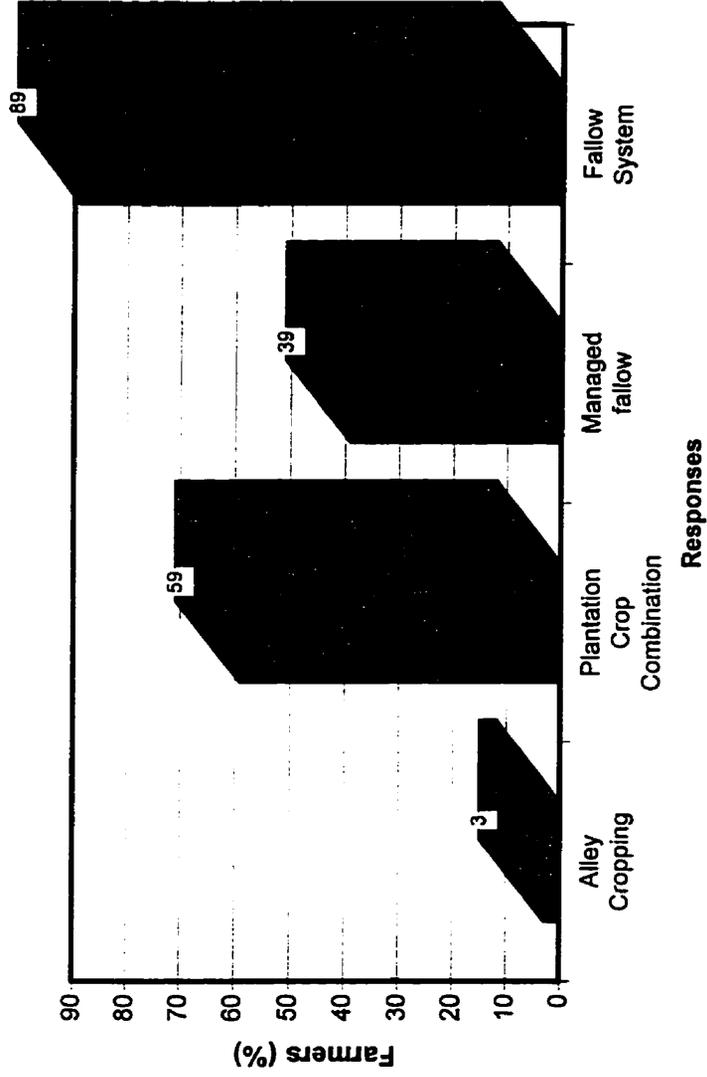
### 5.31 Alley Cropping

Alley-cropping is a system of farming in which rows of fast growing nitrogen-fixing leguminous trees are interspersed with food crops. This farming method has been introduced to farmers in the area as a response to soil degradation and shortening fallow periods. However, only 3% of the respondents practice this method of farming (Figure 5.7).

All three farmers who practiced alley cropping also said they cultivate the same land every farming season. None of the farmers who maintain a fallow period of more than three years practice alley cropping. Thus, this version of agroforestry tends to be attractive to farmers who do not have enough land to practice land rotation to regenerate the soil nutrients. Such farmers turn to the fast nitrogen-fixing-trees, especially acacia, and leucenia for soil nutrients. At the beginning of the farming season, the farmers cut the overgrown branches of the rows of acacia and put the branches between the rows (Plate 5.14). All the leaves are separated from the branches onto the soil in two to three weeks. The bigger branches are removed to serve as fuelwood, leaving the thick layer of leaves and twigs on the soil. At the first rains the farmers plant the crops. The layer of leaves and twigs serves as a mulch to protect the soil against evaporation. The twigs and leaves gradually decompose to provide nutrients for the crops throughout the growing period. Meanwhile, the rows of the fast growing trees which have been pruned grow new branches which will serve as fuelwood, fertilizer and mulch in the next farming season (Plate 5.14). Farmers who maintain a fallow period of three or more years argue that they do not have to plant trees. One farmer explained his refusal to plant trees thus:

“The agricultural advisers have told us to plant some trees on our farms but I don’t see the sense in planting trees when trees are already growing in the field. If the trees that grow on farms are not good why should I spend more time and resources to plant more trees”.

**Figure 5.7 Farmer Response<sup>1</sup> to Vegetation Change**



Note. 1 Farmers use a mix of these responses on their different fields.

Source: Author's Survey 1996



**Plate 5.14**

*Leucaena*. They grow fast after crops have been harvested. They will soon be ready to be cut down to provide fertilizer and fuelwood



**Plate 5.15**

Farmers nurture trees such as this Sinduro (*Alstonia boonei*) tree while they subdue all other noxious weeds.

According to the farmers who practice alley cropping, the labor demands for the management of trees in the agro-system is higher than in the bush fallow system. These may be valid reasons why most of the farmers do not practice alley cropping. It seems, however, that most farmers are not practicing this type of agroforestry because of lack of knowledge of the relative benefits of fast nitrogen-fixing leguminous trees compared to the trees that grow in the wild. Because farmers are not aware of the special benefits of alley cropping to the short fallow periods, they are not ready to invest human and financial resources to grow what the fallow land gives them without cost— trees that regenerate naturally. The farmers know that trees are important for the success of agriculture. To maintain trees on the fallow land, the farmers have developed their own system of agroforestry—plantation crop combination

### 5.32 Plantation Crop Combination

Innovation in forest regenerative-technologies appears to be a recent phenomenon, but farmers already practiced it in the FSTZ during the cocoa/coffee era. A wide variety of selected trees was left standing in the cocoa/coffee and food crop farms for shade and for fertilizing (section 3.22). With the rapid loss of biodiversity due to logging and farming activities, the need to nurture the remaining tree species for their shade and for their fertilizing effects is now felt more than ever.

Ninety-seven percent of the respondents practice plantation crop combination (Figure 5.7). In this method the farmers, drawing from their experience, select and nurture on their farms, tree species which have some benefits for farming. The trees that are nurtured usually have some fertilizing effect and are known to be good shade trees for crops. In addition, the trees are able to regenerate naturally from the seed bank, roots, and stumps. In addition, they are fast-growing and have the potential to be used as fuel wood.

Most common among the nurtured trees on the farms are *Fruentumia elastica* (Fruentum), *Ricinodendron heudelottii* (Wamma), *Tabernaemontana crassa* (Pepae), *Discoglyprena caloneura* (Fetefre), *Ceiba petendra* (Onyina), *Ficus capensis* (Nwadua) and *Alstonia boonei* (Sinduro) (Plate 5.15). These and others have been able to survive the transformation of the environment and have been selected by farmers from the original forest for the regeneration of fallow land. In an attempt to retrieve as much of the original vegetation as possible, farmers also preserve other tree species, such as *Kalanchoe integra* (Aporo) and *Milicia excelsa* (Odum), which are good for timber but which have no direct farming value.

### 5.33 Managed Pioneer Fallow

The managed fallow method is another version of agroforestry used by farmers in the study area. It is practiced by 34% of the respondents (Figure 5.7). Under this system farmers deliberately bring under cultivation for three to four continuous years, a fallow land dominated by any of the foreign weeds such as *C. odorata*, and *Panicum maximum*. During these years, the farmer first uproots and destroys any hint of these weeds while at the same time protecting and nurturing any remaining forest species (Plate 5.15). The land is dominated by the indigenous vegetation after two or three years. The farmer leaves the land to fallow and moves to the next piece of land to repeat the same process. In this way, the farmer counters the expansion of the savanna vegetation and other foreign weeds, while generating a dominant forest vegetation. Results of some research show that there is more organic matter content in soils under this management than in the conventional fallow left for the same length of time (Amanor 1995).

## 5.34 Other Responses to the Changing Vegetation

### 5.341 Weeding

To protect their crops, all farmers have increased weeding from an average of twice per farming season in the 1980s to an average of three to four times. Slashing the weeds with a cutlass in the dry season is a partially effective way to protect perennial crops from the aggressive weeds. In responding to the changing vegetation, farmers not only control aggressive weeds and preserve indigenous plant species, they are also finding uses for some of the new weeds.

### 5.342 Making use of weeds

*C. odorata*, *Rottbellia exalta*, *Imperata cylindrica* and the *Panicum maximum* are among the most common new weeds. Most of the grass species, such as *Panicum maximum*, *Paspalum coonjugatuon*, and *Paspalum puppurem* provide abundant fodder for livestock. The increased grass composition facilitates animal movement, since it makes the vegetation much more open than before. Even though all respondents raised some livestock for home consumption, none of these farmers raised livestock for commercial purposes prior to 1983. Now, the right environment created by the new vegetation mix is a significant factor that has encouraged as many as 25% of the respondents to diversify their agricultural activities to include commercial livestock rearing (Table 5.2; Figure 5.4). The low average of head per farmer may be explained by the fact that animal rearing is a recent and a secondary job. Though the average number of each type of livestock owned by a farmer is low, it is important to note that farmers are adapting to the changing vegetation by exploring new productive ventures, instead of placing total reliance on food crop production.

**Table 5.2. Livestock Owned by Respondents in Wamanafo**

Livestock	Goats	Sheep	Cattle	Rabbits	Chickens	Pigs
No. of Animals	398	313	10	25	1500	18
No. Farmers	51	71	1	2	2	2

Source: Author's Survey 1996

#### 5.343 Grass as roofing material

Most of the grass species that were introduced into the area, such as Spear Grass (*Heteropogon contortus*), Lalang (*Imperata cylindrica*) and Elephant Grass (*Pennisetum purpureum*), are used as cheap and popular roofing materials in rural areas since they are obtained at no financial cost in the new bush. Thatched roofs promote comfort since they provide a cooling effect in the hot afternoon sun and warmth on chilly Harmattan nights. These roofing materials now have a market in the urban centers, where the rich use them to build summer huts to insulate themselves against the summer heat. These grasses thus provide income for the rural farmer.

#### 5.344 *Chromolaena odorata* as fertilizer

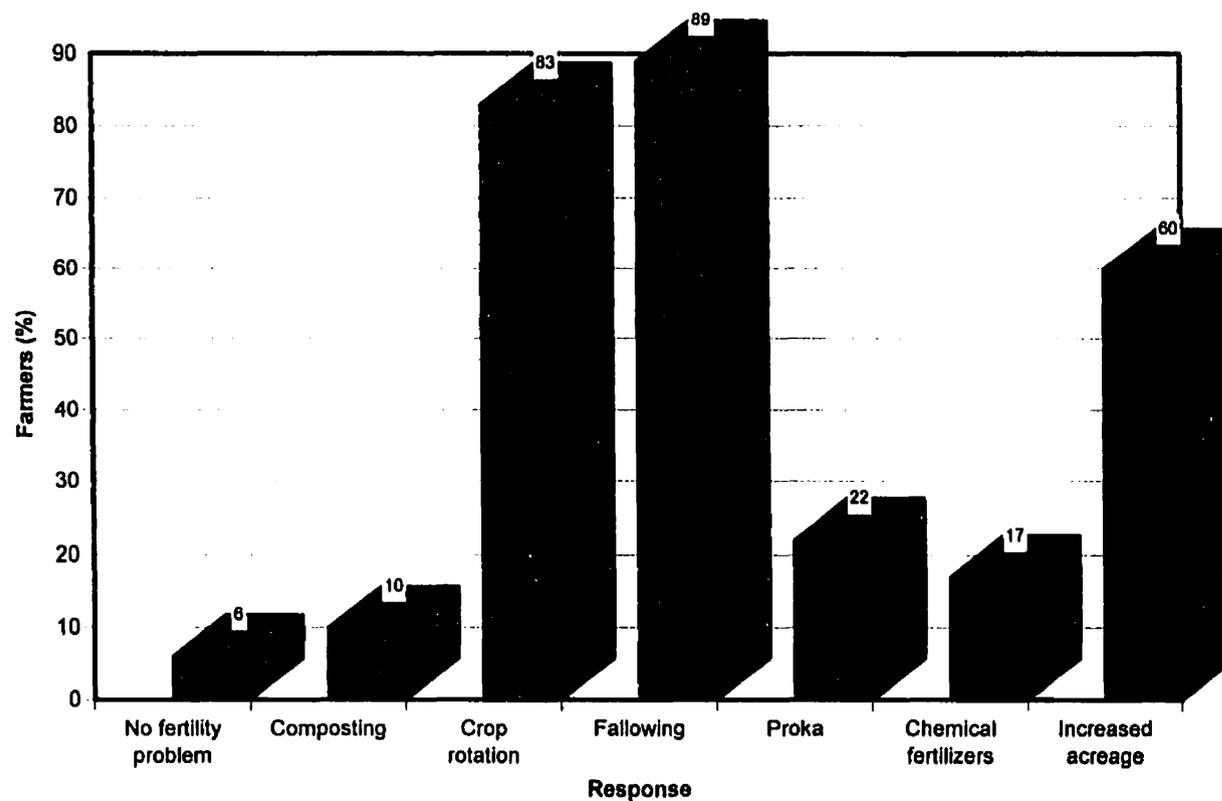
In the view of farmers, *C. odorata* is a mixed blessing. Because it is aggressive and grows so fast, it decreases biodiversity in fallow land while it increases the number of times farmers have to weed around their crops in a farming season. On the other hand, its dense soil-root mat, massive foliage and litter check excessive soil erosion, protect the soil from

direct sunshine and the kinetic impact of the rain. Farmers attested that the labor cost of preparing fallow land dominated by *C. odorata* is lower because the weed is easy to clear in a fallow. When it is burnt on a new field, its massive foliage and litter provide large quantities of ash, serving as fertilizer (sections 4.21 and 4.32). Some farmers also reported that the weed repels mosquitoes. The study by Abbiw (1990:244) confirms that fresh leaves of *C. odorata*, since they are styptic, repel mosquitoes. Others have observed that, among other things, the weed has the potential to be used as paper pulp (Abbiw 1990:244). The pithy stems are already used as fuelwood in some villages in Ghana (Gyasi et al. 1995).

#### 5.4 RESPONSE TO SOIL DEGRADATION

It was shown in section 4.3 that soils in the study area are generally suitable and rich enough to sustain the various food crops. However, because soil quality is beginning to decline on some farms (section 4.23), some farmers are developing strategies to sustain the soil's fertility. Figure 5.8 illustrates some of the methods that farmers are using for this purpose. In discussions with the farmers it was discovered that in their view soil degradation is not an objective but a subjective concept. To the farmers, soil degradation makes sense only with reference to a crop that is being considered for cultivation. That is, the fact that a soil no longer supports cocoa/coffee is not an indication that the quality of the soil has declined, rather that the soil has lost its fertility relative to cocoa/coffee or the crop concerned, and may still be best for plantain, cocoyam, cassava or some other crops.

Figure 5.8. Farmer Response to Soil Degradation



Note:

Since the responses are not mutually exclusive, some farmers use more than one method on the same field. For example a farmer may use the fallow method to regenerate soil fertility, and use the *proka* method to further fertilize the soil when s/he is planting crops. Also, since a farmer can have more than one field at any time s/he may use different methods on the different fields. The method(s) used on a particular field is dictated by soil conditions and what the farmer perceives to be the best affordable method for the soil.

Source: Author's Survey 1996

One respondent summed it all up when he said:

“Now we cannot cultivate cocoa or coffee, but we can cultivate cassava and plantain. When a time comes when we cannot cultivate these crops we will find something else to cultivate. But now we are not thinking of what to cultivate because the crops we are cultivating are doing very well”.

These conceptions and attitudes are what shape the farmers’ responses to soil degradation in the study area.

#### 5.41 Application of Chemical Fertilizers

Even though 75% of respondents claim that they have soil fertility problems on their farms, only 17% of farmers use chemical fertilizers (Figure 5.8). Since 1983, 49% of those who use chemical fertilizers have increased their application in response to soil degradation, while 41% have decreased the amount used (Figure 5.3). In the case of those who have decreased fertilizer application, most of the fertilizer that they applied was used on their cocoa farms, which have since been destroyed by fire. Although these farmers still use fertilizer they use less fertilizer now than before since food crops do not need as much fertilizer as the tree crops.

Among the reasons offered by 83% of farmers who would not use fertilizer are prices which are beyond their economic means (section 6.223) and the unavailability of fertilizer on the market. Other reasons are that fertilizer enhances weed competition, makes food crops lose their natural flavor, and increases the rate of crop decay after harvest. These may be valid reasons why most farmers are not using fertilizers. But it appears that the prevailing soil nutrient levels on most farms sufficiently support the food crops which farmers have turned to. Hence, most of the farmers do not think that there is any urgency to use fertilizer (section 4.32). Even though fertilizer could increase production beyond current levels, because it is so expensive, and food crops are doing so well,

farmers find it more beneficial and economical to do without fertilizer. As a substitute for chemical fertilizers, farmers are turning to a cheaper and more affordable fertilizer – organic compost and manure.

#### 5.42 Application of Compost and Manure

Turning to compost and manure is one of the many local initiatives by farmers to solve soil fertility problems using affordable resources. The use of compost as fertilizer has not been part of the farming practices in the area until recently, even though compost has always been available at refuse dumps. As farmers begin to feel the impact of declining soil fertility on production, they have started to make use of the compost they have accumulated on refuse dumps over the years. Already 10 % of the farmers use compost on their farms (Figure 5.8). Because organic manure is cheap and readily available, its use is expected to increase rapidly. Some farmers now dump household organic refuse, droppings from livestock, and crop-waste such as corn husks and chaff at a site (Plate 5.16). During the farming season the compost from the mixture is carried to the farms as fertilizer. Another source of compost is the public refuse site. In a rural setting, where the use of synthetic material is very limited, and where most plastic and metallic materials are recycled, waste materials sent to refuse dumps are for the most part organic materials that biodegrade into good quality compost. Manure from livestock is insignificant at the moment since the livestock population is small. Livestock manure can become another important source of fertilizer if the population of livestock increases so that there is more manure.

**Plate 5.16**

A private compost site. Farmers dump crop waste, household and animal waste at a site and use the composted material as fertilizer.

#### 5.43 The Fallow Method

In spite of the increasing interest in compost, the traditional practice of bush fallow or land rotation remains the leading method of maintaining soil fertility. As many as 89% of respondents use this method to maintain soil fertility (Figure 5.8). Because of the many advantages associated with the bush fallow system it will continue to be the main method of soil regeneration until population pressure makes its practice impossible (section 3.1).

#### 5.44 The *Proka* Method (Green manure)

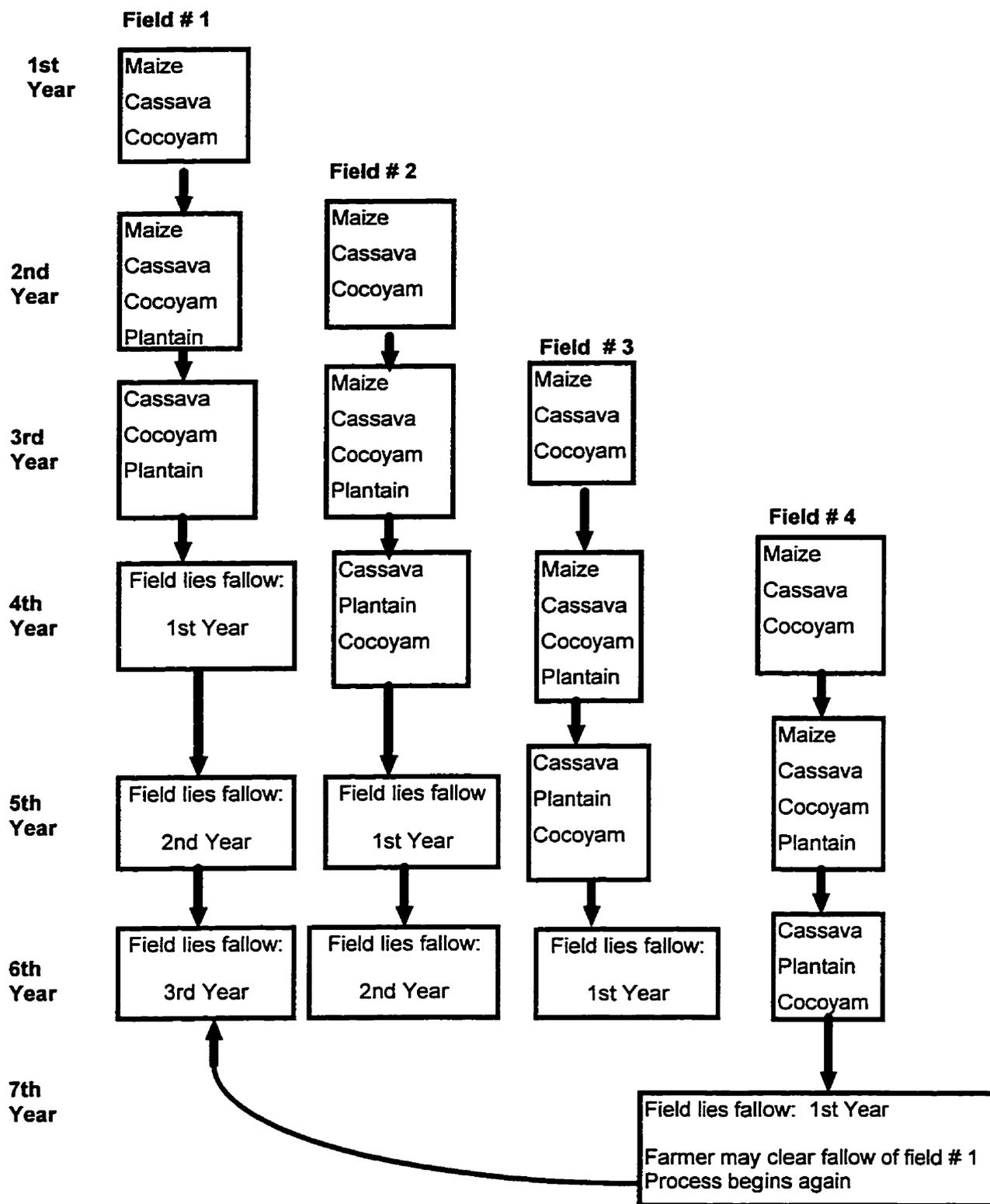
Twenty-two percent of the farmers use the *proka method*. This method is a deviation from the traditional way of farming in which newly cleared weeds on a fallow land are burnt before crops are planted. In the *proka method*, the farmers allow a few weeks for the newly cleared weeds on a fallow land to wither. They start planting the crops when the thick leaf mat on the soil begins to decompose. Because a *proka* field is covered with a dense leaf litter and branches, it is more difficult to work on than on a field where the cleared weeds are burnt. However, one farmer said,

"It is worth the pain because the leaves serve as green manure. The thick leaf layer acts as mulch for the crops and soil, especially when the rains cease during crop growth. The gradual decomposition of leaf litter also ensures constant nutrient supply throughout the gestation period of the crops".

#### 5.45 Crop Rotation Farming

This method is practiced by 83% of the respondents (Figure 5.8). In this method a newly cleared fallow land is first planted with cocoyam, maize and cassava. Vegetables and legumes are also planted on new fields in the first year. In the second year, the farmers maintain the cassava and cocoyam, since they are perennial (Figure 5.9). Maize is planted

Figure 5.9. Crop Rotation in a Bush Fallow System in the FSTZ



Source: Author's Survey 1996

among the cassava and cocoyam for the second time, and plantain is planted for the first time. The field in its second year is called *ntufuo*. Meanwhile, a new land is cleared for cocoyam, maize and cassava so that two farms are in operation. In the third farming season, the first farm is left free of maize but the second farm, now in its second farming season, is planted with maize. The cocoyam, plantain and cassava on the first farm are harvested for two or three more years before the land is left to fallow for two or three years. After three years of fallow, the land is cleared and the cycle begins all over again. Formerly, a farm was planted with maize only once. The farm was then left free of maize while other perennial crops continued to grow for two or more years. Farmers reported that crop rotation methods regenerates the soil faster, and that they get more from the land than when all the crops are grown in one planting season. However, there is no research to back the farmers' claim that soils regenerate faster, or that farmers get more produce from the land when crops are rotated in this way.

#### 5.46 Tractor and Bullock Ploughing

Only one farmer in Wamanafo had attempted tractor ploughing. He explained his experience with tractor ploughing thus;

"I alternate maize with beans on my farm. In the first two years I had a good harvest of beans and maize. In the third year, the harvest was discouraging. I was told to increase the amount of fertilizer but the soil is no longer responding to the fertilizer application. I have to stop using the tractor and fertilizer".

However, in the northernmost sections of the transitional zone, around the Wenchi area, tractor ploughing and fertilizer application have become a popular way of combating soil compaction and declining soil fertility. Through the Subinso Agricultural Project<sup>3</sup>, some

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<sup>3</sup> A joint agricultural project set up by the German Government and the Roman Catholic Diocese of Sunyani to help smallholder farmers adopt some modern methods of production.

farmers in this area get supplies of improved seeds, fertilizers, and ploughing services on loan. Some of the farmers concede that in a year of good rains, ploughing and planting in lines increase their output from an average of 240 to an average of 300 kilograms per hectare. If fertilizer is applied in addition to ploughing and planting in lines, production per hectare ranges between 320 - 400 kilograms. However, according to the Agricultural Extension Officers of the Subinso Agricultural Project, the small-scale farmers are beginning to distrust tractor ploughing for various reasons. First, the tractor ploughs too deep into the generally shallow soils, burying the thin layer of the topsoil beyond the reach of most plant roots while bringing to the surface the third layer (20–40 cm), which requires liberal quantities of fertilizer before crops can do well (Plate 3.5). Secondly, farmers stump the trees in the field to ease ploughing. But stumping accelerates soil erosion leading to the loss of the topsoil and the much needed nutrients. Thirdly, tractor ploughing is not suited for some of the crops such as yams, plantain, and cocoyam which are important to the farmers. For these reasons, some of the farmers use bullock ploughing instead of tractors. Using bullocks, the farmer is able to plough without uprooting the trees. The plough cuts only shallowly into the soil and prevents excessive soil erosion and disturbance of the soil root-mat (Plate 3.6). But, only few farmers can afford the price of a pair of bulls. As a result, most of the farmers in the area (about 75%) still use the fallow system for the regeneration of soil nutrients.

#### 5.47 “Environmental Migration” and Off-Farm Activities

One way of easing the pressure on agricultural land has been the emigration of young people to the urban centers, and to other countries in the sub-region – Gabon, Côte d'Ivoire, Guinea, and Nigeria – in search of greener pastures. Many of them also emigrate

to North America, Europe and Asia. An informal survey<sup>4</sup> revealed that in the past four years at least 221<sup>5</sup> young men and women have emigrated from Wamanafo. Another stream of emigrants consists of farmers who relocate to new farming frontiers in other parts of the country, especially in the Western Region of Ghana, where they “buy” virgin lands for the cultivation of cocoa or coffee. The same survey mentioned above revealed that in the last ten years, 66 farmers have moved out of the settlement to do farming at other places. While these figures show that emigration is only in trickles, it is important to note that by these emigrations average per capita land availability in the community is higher than it would have been if these emigrations did not occur.

Investment in the education of the younger generation is another strategy used by the Wamanafo community to ease the pressure on agricultural land. Until 1988, most parents did not send their Junior Secondary School (JSS) graduates to Senior Secondary Schools (SSS)<sup>6</sup> -- the gate-way to off-farm jobs, and to the universities -- because of the high cost of boarding fees in the urban centers where the SSS were located. Many young men and women in the community therefore ended their education at the JSS level, and

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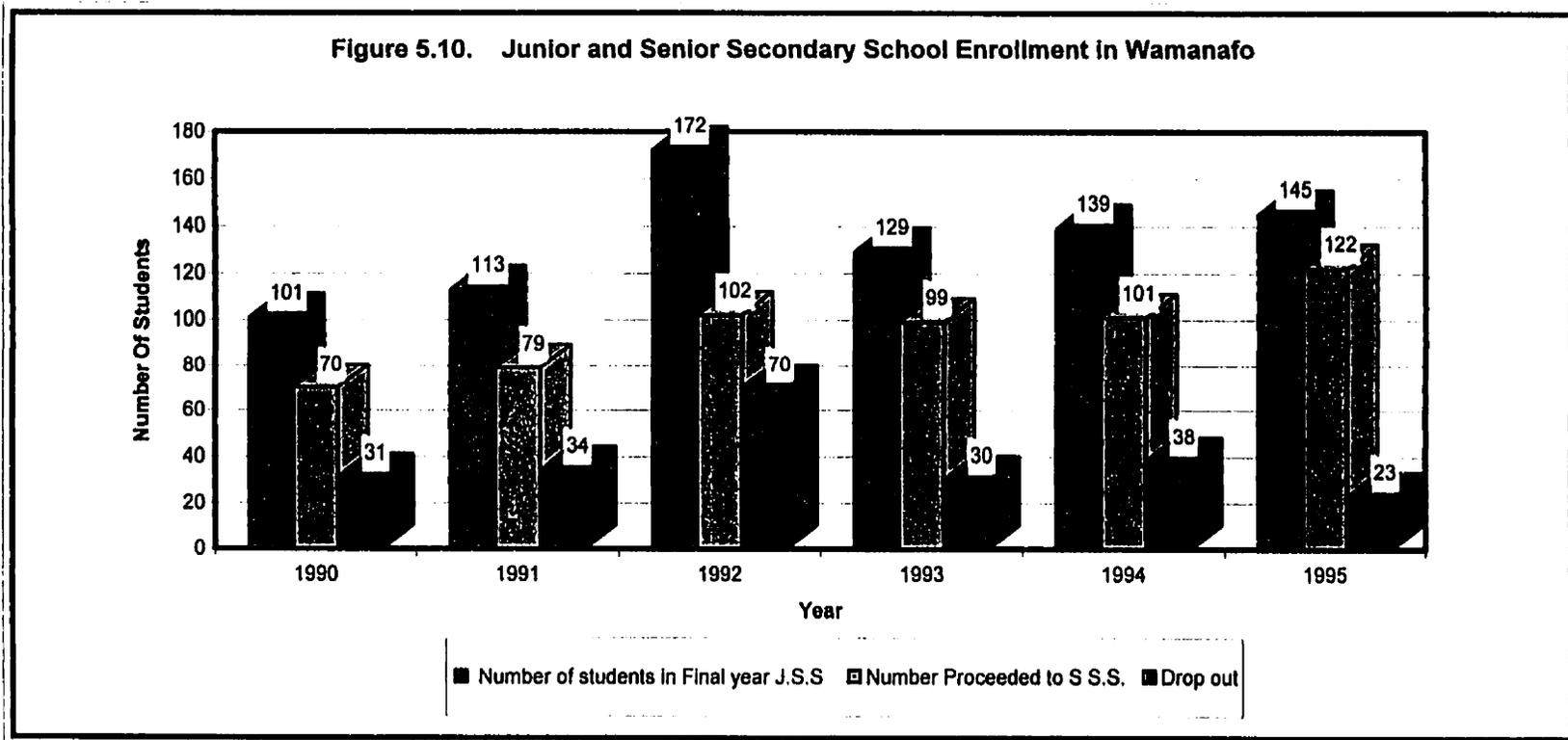
<sup>4</sup> I asked five members of the Town Development Council to conduct this survey. They arrived at this figure based on their own knowledge of the people in the settlement who have traveled outside the country.

They also asked people who knew of others who had traveled overseas. These informants in turn provided the council members with leads as to who might know other people who have traveled overseas.

<sup>5</sup> This number excludes people who have moved to find jobs in urban areas in the country. It was difficult to make reasonable estimates of this number since some of them keep moving in and out of the settlement. Some of them go to the urban areas to work after the farming season but come back to farm at the beginning of the farming season either because they did not get a job or because they want to continue farming to supplement their off-farm incomes.

<sup>6</sup> Children in Ghana do six years of primary schooling. They then proceed to the Junior Secondary School (JSS) where they spend three years before moving on to the Senior secondary school (SSS) for three years. SSS students who pass the external Examination conducted by the West African Examinations Council may further their education in a third cycle institution.

Figure 5.10. Junior and Senior Secondary School Enrollment in Wamafo



Notes:

- 1 The enrollment includes students from the nearby villages -- Ampenkro, Kobedi, and Asupra.
- 2 The over-all number of drop-outs is higher since about 25% of the children in Ghana do not start primary school. Of those who start, only 39% enroll in SSS (World Bank 1992:274)

Source: Enrollment records of the Local Authority (L.A), LA/Roman Catholic and the St. James Junior Secondary Schools in Wamafo

ultimately on the land as farmers. From its own resources, the community donated the physical structures for a SSS in 1988 to ensure easy access of their children to a SSS education. In the words of an elderly member of the Town Development Committee (TDC);

"We did not get any formal education because there were no schools around here. Our parents taught us how to farm, but we have to help our children to get good education. Since we do not have enough land for ourselves and for our children, we have to sacrifice to build this Senior Secondary School to educate our children so that they can also enjoy the good life in the cities".

Unlike their parents, most of whom had no formal education (section 5.1), most children in the community have a JSS education. On the average, 72% of all JSS students proceed to SSS (Figure 5.10). Young men and women who do not proceed to SSS learn off-farm trades. Generally, the young women engage in activities such as oil processing, soap making, seamstressing, hair dressing and petty trading. The men learn trades, such as carpentry and masonry, and tailoring. Thus, unlike the respondents who have off-farm activities as secondary jobs, the younger generation aim to have off-farm activities as their main economic activity. Forty-three percent of those interviewed had some off-farm activities to supplement their incomes from farming (Figure 5.4). Before 1983, the men who did not own cocoa farms had secondary jobs on the cocoa and coffee plantations. With the destruction of the cocoa farms, the men lost these jobs. Similarly, the women had off-farm income generating activities such as oil processing, soap making and petty trading. Most of the women (55%) still engage in these activities, though a few of them are too advanced in age to effectively engage in these off-farm activities. As a 67 year old woman said:

"I used to sell clothing but now I cannot walk around as I used to do. I think I should leave this work to the younger women".

Another 69 year-old woman said:

"I used to make soap. Soap-making involves the use of fuelwood but I do not have the strength to walk far into the woods to collect fuelwood any more"

Of the 43 respondents who had off-farm income generating activities, 58% (25) said their current off-farm income has decreased relative to their incomes from the same activities in 1983 (Figure 5.4), while 42% (18) said their off-farm income has increased. The general decrease in off-farm income is attributed to the destruction of the cocoa and coffee farms on which some men depended for secondary jobs, and to the inability of some of the women to engage in off-farm activities due to old age.

While the emphasis on emigration and off-farm activities in the community eases the pressure on the agricultural land, the pressure is still significant for a number of factors. One reason is that most farmers in the settlement are reluctant to emigrate because they feel attached to family land, which cannot be sold. Even if they are willing to relocate, there is the difficulty of getting land to buy elsewhere, since in most parts of the country land is not a commodity that can be sold (section 1.434). As one farmer asserted;

"This is the land my ancestors gave me. They will be angry if I leave this land. I am not leaving it. I cannot sell this one. Even if I were to sell it, I cannot get land anywhere else to buy".

Another reason for the increased pressure on agricultural land is the high rate of school drop-out (Figure 5.10). While enrollment in the SSS is high compared to previous years, a significant number of the children who do not get SSS education become farmers by default, thus increasing the pressure on the land. Even people who have off-farm jobs as their main occupation, do some farming to supplement their incomes. One nursery teacher who was interviewed said:

" I can get land from my landlord so I grow almost all I need for home consumption. Because I do not buy food I am able to save more of my income from teaching".

Furthermore, farming is a refuge for all who fail in their off-farm jobs. Because there is free access to family land, it is far easier to enter farming than any other occupation. People who fail in their off-farm jobs, return from the cities to do some farming on the family land. For instance, 14% of the respondents acknowledged that they started farming as their main economic activity after they failed in their off-farm trade, or after they were laid-off from their jobs.

Off-farm activities are not new to the farmers but the need for such jobs is felt more than ever. However, since the farmers do not have much formal training their options, with respect to off-farm jobs, are limited to agriculture-related activities and a few trades. On the other hand, the prospects of off-farm jobs for the younger generation is bright since the enrollment in the SSS is on the increase. Most of the young people with formal education will have jobs in the urban centers and not in the field, thus easing the pressure on the farmlands.

## 5.5 CONCLUSION

Most of the adaptations pursued in the study area are induced or ad hoc responses rather than responses to guided planning in anticipation of long and short-term changes (section 2.3). The farmers respond to environmental problems as and when they occur without any long-term planning. The responses include adopting new practices, such as selective cultivation of crops, and changes in land use patterns that minimize the effects on production of climate change and soil degradation. Farmers are also taking advantage of the new opportunities that the changing biophysical environment brings by diversifying their farming activities to include animal rearing. They are also investing in off-farm activities to minimize their dependence on farming.

The responses do not involve the use of a "technofix", and while most of them are

not unique and not unexpected, they provide examples of simple ways of dealing with big problems. Their significance stems from the fact that they are developed from the farmer's own experience in dealing with the local agro-ecosystem. Nevertheless, the lingering question remains whether these strategies are only short-term moves, or if they are adaptations that can be developed to keep up with the trends in the agro-ecological environment. The next chapter seeks to answer this question by evaluating the responses discussed above.

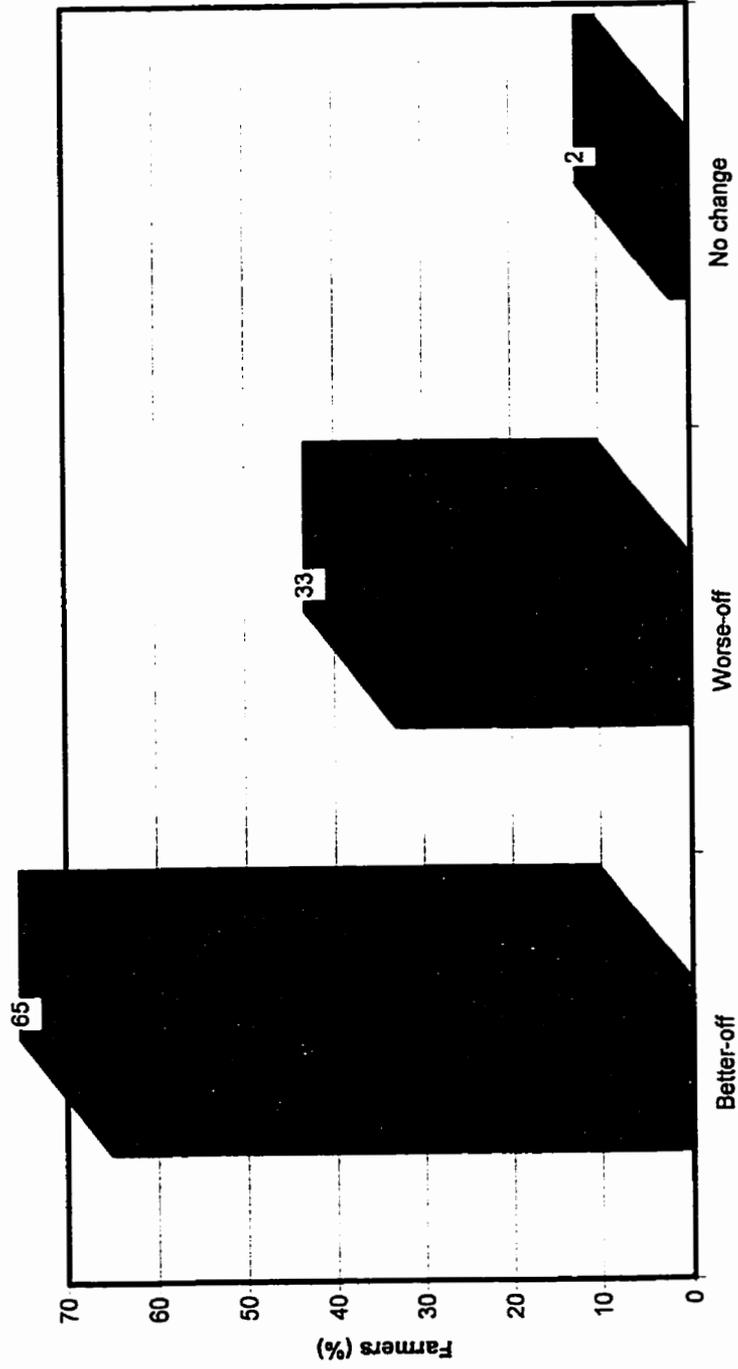
## **6.0 EVALUATION OF FARMERS' ADAPTATION STRATEGIES**

This chapter evaluates the success or otherwise of the farming strategies discussed in the previous chapter and the problems farmers face in the adaptation process. It also discusses how the social structure is responding to the environmental shocks. The criteria for the evaluation are: whether the adaptations have the potential to minimize the adverse effects of the current and projected changes in the environment; and whether farmers benefit—by increased production and improved conditions of living—from the changes they are making.

### **6.1 FARMERS' OWN EVALUATION OF PERFORMANCE**

One indicator used to determine the success or otherwise of farmers' adaptation was how farmers perceived their own performance. When farmers were asked to indicate whether they were progressing or regressing in their present farming activities as compared to the pre-1983 era (cocoa/coffee era), 65% of them said they were better-off while 33% said they were worse-off since 1983 (Figure 6.1). All those who said they were better-off attributed their fortune to increased production for home consumption, and increased surplus for the market since 1983. These figures prompt some interesting observations. First, farmers perceive their agricultural performances differently depending on whether or not they owned cocoa farms prior to 1983. Seventy three percent of all the respondents owned cocoa farms prior to 1983 (section 5.1). Those who owned cocoa tended to be worse-off than those who had never owned cocoa (Table 6.1). This situation is due mainly to the inability of the former cocoa owners, who owned most of the plantations, especially the men, to adjust to food production which has become the main cash crop in the area.

**Figure 6.1 Farmers' Overall Perceived Performance Compared to Pre-1983 Era**



Source: Author's Field Survey, 1996.

**Table 6.1. Agricultural Performance of all Farmers Classified by Cocoa/coffee ownership before 1983.**

Present agricultural performance  
relative to pre-1983

		Better-off	Worse-off	Total
Had cocoa/coffee Farm before 1983	Yes	O:18 E:24.6	O:55 E:48	73
	No	O:15 E:8.4	O:10 E:16.6	25
	<b>Total</b>	33	65	98 *

O = observed frequency; E = expected frequency.

**Note:**

- \* Two female farmers said there had been no change in their agricultural performance
- Null hypothesis ( $H_0$ ): Ownership of cocoa/coffee farm prior to 1983 and how farmers perceive their present agricultural performance and are independent.  
Alternate hypothesis ( $H_A$ ) Ownership of cocoa/coffee farm prior to 1983 and how farmers perceive their present agricultural performance are not independent.
  - Test is at 0.5 level of significance.
  - Reject null Hypothesis if  $\chi^2 > 3.841$  (value for 1 degree of freedom (df)), otherwise accept the null hypothesis.
  - Since  $\chi^2 = 10.48$  exceeds  $\chi^2_{0.05} = 3.841$ ,  $H_0$  is rejected; that is, there is a relationship between how farmers perceive their present agricultural performance and whether or not they owned cocoa/coffee farm prior to 1983 (Appendix 8a).

Source: Author's Field Research 1996

**Table 6.2. Agricultural Performance of all Farmers Classified by Gender**

		Agricultural Performance		
		Better-off	Worse-off	Total
Gender of Farmer	Male	O: 16 E: 21.9	O: 17 E: 11.1	<b>33</b>
	Female	O: 49 E: 43.1	O: 16 E: 21.9	<b>65</b>
	<b>Total</b>	<b>65</b>	<b>33</b>	<b>98 *</b>

O = observed frequency; E = expected frequency

**Note:**

- Two female farmers said there had been no change in their agricultural performance.
1. Null hypothesis ( $H_0$ ): Gender and agricultural performance of farmer are independent  
Alternate hypothesis ( $H_A$ ): Gender and agricultural performance of farmer are not independent..
  2. Test at 0.5 level of significance.
  3. Reject null Hypothesis if  $\chi^2 > 3.841$  (value for 1 degree of freedom (df)); otherwise accept the null hypothesis.
  4. **Since  $\chi^2 = 7.13$  exceeds  $\chi^2_{05} = 3.841$ ,  $H_0$  is rejected; that is there is a relationship between the gender of farmers and how they perceive their agricultural performance (Appendix 8b).**

Source: Author's Field Research 1996.

**Table 6.3. Agricultural Performance of all Farmers Classified by Age**

		Farmers' Age			
		21-40	41-60	>61	Total
Satisfaction with present performance	<b>Yes</b>	O:16 E:9.8	O: 13 E:14.1	O:4 E:9.1	<b>33</b>
	<b>No</b>	O:13. E:19.2	O:29 E:27.9	O: 23 E:17.9	<b>65</b>
<b>Total</b>		29	42	27	<b>98 *</b>

O = observed frequency; E = expected frequency

**Note:**

- Two female farmers said there had been no change in their agricultural performance.
1. Null hypothesis ( $H_0$ ): Age and agricultural performance of farmers are independent.  
Alternate hypothesis ( $H_A$ ): Age and agricultural performance of farmer are not independent.
  2. Test is at 0.5 level of significance.
  3. Reject null Hypothesis if  $\chi^2 > 5.991$  – value for 2 degree of freedom (df); otherwise accept the null hypothesis.
  4. **Since  $\chi^2 = 10.36$  exceeds  $\chi^2_{05} = 5.991$ ,  $H_0$  is rejected; that is there is a relationship between the age of farmers and how they perceives their agricultural performance (Appendix 8c).**

Source: Author's Field Research 1996.

Women, who generally depended on food production tend to be more satisfied than men in their present agricultural performance relative to the pre-1983 period (Table 6.2). Seventy-six percent (49) of those who acknowledge that they are financially better-off are women while 53% (17) of those who are worse-off are men. That is, 75% of the women compared with only 48% of the men think they are better-off now relative to the pre-1983 period.

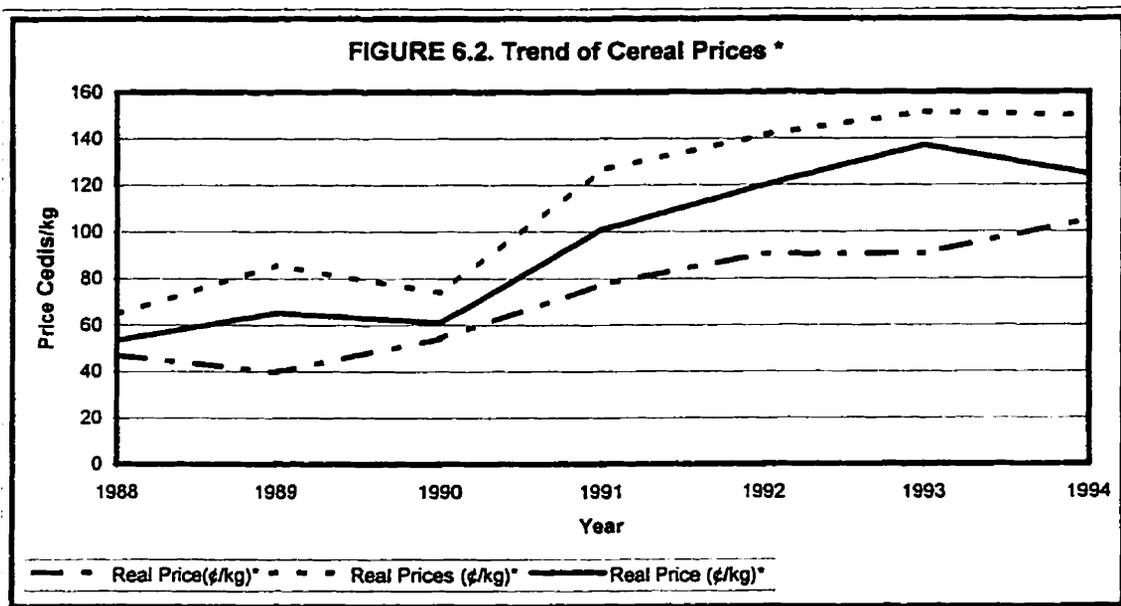
Farmers' perception of agricultural performance also depends on the age of the farmer (Table 6.3). All respondents between the ages of 21-30 years (5%) are satisfied with their performance, while all the farmers who are 71 years old (9 % of respondents) claim that they are worse-off. A possible explanation for the differences in performance is that the farmers between the ages of 21 and 40 (29%) do not have much to compare with. Only two of the farmers between 31 and 40 years had cocoa farms before the 1983-bushfires. In fact, the five respondents, who were below 28 years, said they assisted their parents on the farm until 1985 when they started their own farms. While these five young farmers had some farming experience prior to 1983, their comparison of the two periods was really an appreciation of their performance since 1985, when they started farming, rather than a comparison with the period before 1983. On the other hand, most farmers over 41 years (71%) had cocoa farms prior to 1983. The older farmers, who have lost their cocoa farms and cannot do food farming because they have neither the physical strength nor the financial resources, are more likely to see the cocoa era as a better time. Another explanation for the differences in perception of agricultural performance, with respect to age, is that since farming is labor intensive, young people are able to produce more while older people, who tend to have neither the financial nor the labor resources, cannot do such effective farming and are, therefore, likely to see themselves as worse-off.

### 6.11 Development Projects

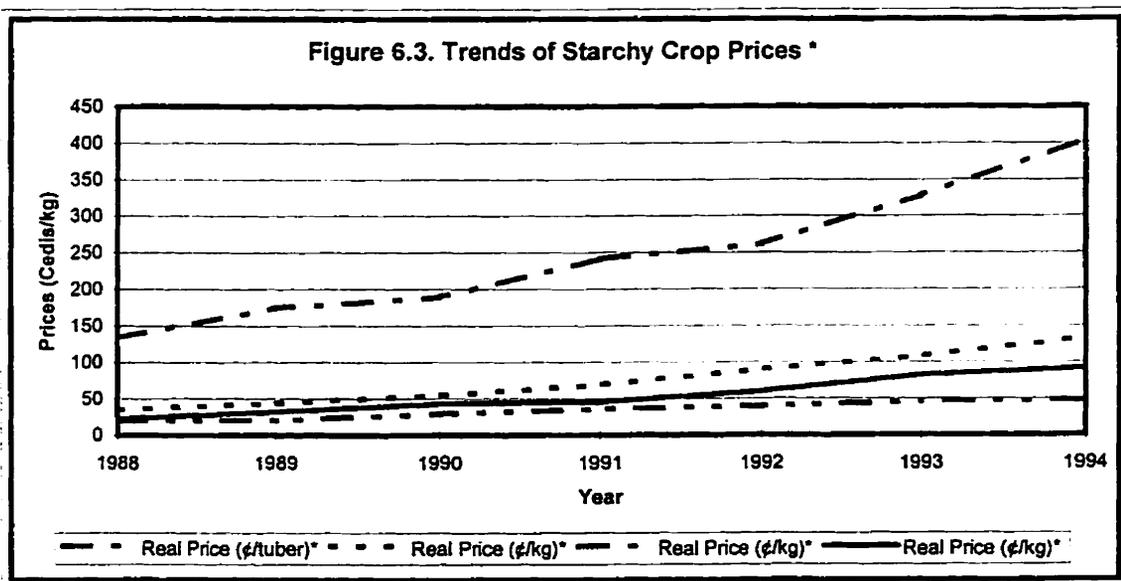
Another indicator that farmers are benefiting from the changes they have made, is their ability to finance some development projects in their community. One would expect that with the destruction of the main cash crop of the area, most development projects (new infrastructure) in the community would cease, but the contrary is the case. An indicator that the quality of life has become better is the ability of farmers to afford better houses since 1983. Twenty-five percent of the respondents have managed, from the proceeds of their own farming activities, to replace their old houses with new buildings. Most of these are better quality, concrete buildings with aluminum roofing in place of the previous mud houses with thatched roofs, which have a life span of only 15 years.

That farmers' income in farming has improved is also evidenced by a number of self-help projects springing up in the village, prominent among which are the settlement's ability to finance the construction of a Senior Secondary School (section 5.47) and the extension of electricity into the community from the national grid. Extension of the national grid into the community was carried out on condition that the people would bear the cost of most of the poles and wiring of the streets within the community, while the government bore the cost of the high tension pylons (Communication with the TDC Chairman). These and other improvements in the living conditions, such as the ability to afford more clothing, pay their children's schools fees and pay medical bills, all suggest some success from adaptation at the farm level.

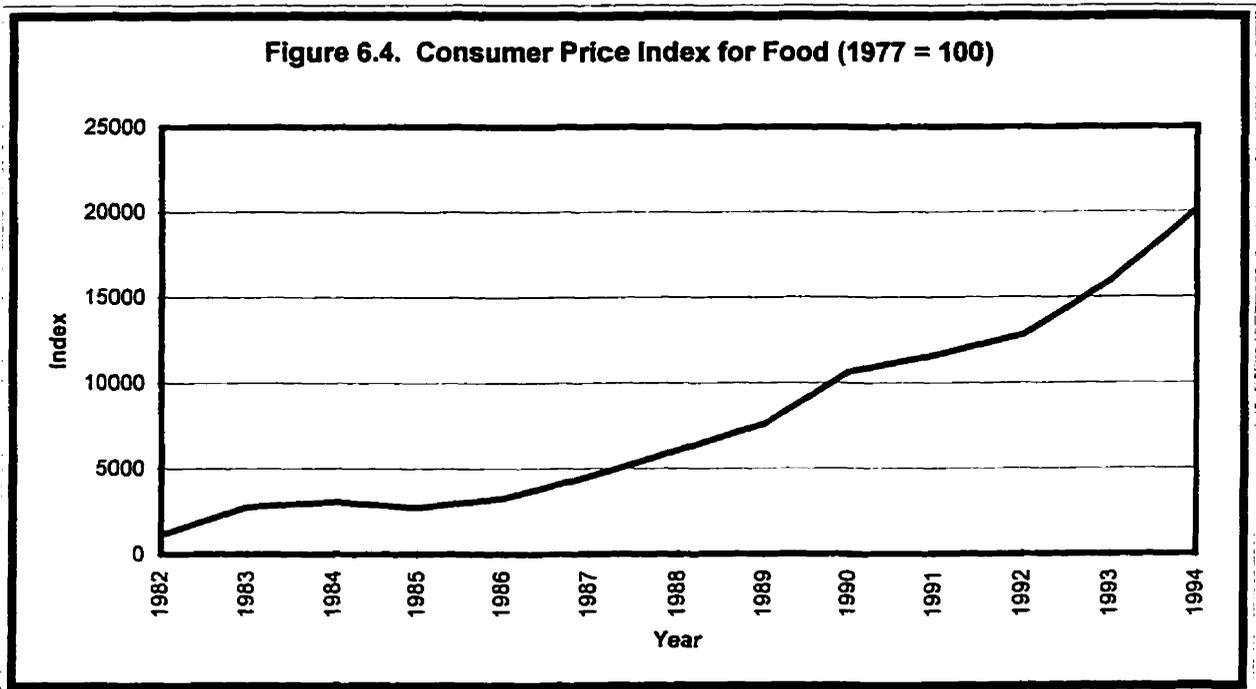
It is important to note, however, that these developments have taken place within the context of a buoyant economy since 1983 relative to the decade before 1983. The farmers' satisfaction with their adaptations may, therefore, be partly explained by the good economy. For example, the real producer prices of the major food crops have been on the



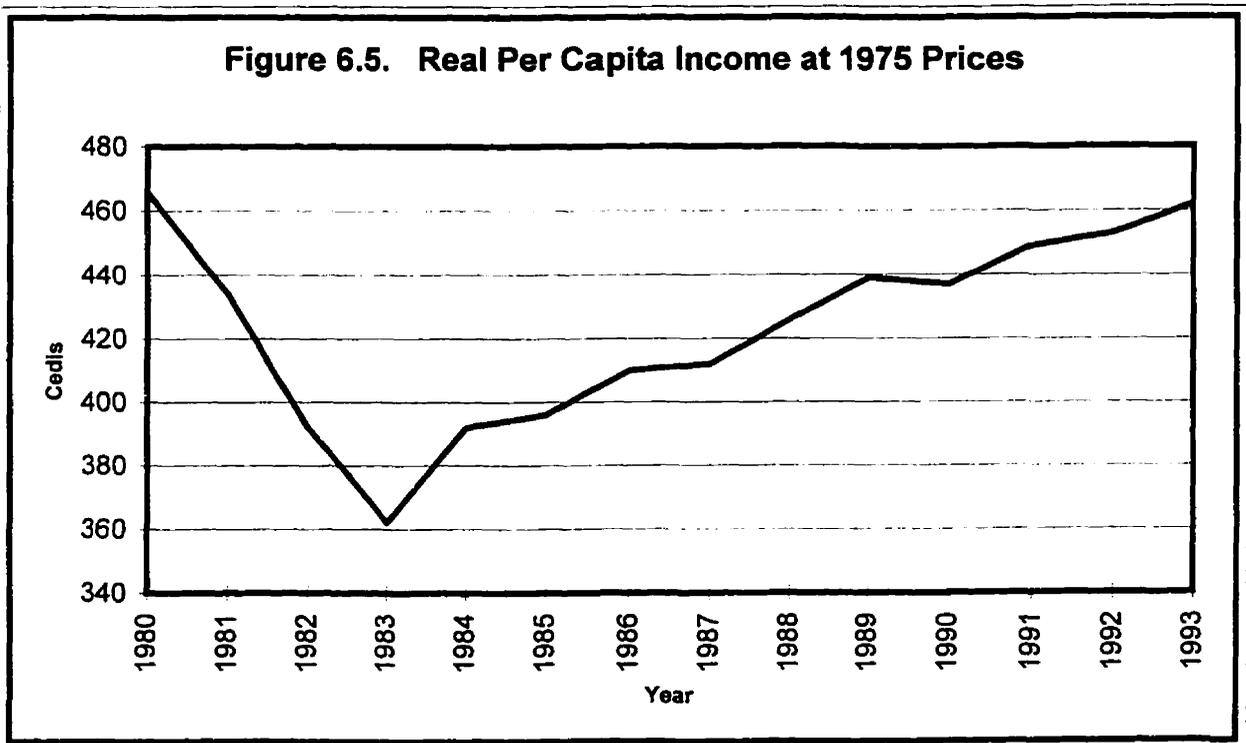
Source: Based on data in ISSER 1992; 1993; 1994



Source: Based on data in ISSER 1992; 1993; 1994



Source: ISSER 1992; 1993; 1994



Source: ISSER 1992; 1993; 1994

rise since 1983 (Figures 6.2; 6.3; Appendix 7). With 1977 as base year, the national consumer food price index reached 20,135 points in 1994 (ISSER 1994), indicating an increase of 17,380 points or 631% higher than it was in 1983 (Figure 6.4). Food prices increased by about 257% between 1986 and 1994. The trend in the food price index from 1980 to 1994 shows that the increase was gradual until 1986, when it became relatively steep, though the percentage changes in 1991 and 1992 were substantially lower than at any time in since 1986. The rate of inflation has been high, with an all average increase of 25.5% from 1986-1994, but real food prices still show a general upward trend (Figures 6.2; 6.3). The increase in prices is a consequence, in part, of the changes in the pricing policies of the government since 1983 when the GFDC replaced its controlled and fixed pricing of food crops with a flexible pricing system (section 1.354). Similarly, from 1977 to 1983, the annual growth rate of the Real Per Capita Income (RPCI) was -1.4%. Since the introduction of the Economic Recovery Program (ERP) in 1983, however, the RPCI has been growing at 2% per annum (ISSER 1992; 1993;1994; sections 1.443; 1.4442).The improvements in the living conditions, such as the ability to afford more clothing and to pay medical bills and school fees, explain why most farmers are more content with the results of the changes they have made in their farming activities since 1983, especially if it is realized that farming is the main, and in many cases the only, economic activity of the farmers. The farmers' adaptations were positively affected by the economy, especially through improved producer prices for the production due to the farm-level adaptations. This is a case of a positive interaction between farm-level adaptation and the socio-economic, political and environmental factors (section 2.31)

## 6.2 ANALYSIS OF ADAPTATION STRATEGIES

In spite of the farmers' positive perception of their performance and the other indicators pointing to improved living conditions, it is not certain whether or not these strategies will endure in the face of trends in the agro-ecological environment. This section therefore evaluates the potential of the main responses vis-à-vis the problems posed by the trends in the biophysical environment.

### 6.21 Evaluation of the Responses to Climate Change —Climate/crop relations

A major adaptation that farmers have made is to change from more water-demanding tree crops to shorter-gestation, less-water-demanding crops and to drought-tolerant annual and perennial crops. While the change to new types of crops may not be a very dramatic and radical response to the rainfall trends in the FSTZ, the move is, nevertheless, a very useful one. It is an affordable response which has the potential to mitigate the negative results of the environmental changes. It is important to note that, generally, most tropical crops have evolved special mechanisms of stomatal control in order to minimize or survive water deficits associated with high evaporative demand: stomata close in response to increasing negative leaf water potential and/or to increasing dryness of the air or saturation deficit (Muchow et al. 1980). Each of the crops cultivated by the farmers has its own unique mechanism for surviving in higher temperatures and drought, though some crops are better adapted than others to mitigating the effects of the increasing temperatures and decreasing rainfall. The crops cultivated by the farmers may be divided into two broad groups: cereal and non-cereal crops. Each of the two groups has its own benefits and weaknesses with respect to the changing environment.

## 6.211 Cereal crops

### 6.2111 Maize

Assuming adequate rainfall, maximum grain number per maize plant is achieved when the average maximum temperature is 31°C and the minimum temperature is 14°C (Norman et al. 1995:134; Fischer and Palmer 1980). Since the average maximum and minimum temperatures for the study area are 30.7°C and 21°C respectively (section 4.13; Appendix 4), maize can still do well in the region even though the minimum temperature is not ideal for optimum yield. The projected temperature increase of 1-3°C for the West African Region by the end of the next century will increase average maximum temperatures in the FSTZ to 31.7°C - 33.7°C (section 2.21). Since grain number per maize plant drops from 600 (optimum) at 31 ° C to 450 at 35° C (Norman et al. 1995:134), the implication is that while the projected temperature range is not ideal for optimum yield, it is still adequate for a harvest of at least 450 grains per maize plant in the next century. On the other hand, maize is particularly sensitive to water deficit at flowering (Salter and Goode 1967). Drought reduces leaf area and leaf photosynthetic rates and also reduces grain yield components, particularly grain numbers (Lemcoff and Trapani 1981). Grain survival is also reduced by water stress (Grant et al. 1989). With the increasing unreliability and declining trend in rainfall (section 4.12), the prospects of maize cultivation in the area are not very bright unless the water problem is solved. Where water stress cannot be avoided, maize should be replaced by sorghum or millet.

### 6.2112 Sorghum

Sorghum displays a tolerance of temperature and water deficit midway between that of maize and millet (Norman et al 1995:150). The optimum temperature for seedling growth, about 33°C, reflects the optimum for net carbon dioxide exchange (Norman et al.

1995:150). Net photosynthetic rates are higher in sorghum – a C<sub>4</sub> species (section 2.21) – and the rates increase with temperature, reaching an optimum at 35–40°C (Downes 1970). This implies that the crop can survive very well in the projected average maximum temperature range of 31.7°C to 33.7 °C for the region by the end of the next century.

The crop adapts to water deficit by a range of processes. Sorghum takes between 110–120 days to mature and it does well in areas with rainfall of 600–1000 mm (Norman et al. 1995:150). The average rainfall in the study area is 1210 and 1252 mm for Sunyani and Wenchi respectively (section 4.12). If rainfall in the region declines by 20%, as is predicted for the region (Downing 1992), average annual rainfall for Sunyani and Wenchi will decline to 968 and 1002 mm respectively. Projected rainfall amounts in the region are therefore ideal for the cultivation of sorghum. The optimum soil moisture for germination is 20–50% of field capacity (Fawusi and Agboola 1980). Photosynthetic rates are maintained or decline more gradually under slow stress owing to stomatal conductance persisting to lower leaf water potentials than maize (Turner 1974). In addition, sorghum can be grown in mixed cropping with other crops such as groundnuts, cowpeas and millet to make optimum use of soil moisture and nutrients. Of the possible crop mixes, the millet/sorghum/groundnuts/cowpeas mix gives the highest return per hectare but millet/sorghum mix yields the highest food energy output per man-hour of labor (Ruthenber 1980). Since sorghum is not a true annual, it has the capacity for continued tillering<sup>7</sup> after grain harvest if water is available in the root zone. Consequently, sorghum stubble can be grazed by ruminant livestock. Thus, the crop is good not only for mitigating the effect of the projected drying conditions but it also provides fodder for livestock. Its ability to tolerate water deficit conditions and higher temperatures makes it a suitable substitute for the more water-

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<sup>7</sup> Tillering is the process where a shoot(s) of a plant spring from the bottom or branch of the original crop. The shoot may or may not bear as much fruit as the parent plant.

demanding crops such as plantain and cocoyam. Even more tolerant of drier conditions is millet.

#### *6.2113 Millet*

Millet varies in maturity from 55 to 180 days or more. It is a C4 crop and is tolerant of temperatures up to 50 °C, far above what is predicted for the region. Leaf photosynthetic and anatomical characteristics associated with C4 photosynthetic pathways in the crop lead to a high potential growth rate and sensitivity to low temperatures (Pearson 1994). High temperatures increase germination, although high soil temperatures (above 50 °C) can cause seedling death (Soman et al., 1986). In view of the temperature trends in the region, the ability of millet to tolerate and make use of extreme temperatures makes it a favored crop for the study area.

Millet grows in areas with 200-800 mm average rainfall (Norman et al. 1995: 166). Millet has a reputation for drought tolerance owing to its rapid and deep root penetration – to 1 m depth within 33 days after sowing (Gregory and Squire 1979). The roots can penetrate to depths of 1.2-1.5 meters (Wetselaar and Norman 1960), a characteristic which allows the crop to tap water and nutrients from the deep soil horizons. In areas with little more than 200 mm of rain, maize has one cropping in a year but in more humid areas with longer rainy seasons it can have two croppings in a year. The relatively higher rainfall in the FSTZ than that which is ideal for millet is not of much concern since millet has a degree of resistance to grain mold disease which can arise with excessive rain (Kowal and Kassam 1978).

Tillering is very important in pearl millet and can contribute up to 50% of the total yield of millet (Rachie and Majmudar 1980). Stress-induced loss of yield components, e.g. grain on the main stem, can be compensated for by increased tillering to a greater extent

than with sorghum and maize (Mahalakshmi and Bidinger 1986). Millet can be grown together with groundnuts, sorghum and maize. Yield advantages due to intercropping are commonly between 20-30% but may be as much as 100% (Reddy and Willey 1980). The extraordinary ability of millet to tolerate drought and very high temperatures makes it an indispensable crop in the adaptation process in the FSTZ.

## 6.212 Non-cereals

### 6.2121 Cassava

Cassava is tolerant of drought and high temperatures. The minimum, optimum and maximum temperatures for sprouting are 12 - 18 °C, 28 - 30 °C and 36 - 40 °C respectively (Bourke et al. 1984; Keating and Evenson 1979). Cassava leaves have a broad and relatively high temperature optimum for photosynthesis of 25 - 35 °C (El-Sharkaway and Cock 1990). These temperature conditions fall within the average maximum temperature range of 31.7 - 33.7 °C predicted for the study area.

Cassava grows in areas receiving more than 500 mm average annual rainfall. Though water requirements of cassava are low it has a high transpiration rate – 200 g m<sup>-2</sup> h<sup>-1</sup> (Mahon et al. 1976). During drought, it is able to avoid water deficit through leaf drop (Mahon et al. 1976). Water stress may or may not affect the rate of tuber growth, depending on whether or not the stress coincides with bulking<sup>8</sup>. Tuber growth may resume after the stress is relieved (Connor, et al., 1981). It is also intercropped with annual and perennial crops as well as tree crops. The importance of cassava with respect to adaptation to climatic trends in the FSTZ lies in its physiological tolerance as well as in drought avoidance through leaf dropping and water capture by deep roots – to below 2 m. The ability of its tubers to remain in the ground for more than a year without deterioration is

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<sup>8</sup> Bulking is a process of increase in the volume of tubers in the soil.

an added advantage (Norman et al., 1995:278). These features make cassava an invaluable crop upon which farmers in the FSTZ can rely.

#### *6.2122 Yams*

The optimum temperature range for yam growth is 25 - 30 °C but the predicted average temperature for the study area is 31.7 - 33.7 °C. Yams are grown in tropical areas which have at least 1150 mm of rain during the growing season and which have a dry season of 2-4 months. In such areas, yields may reach 60 - 70 t/ha (Gurnah 1974). In areas with higher annual rainfall – 3000 - 8000 mm average – annual yield is 10-50 t/ha (Zaag and Fox 1981). In very dry areas with annual rainfall of less than 400 mm, yam yields decline to 5 t/ha (Sobulo 1972). These conditions suggest that yams grow in regions with low as well as very high annual rainfall. Therefore, it has the potential to be cultivated in the FSTZ. However, as rainfall amounts continue to decline in the FSTZ (predicted annual average of 968 mm in the next century), and as temperature increases, yields will decline as well. Early planting, up to 3 months before the start of the wet season, may increase yield (Kay 1973), presumably by providing a longer period of near-optimum conditions for vegetative growth (section 5.214). Low yields are usually ascribed to poor rainfall during the period of maximum leaf growth, which coincides with early tuber growth (Norman et al., 1995:310). Slow crop growth and inefficient husbandry appear to be more of a constraint on production than crop/climate relations. It appears that, contrary to what farmers think, yam cannot be an important crop in the FSTZ (section 5.214) because the predicted rainfall and temperature conditions for the FSTZ allows for yields of little more than 5 t / ha.

### *6.2123 Plantain*

Plantain grows in wet-and-dry cool tropics with a mean minimum temperature above 15.5°C and a mean maximum temperature of about 27 °C (Stover and Simmonds 1987; Pursglove, 1972). Fruit growth increases with mean daily temperature from 13 - 22 °C (Turner and Barkus 1982). Higher temperatures reduce the number of leaves produced before flowering (Olsson et al. 1984). Plantains grow best in areas with more than 1250 mm average annual rainfall. Water deficit accelerates leaf senescence (Turner and Barkus 1980). Drought also reduces fruit filling but accelerates its maturation, thereby reducing fruit quality (Eastwood and Jeater 1949). Plantains are often shallow-rooted consequently, 65% of the total water taken up is from the top 30 cm of soil and only 55 from deeper than 60 cm (Olsson et al. 1984; Shmueli 1953). The shallow roots make the crop susceptible to wind damage and water deficit (Norman et al. 1995:324). Drought reduces the strength of the stem while over-wet soils make the plantain susceptible to wind damage through uprooting. Conversely, good soil-water conditions reduce susceptibility to wind damage by increasing stem thickness as well as directly increasing fruit yield and the proportion of fruit which is harvestible (Holder and Gumbs 1983). However, as discussed in Chapter Four, good soil-water conditions cannot be guaranteed in the unfolding climatic trends in the FSTZ. Predicted average annual rainfall (968 mm) in the FSTZ is lower than the amount (1250 mm) needed for plantain growth. Similarly, predicted average temperature range (31.7-33.7 °C) for the FSTZ is higher than the average temperature for plantain growth (27 °C). These figures indicate that while plantain may be doing well in the current climatic conditions, it cannot be successfully cultivated in the future in the FSTZ if current rainfall and temperature trends continue.

**Table 6.4. Comparative energy yield of cereals and non-cereal energy crops**

Crop	Average Tropical Yield (t ha <sup>-1</sup> )	Edible Energy Value (MJ kg <sup>-1</sup> )	Proportion of Edible energy (%)	Edible Energy per ha (10 <sup>3</sup> )	Average Crop Growth Period (days)	Edible Energy Per Ha per Day of Growth (MJ)
<b>Cereals <sup>a</sup></b>						
Rice	2.69 <sup>b</sup>	14.8	70	27.9	140	199
Maize	1.59	15.2	100	24.2	130	186
Sorghum	0.87	14.9	90	11.7	110	106
Millet	0.65	15.0	100	9.8	100	98
<b>Non-Cereals <sup>a</sup></b>						
Cassava	9.63	6.3	83	50.3	330	152
Yams	7.00	4.4	85	26.2	280	94
Plantain/ Banana	13.00	5.4	59	41.4	365	113

a. Cereals, air-dry; non cereals, fresh.    b. Paddy

Source: Adapted from Norman et al., 1995:90.

The discussion of examples of cereals and non-cereals suggests that, in the face of the ensuing climatic change, more cereals have a better chance of being successfully cultivated in the FSTZ than non-cereals. Non-cereal crops have longer maturation periods compared to cereals (Table 6.4). The cereals are more tolerant of drought and higher temperatures than non-cereals. In addition, cereals provide more protein than the non-cereal crops, which are mainly carbohydrates (Norman et al. 1995). Table 6.4 compares the energy yields of some tropical cereals and non-cereal crops grown in the study area. On a per crop basis, edible energy yields of cereals compare unfavorably with those of non-cereals. However, the time required to accumulate the high yields of non-cereal crops is correspondingly long. Where rainfall or irrigation permit more than one cereal crop to be grown in each year, the annual output of edible energy per hectare from cereals may readily exceed that from non-cereal energy crops. The advantage of cereals over non-cereal energy crops is not their yield of edible energy per crop, but the fact that a moderate energy yield may be obtained in a short cropping period. Thus, even though both cereal and non-cereals can be cultivated in the FSTZ, cereals have a particular advantage over non-cereals by having a shorter-gestation period, especially as the rainy season in the region is becoming shorter and shorter. Cereals are, therefore, more likely to replace most tuber and starchy crops as the main crops in the FSTZ if current climatic conditions persist. The starchy crops and longer gestation crops have their benefits (section 5.23) in the prevailing climatic conditions but with declining rainfall and increasing temperatures their survival is doubtful. Cereal crops will do better than the non-cereal crops if climatic trends persist.

### 6.213 Reliance on improved and specialized crop varieties

High-yielding and shorter-gestation crop varieties play a pivotal role in the on-going process of adaptation to the shortening rainy season. Those who use the improved seeds think they are better-off than those who do not use them (Table 6.5). However, there are many constraints on the use of improved seed varieties which have to be identified and resolved to make it easier for farmers to accept this "new" technology. Most important of these obstacles is the high price of the seeds. Because farmers are not accustomed to buying seeds for planting, the adjustment to an annual purchase of special seeds is rather slow and very susceptible to price increases. Thus, only 21% of respondents use improved seeds on a consistent basis (Figures 5.3; 5.5). Nationally, the number of farmers using improved seeds decreased by 3% between 1993 and 1994 because of a 100% increase in prices in the period (ISSER 1994:84; 86; section 6.223). Consequently, with price increases, one cannot be sure that farmers will stay with this technology. It is expected, however, that the necessity for improved seeds in the changing agro-environment can *force* farmers to accept the higher prices since the farmers cannot hope to get a good harvest without the improved seeds.

Other major problems in using specialized crops as a response to rainfall are the sensitivity of some of the crops to shortages in rainfall and the longer gestation periods of others. For example, when rainfall is insufficient, improved maize seeds tend to have average yields that are generally lower than the yield of the old seed varieties (ISSER 1994:86). Cocoyam, yam and cassava survive long periods of drought, but they tend to have over-all low yields because their longer-gestation periods allow only one cropping and one harvest within the farming season. Though recent research has produced more drought-resistant and shorter-gestation plantain and yam species (IITA 1996), these improved varieties are not drought-tolerant enough to survive in the predicted climatic

**Table 6.5. Agricultural Performance of all Farmers Classified by Use of Improved Seeds**

		Agricultural Performance		
		Better-off	Worse-off	Total
Use Improved seeds	Yes	O: 18 E: 13.9	O: 3 E: 7.1	21
	No	O: 47 E: 51.1	O: 30 E: 25.9	77
Total		65	33	98 *

O = observed frequency; E = expected frequency

**Notes:**

- \* Two female farmers said there had been no change in their agricultural performance.
- 1. Null hypothesis ( $H_0$ ): Use of improved seeds and agricultural performance of farmer are independent  
Alternate hypothesis ( $H_A$ ): Use of improved seeds and agricultural performance of farmer are not independent.
- 2. Test at 0.5 level of significance.
- 3. Reject null Hypothesis if  $\chi^2 > 3.841$  (value for 1 degree of freedom (df)); otherwise accept the null hypothesis.
- 4. Since  $\chi^2 = 4.6$  exceeds  $\chi^2_{05} = 3.841$ ,  $H_0$  is rejected; that is there is a relationship between use of improved seeds and how farmers perceive their agricultural performance (Appendix 8d).

Source: Author's Field Research 1998

conditions for the region. The best response to the climatic trends is an extensive irrigation system which would be used in conjunction with the improved seed varieties.

#### 6.214 Irrigation

Extensive irrigation could reduce the effects of rainfall variability within the farming season, but the prospects of it being used in the near future are bleak (section 1.434). Smaller scale irrigation has been practiced at one time or another by 42% of the respondents whose farms are near rivers and streams (Figure 5.5). In this system of irrigation no water pumps are used because farmers cannot afford the pumps and the government has not helped the farmers to acquire the pumps. Rather, to water their crops, the farmers use buckets to collect water from the stream. Because this method is too labor intensive to be successful on a large-scale, farmers limit its use to small-scale cultivation of vegetables for home consumption only. Of the 42% who use this version of irrigation, mainly for dry season farming, 22% have stopped its use since 1983 because there has not been enough water in the streams in the dry season. Because proximity of a farm to a river determines who can practice this type of irrigation, more than half of the farmers (58%) who do not have any land near a river do not have the benefits of this system of irrigation. While waiting for the construction of extensive irrigation systems, farmers whose farms are near rivers can make miniature dams to trap water for irrigation. Farmers whose farms are located far away from the rivers could be given financial assistance to drill wells for the purposes of irrigation.

If the observed rainfall trends persist, the drought tolerance level of some of the crops will soon be exceeded. For this reason, the adoption of more drought-resistant crops is not an effective solution to the water problem in the long run. To help farmers deal with the increasing unpredictability of rains in the farming season, the Meteorological Services

Department, basing itself on the location of the ITD, is able to offer advice to farmers in the study area and other parts of the country as to when to expect the first rains and when they may plant their crops (Personal communication with Mr. Ussher, Deputy Meteorological Officer of the Ghana Meteorological Services Department, 1996). Since there are no long-term programs to combat the water problem, water, the single most important factor determining the success of farming in the area, will remain the most formidable challenge to the farmers' adaptation strategies. Though farmers have adopted more drought-resistant crops, this is not an effective solution to the water problem in the long run because if the observed rainfall trends persist, it will be difficult for some crops to survive in the new environment since their drought tolerance level will be exceeded.

## 6.22 Evaluation of the Responses to Soil Degradation

### 6.221 Soil/crop relationship

Farmers have turned to a variety of crops which are not only drought resistant but also do well in low quality soils that do not support the high nutrient-demanding crops such as cocoa and coffee. While some of the major crops survive on relatively rich soils, others do well even on marginal soils. A notable feature of pearl millet is its capacity to grow on marginal soils whose chemical fertility has declined severely (Ahn 1970). Pearl millet survives on light loam soil (Kowal and Kassam 1978). Although millet is adapted to soils of low fertility, it is also capable of taking up large amounts of nutrients when fertilized or grown on more fertile soil. The capacity of millet to grow on infertile soils may be related to its ability to root deeply and rapidly (Norman 1995:174). Farmers can depend on it to lessen the impact of declining soil fertility. Its ability to do well in an environment that is experiencing not only declining soil fertility but also increasing temperatures and declining rainfall (section 6.2113) makes it one of the crops that farmers can use to mitigate the

effects of environmental changes in the FSTZ.

Apart from millet, sorghum is most tolerant of poor soils of any of the other crops in the study area. Sorghum crops obtain much of their nitrogen from soil organic matter, which mineralizes in a flush at the onset of the wet season (Jones and Wild 1975). Phosphorous nutrition of sorghum is often inadequate on weathered *ochrosols*, such as those found in the study area (section 1.513). Since sorghum responds effectively to phosphorus, soil conditions for sorghum can be improved with minimum amounts of phosphorous fertilizer (Mokwunye 1979; Olsen et al. 1962). Sorghum is both drought- and temperature-resistant (section 6.2112) in addition to tolerating poor soils. Therefore, it is a crop farmers can depend on to get the most out of the declining conditions of the soil.

The intermediate textured soils – sandy loam and clay loam soils – found in the study area are some of the best soils for maize because they provide adequate soil water, aeration and penetrability (Norman et al. 1995:135; ). Nutrient deficiencies in these soils commonly limit maize yields. When the nutrient deficiencies are corrected with fertilizers and improved cultivars are used, high yields are attainable. On *ochrosols*, such as found in the study area, 95% of maximum maize yield can be obtained at 80-120 kg/ha applied nitrogen (Norman et al. 1995:137 Grove (1970). The problem, however, is whether farmers will be able to afford the liberal quantities of fertilizer needed. The high water requirements (section 6.2111) and fertilizer demands for maize do not place maize high on the lists of crops farmers can rely on in the future.

Friable soils – deep sandy loams and deep loams – are important for yam cultivation (Kassam 1976; Kay 1973), because while other tuber crops such as cassava first penetrate the soil with their narrow roots before expansion, the yam tuber penetrates the soil as it expands (Onwueme 1978). While the soils in the study area are loamy and sandy, they are not friable (section 4.32, ). This explains why mounding is used to alleviate

this poor soil physical condition and to increase the response of yam to fertilizer (Kang and Wilson 1981). One disadvantage with respect to the yam/soil relationship in the study area is that, unlike cassava, yams require highly fertile soils (Norman et al., 1995:312). Because of their relatively high nutrient demand, yams are usually grown as the first crop after clearing the land so that they can take advantage of the accumulated nutrients before other crops start competition for these nutrients. With the increasing pressure on the land, it is doubtful whether the fallow period will be long enough for the soil to regain nutrients to the levels required for yams. Some yam cultivars and species such, as *D. alata*, a common yam species grown in the study area, are more tolerant of low fertility than most other edible yam species (Kay 1973) but the general view is that without liming and fertilizing, only low yields can be expected on the acid soils in the study area (Norman et al. 1995:315; Koli 1973). In addition to abundant rain, yam needs a continuous supply of fertilizer to have a good yield (section 6.2122). Since both demands are difficult to meet, yam is not a crop that can be successfully cultivated in the future in the FSTZ.

Cassava will help farmers to get the most out of degraded soils. It is also drought-tolerant (section 6.2121). Cassava is a species that will still produce a harvestable yield, about 5-6 t ha<sup>-1</sup> in marginal soils, where other starchy crops will fail (Edwards et al., 1977; Cock and Howler 1978). Cassava takes up significant quantities of nutrients from the soil (Cock and Howler 1978) but on a per unit weight basis cassava requires much less nitrogen and phosphorous than most other crops (Howler 1991; Table 6.5). Continuous cassava cultivation may lead to a reduction in soil pH through the depletion of nutrients (McIntosh and Effendi 1979). Nonetheless, the resulting yield decline may be reversed by fertilization (Howler 1991), especially by potassium, the nutrient required in the largest amounts by cassava (Asher et al. 1980:48). One disadvantage of cassava with respect to soil nutrient is that when they are grown they expose the soil to erosion since they have low

leaf area (Ezumah and Okigbo 1980). This disadvantage is lessened by intercropping cassava with other crops such as cocoyam, maize, plantain and vegetables to reduce the erosive power of early-season rain. Since soil quality is likely to decline further in the FSTZ, cassava is one of the crops farmers will have to depend on in the future to get the most out of the soil.

Deep well-drained loams and light clay loams are ideal for plantain with respect to both physical and chemical properties (Lahav and Turner 1983). When yields are heavy, uptake and removal of nutrients in harvested fruit is high. Only exceptional soils will sustain high yields of plantain without fertilization (Stover and Simmonds 1987). Nitrogen and potassium fertilizers are the most commonly required by plantain (Martin-Prevel 1980). Some minerals required for growth immediately after planting are contained in the rhizome<sup>9</sup> (Twyford and Walmsley, 1974), but uptake from the soil is the major source of nutrients in a plant crop. Plantains may be established as intercrop with cassava, cocoyam, maize, and with shade-demanding tree crops such as cocoa and coffee. Plantain combines the advantages of both perennial and annual crops when the right conditions of soil and rainfall are available. However, the chances of successfully cultivating plantain are limited because of its water requirements (*section 6.2123*).

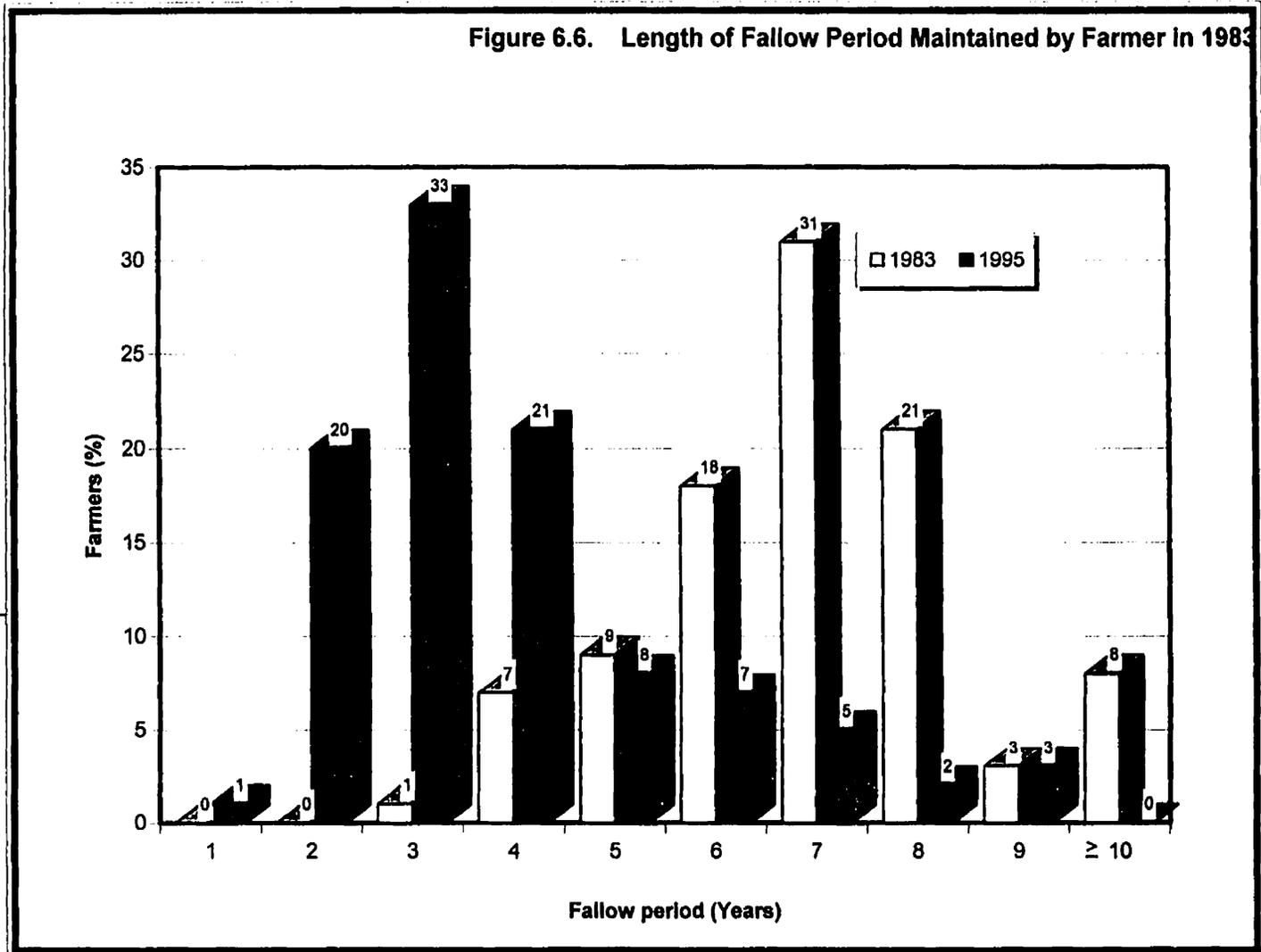
#### 6.222 The bush fallow method

While the physical properties of the soils in the study area can support all of the crops that the farmers have turned to, the nutrient requirements of the crops imply that the soil nutrients need significant regeneration in order to sustain crop production. The main method of soil nutrient regeneration in the area is bush fallow (*section 5.43*). It is doubtful whether this method can be relied upon for soil nutrient regeneration in the long run.

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<sup>9</sup> Rhizome is the underground root-like stem of the plantain bearing both roots and shoots.

Figure 6.6. Length of Fallow Period Maintained by Farmer In 1983



Note:

The average fallow periods for 1983 and 1995 are 7 and 4 years respectively. The standard deviation are 1.7 and 1.8 respectively. In 1983 only 8% of the farmers maintained a fallow period below 4 years. In 1995, 75% maintained a fallow period below 3 years.

Source: Author's Survey 1996

**Table 6.6. Agricultural Performance of all Farmers Classified by Length of Fallow Period Maintained by Farmer**

		Length of Fallow Period maintained by farmer		
		Below 3 Years	3 Years or more	Total
Agricultural Performance	Better-off	O: 50 E: 49.7	O: 15 E: 15.3	65
	Worse-off No	O: 25 E: 25.3	O: 8 E: 7.7	33
	<b>Total</b>	<b>75</b>	<b>23</b>	<b>98 *</b>

O = observed frequency; E = expected frequency

**Notes:**

- Two female farmers said there had been no change in their agricultural performance.
1. Null hypothesis ( $H_0$ ): Length of fallow period maintained by farmers and the agricultural performance of farmers are independent  
 Alternate hypothesis ( $H_A$ ): Length of fallow period maintained by farmers and the agricultural performance of farmers are not independent.
  2. Test at 0.5 level of significance.
  3. Reject null Hypothesis if  $\chi^2 > 3.841$  (value for 1 degree of freedom (df)); otherwise accept the null hypothesis.
  4. Since  $\chi^2 = 0.02$  does not exceed  $\chi^2_{05} = 3.841$ ,  $H_0$  cannot be rejected; that is length of fallow period maintained by farmers and the agricultural performance of farmers are independent (Appendix 8e).

Source: Author's Field Research 1996.

Increasing food demand due to a rapidly growing population and the consequent expansion of acreage under cultivation have resulted in shorter fallow periods which could lead to declining soil quality (Figure 6.3). For instance, the overall average fallow period in Ghana fell from nine years in 1970 to seven years in 1984 (Sarris and Shams 1991:27). Though the actual fallow periods in 1983 vary between one and twelve years in the study area, the average fallow period dropped from seven years in 1983 to four years in 1995 (Figure 6.6). In 1983 only 8% of the farmers, as compared to 75% in 1995, maintained a fallow period of less than four years. Twenty-five percent of the respondents who have seen fallow periods drop below the critical threshold of three years complained of soil infertility (Table 6.6) Yet, length of fallow period maintained by the farmer did not make a difference in how farmers perceive their performance (Table 6.6). This situation may be because those who maintain fallow periods of less than three years are those who tend to use soil improvement methods such as agroforestry, application of compost and the *proka* methods (section 5.31). For this reason, the effects of the decline in the natural soil fertility are not reflected much in their output.

Fallow periods in 1995 would have been shorter but for the continuous conversion, since 1983, of lands formerly used for cocoa and coffee cultivation into food farming lands. This trend shows that it is only a matter of time before the increasing pressure on land leads to a break-down of the fallow system, and to continuous cultivation of the same land. In the meantime, as long as farmers can afford the luxury of land rotation, and as long as the fallow system continue to offer benefits such as timber, game and fuelwood, farmers will continue to retain the fallow system.

While the fallow system has supported farming activities over the years, sustained higher yields in the future will require other measures that can maintain, at least, the existing levels of soil fertility. In the short-term, short managed fallow with fast growing

trees may ensure rapid soil nutrient recycling. But managed fallow and traditional agroforestry are difficult to sustain because of the frequent bushfires which cause damage to most of the nurtured trees every year. Besides, bushfires delay organic matter regeneration in fallowing soils because the litter that would otherwise be converted to organic matter is consumed by the yearly fires. What is needed is research to discover methods to enable farmers to switch from the bush fallow system into a permanent/continuous system of farming. For example, what could be done to help the sensitive shallow soils support an intensive and permanent farming system?

#### 6.223 Inadequate supply of fertilizers

Low levels of fertilizer application at a time when soil quality is declining and fallow periods are shortening is a constraint to sustaining soil fertility (Figures 5.8). The government's policy of reducing fertilizer imports further discourages farmers from embracing fertilizer application (ISSER 1994:81) since the limited supply leads to higher fertilizer prices (Figure 6.7). At the same time, there is no relationship between the use of fertilizer and the agricultural performance of farmers in the study area (Table 6.7). When farmers who have been using fertilizer since 1983 were compared to those who have not used fertilizer for the same period, there were no differences between them with respect to their performance. This unexpected situation is due to a number of constraints that limits the successful application of fertilizer now and in the future. The high cost of fertilizers without a corresponding increase in producer prices encourages those already using them to stop such use. For example, agricultural extension officers in the study area stated that fertilizer cost for an acre of land for tomato cultivation was C 55,000 (US \$ 36.7) but the income from the sale of tomato from the land could be anything between C45,000 to C100,000 (US \$ 30 to 66.7) – a possible negative return. Furthermore, when the rains fail in a particular

**Table 6.7. Agricultural Performance of all Farmers Classified  
by Use of Fertilizer**

		Agricultural Performance		
		Better-off	Worse-off	Total
Use Fertilizer	Yes	O: 11 E: 11.3	O: 6 E: 5.7	17
	No	O: 54 E: 53.7	O: 27 E: 27.3	81
Total		65	33	98 *

O = observed frequency; E = expected frequency

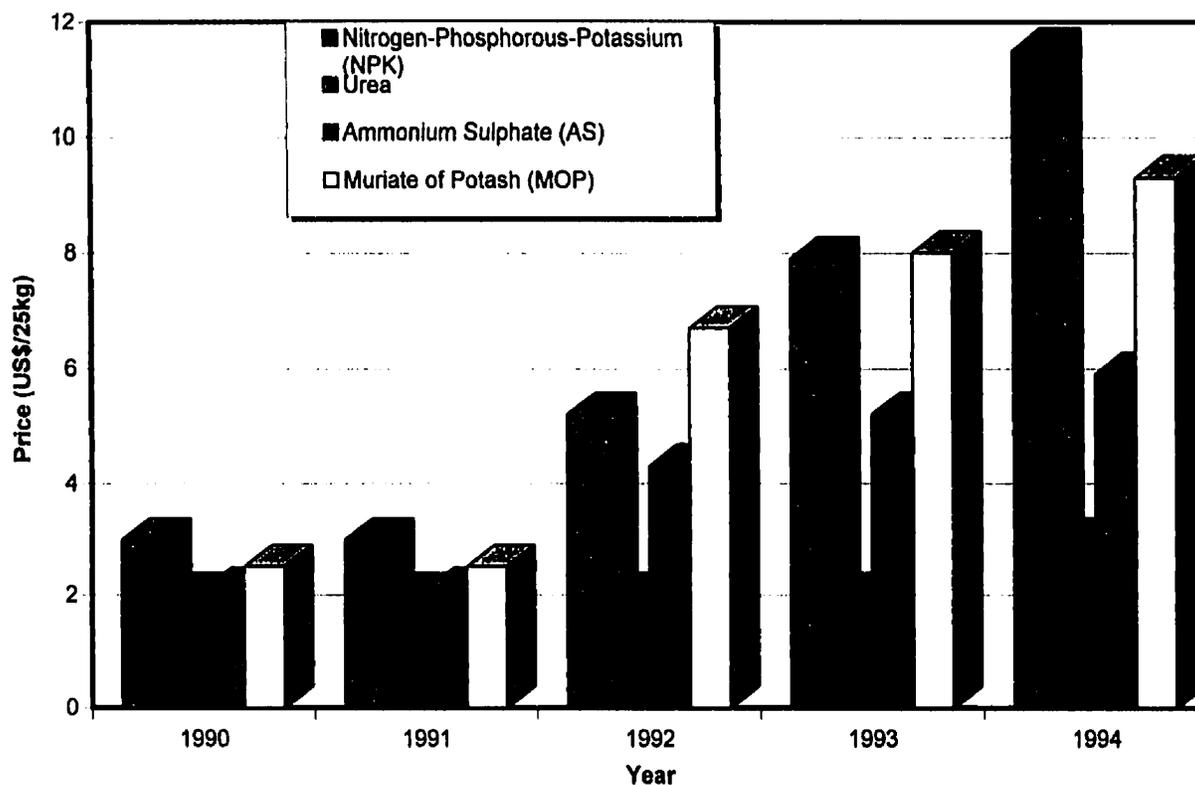
**Note:**

- \* Two female farmers said there had been no change in their agricultural performance.

1. Null hypothesis ( $H_0$ ): Use of fertilizer and agricultural performance of farmers are independent  
Alternate hypothesis ( $H_A$ ): Use of fertilizer and agricultural performance of farmers are not independent.
2. Test at 0.5 level of significance.
3. Reject null Hypothesis if  $\chi^2 > 3.841$  (value for 1 degree of freedom (df)); otherwise accept the null hypothesis.
4. Since  $\chi^2 = 0.03$  is less than  $\chi^2_{05} = 3.841$ , the  $H_0$  cannot be rejected. That is, the use of fertilizer and agricultural performance of farmers are independent (Appendix 8f)

Source: Author's Field Research 1996.

**Figure 6.7. Prices of Common Fertilizer used in Ghana:  
1990-1994<sup>1</sup>**



1. The prices of NPK increased by 282% between 1990 and 1994. The corresponding figures for AS, MOP and KNP, SSP, and Urea were 183%, 268% and 91% respectively.

US\$ 1 = C1, 500

Source: ISSER 1994:83

**Table 6.8. Estimated Crop Yields under Traditional, Improved and Advanced Cultivation (kg/ha)**

<b>Food Crop <sup>1</sup></b>	<b>Traditional</b>	<b>Improved <sup>2</sup></b>	<b>Advanced <sup>2</sup></b>
<b>Maize <sup>3</sup></b>	700	1 200	1 800
<b>Sorghum</b>	300	600	-
<b>Millet</b>	300	500	-
<b>Rice</b>	600	1 000	1 200
<b>Cassava</b>	3 000	7 000	-
<b>Yam</b>	3 250	5 000	-

**Notes:**

1. Yields of annual crops refer to mono-cropping.
2. Anticipated yields for improved and advanced farming are estimates and reflect experimental yields discounted by about 30%
3. Maize yields are for transitional and forest zones; yields for savanna areas would be 15-25% lower

Source: Adapted from Sarris and Shams 1991: Table A.8

farming season, the farmers do not get enough income from the crops to pay for the fertilizer, since there is no insurance for crop failure. For these reasons, farmers are not ready to take the high financial risks associated with the use of chemical fertilizers. From the farmers' viewpoint it is more economical to have the current crop yields with minimum risks than to risk the cost of the application of fertilizer. One farmer who ran into debt when the rains failed expressed his dissatisfaction with fertilizers and tractor ploughing:

"If I do not gain then I do not expect to lose either (get into debt). Since the chances that the rain and the markets will fail me again are so high, because these are unpredictable, I prefer my old ways of farming. In my old ways of farming if I do not gain I do not lose (get into debt). But in the new way (use of fertilizers and tractors), you lose (get into debt) if you do not gain. So my old ways of farming is a better deal. Isn't it?"

The farmers who have used fertilizer complain that the soil is no longer responding effectively to fertilizer as it used to do when they first started using it -- a phenomenon which is attributed to an increased rate of mineralization of soil organic phosphorous when lime is applied to the soil (Lathwell (1979a).

The agriculture extension officers in Wenchi said there has not been any significant change in the production patterns between those using fertilizers and tractor ploughing, and those who farm without these services. When I asked one of the officers why farmers who are using fertilizers are still producing at much the same scale as the farmers who are not using fertilizers he said:

"It is a function of the weather. The extension service supplies them with fertilizers on loans to be repaid after harvest. If the rains come at the right time farmers who are using the fertilizers make a better harvest relative to those who are not using fertilizers. If the rain fails in one year, the farmers using fertilizers lose their crops and get into debt. It takes them two or more seasons of good weather and good

harvest to repay the loan. If the rains fail the farmers in two successive years, it takes them six years to pay the loan. Some do not pay the loans. Others stop using the fertilizer and ploughing and return to the traditional way of farming to pay the loan. Those who use the traditional methods do not get into this trouble”

Hence, while ploughing and fertilizer both increase production over traditional methods (Table 6.8) the net benefit per hectare for the different methods is not significant when the costs of ploughing and fertilizers are factored into the equation. Farmers who use fertilizer and ploughing have the additional burden of the cost of ploughing and fertilizers in years when the rains fail or market prices fall drastically. The efficient use of fertilizers in the FSTZ therefore requires that natural risks such as failure of rain is minimized and that there is a ready market for the increased production. Because of problems such as these, increased adoption of chemical fertilizers to replace land rotation as a method of soil regeneration is unlikely, at least in the short-term, even though farmers realize the need for them. This need for fertilizers to sustain soil fertility explains why some farmers are beginning to use a more affordable kind of fertilizer – compost – in place of expensive chemical fertilizer. Composting is a cheaper source of fertilizer since it is readily available from most household waste, which tends to be organic and biodegradable. The problem with this type

### 6.23 Evaluation of Responses to Changes in Vegetation and Fauna

of fertilizer is whether there will be enough supply to meet the growing demand. Currently, there is an abundant supply because of the compost accumulated over the years on refuse dumps (section 5) and because few farmers are using it. As more and more farmers show interest in the use of compost, demand will outstrip supply. The increased demand could then be met only if new sources of supply, such as compost from urban centers, were

obtained. In this respect, the farmers will need external technical support and expert advice on enhancing the composting process, and on converting urban waste into compost for agricultural purposes in the rural areas.

#### 6.231 Agroforestry

The various attempts to halt further degradation of the vegetative cover have been short-term measures whose success has been dependent on the maintenance of the fallow period. As these strategies are versions of the fallow methods, they will survive only as long as the fallow system operates. Yet, the fallow period is getting shorter and shorter (section 6.222). It is not reasonable to practice plantation crop combination forestry or the pioneer managed fallow if there is no fallow period during which the nurtured trees can grow. Even though few farmers are practicing the different versions of agroforestry, the shorter fallows and, the need for trees for fuel and soil nutrient will 'force' farmers to resort to fast nitrogen-fixing trees, such as acacia and leucaenia. Though these exotic trees cannot sustain the original vegetation, they can provide some of the services of the indigenous vegetation, especially the regeneration of soil fertility and provision of fuel wood.

#### 6.231 Weeds and pests control

Weed control has become an important factor in determining the amount of harvest in any farming season. Weeds choke food crops, retard their development, and cause a reduction of from 30 to 60% in yield and sometimes a complete failure (Carson 1978). Labor spent on weed control is responsible for the exponential growth in the cost of farming in the study area. Weed control is estimated to account for 80% of total farm labor (Abbiw 1993:24). Therefore, increasing the frequency of weeding per farming season as a way of controlling

aggressive weeds is a severe drain on the human and financial resources of the farmers which in turn impedes farmers' ability to increase their profit margins.

Effective application of herbicides has been difficult because of their adverse effects on crop yield, especially in dry years (Abbiw 1990:142). While some of the most effective herbicides produce optimum crop yields when very wet periods precede their application, the same herbicides depress yields during dry periods (Carson 1978). Other herbicides, such as the *Gramozone* chemicals, have been applied in India and Nigeria to eradicate the *C. odorata*; however, weeds killed in this way quickly re-established themselves from the seeds and roots (Abbiw 1990:244). Attempts to use the green aphid (*Aphis spiraecolae*) – an insect which feeds by sucking sap from leaves – to control the *C. odorata* have also failed because the aphids themselves are known to be very vulnerable to the larva, *Parogus borbonicus* (Hall, Kumar, and Enti 1972). Likewise, there is no known effective way to halt the invasion of farms by termites, lizards, mice, giant rats, frogs and crows, who have the more open vegetation for a habitat (section 4.23).

The methods currently used to address the vegetation problems in the study area are at best only short-term palliative measures. They may continue to be successful as long as the bush fallow system operates. In the long run, they will be ineffective to halt the invasion of the indigenous vegetation by more aggressive weeds and the pests which have these weeds as their habitats. More effective herbicides can help control the weeds on farms. It is expected that continuous cultivation and selective use of fast growing nitrogen-fixing trees will be another effective way to control weeds. In continuous cultivation there is no fallow, so the weeds do not have the length of time needed to establish themselves as they do in a fallow system. The dominance of nitrogen-fixing trees can be an effective check on weed invasion in the agroforestry system, since the tree cover controls the germination of weed-seeds (Plate 5.14).

### 6.3 OTHER IMPEDIMENTS TO ADAPTATION

#### 6.31 Reliance on Human Energy

The continuing reliance on human energy is a big stumbling block to increased agricultural productivity in the area. Using man-hour data from Africa, south-east Asia and Mexico and assuming an average man-hour value of 0.63 MJ/hr for net energy expenditure of tropical cultivators engaged in farm work, Black (1971) has calculated the energetic efficiency of rainfed-hoe-cultivation of a range of cereal crops. The average food energy output was  $10.5 \times 10^3$  MJ/ha and the human energy input was 654 MJ/ha with an average efficiency ratio of 17.5, and a range of 9 - 34. In a similar study, Norman (1978), assuming an average man-hour net energy expenditure rate of 0.75 MJ/hr (based on Clark and Haswell 1970) in rainfed cereal production in tropical Africa, arrived at an average efficiency ratio of 18.5, with a range of 7 - 39. Out of the 21 sets of data examined by Black and Norman, eight gave an efficiency ratio of between 15 and 20. That is, in non-mechanized, subsistence cereal production in the tropics, farmers can expect to produce from a cereal crop, 15 - 20 times more food energy than they expend in growing it. This suggests a comfortable secure mode of life if it is assumed that the subsistence farmer is in a vulnerable situation only when the average ratio of crop energy output to net human energy expended in crop production is less than 10 (Norman 1978). The energetic efficiency of non-cereal energy crop production is even higher than that of cereal production (Norman 1976; Chandra 1981). This is illustrated in Table 6.9, which gives the output/input ratio of Fijian and Indian farmers. The higher energetic efficiency of non-cereal production relative to cereal production may be explained by the fact that while the inputs of land preparation, planting and early weeding are comparable to those of cereals, the non-cereal energy crops continue to accumulate carbohydrates in the latter part of their long gestation period without a great deal of input on the part of the farmer (Norman et al 1995:263).

**Table 6.9. Energy Output/Input Ratio of Cropping Enterprises in Fiji**

	<b>Fijian Farms</b>	<b>Indian Farms</b>
Cassava	52:1	42:1
Yams	66:1	-
Rice	17:1	9:1
Maize	39:1	22:1

Source: Chandra 1981

However, in assessing the energy balance of the subsistence farmer “a more appropriate denominator for the calculation of an efficiency ratio is the total energy requirement of the *farm family* throughout the year” (Norman et al. 1995:91) – a factor which was not considered in the above calculation. For instance, many family members (children) do some work on the farm and will be dependent on its output at one time or the other. This energy requirement may be as high as five times that of the net energy actually expended in crop production (Norman 1978). Crop energy output under rainfed conditions can also vary greatly from season to season owing to climate, attack by pest or disease, and crop storage losses.

The ratio of crop energy output to net human energy in the FSTZ has not been calculated. However, considering that 80% of total farm labor is invested in weeding (Abbiw 1993:24); the persistent invasion by pests (section 6.231), and crop storage losses in the region section (section 3.1), one can reasonably infer that the ratio is more likely to be lower than ten. The continuing reliance on human energy in the FSTZ is therefore a serious obstacle to increased agricultural productivity in the area. While the use of simple tools such as hoes, cutlasses and dibble sticks is appropriate for the special conditions of

the tropical soils (section 3.11), these implements in human hands make it increasingly difficult to increase food production to meet the demands of a rapidly growing population. On the other hand, heavy machines, such as tractors, are not suitable for the shallow soils and vegetation of the area. It is therefore important to research intermediate tools that can work the FSTZ soils without degrading them. Bullock ploughing should also be considered since it can at least reduce the drudgery of land clearing in areas where it can be used. Perhaps the real stumbling block to farmers' adaptation efforts are government policies such as low producer prices, lack of credit, and similar disincentives which discriminate against food farmers.

### 6.32 Discriminatory Government Policies

Government policies subsidize the rehabilitation of export crops such as cocoa but provide no such incentives for food production (ISSER 1994; Konings, 1986). The pattern of discrimination is well demonstrated in the allocation of resources within the agricultural sector over the years. For example, cocoa studies received 45% of the research funding for agriculture in 1987 although it contributed only 17% of the agricultural GDP (AGDP). Food crop farming and livestock rearing received 50% of the research funding and contributed 71% of the AGDP (Sarris and Shams 1991:123). The allocation of resources within the agriculture sector has followed a similar pattern since 1987 (ISSER 1992; 1993; 1994).

Marginalization of food crop farmers has also been aggravated by the commitment of the central government to the support of agribusiness<sup>10</sup> and of large scale farmers in the domestic food sector with the belief that the smallholder peasant food farmers are backward in their methods of production (Amanor 1995). Yet, several studies have shown

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<sup>10</sup> Agribusiness refers to large-scale production of crops such as pineapples, lemon, cola, and cashew nuts for export.

that the smallholder farmers supply as much as 90% of domestic food production (Hansen 1989; Dickson and Benneh 1988; Miracle and Seidman 1968). With little or no encouragement from the government, the farmer is not motivated to look for ways to increase production beyond subsistence levels.

### 6.33 Inadequate Producer Prices

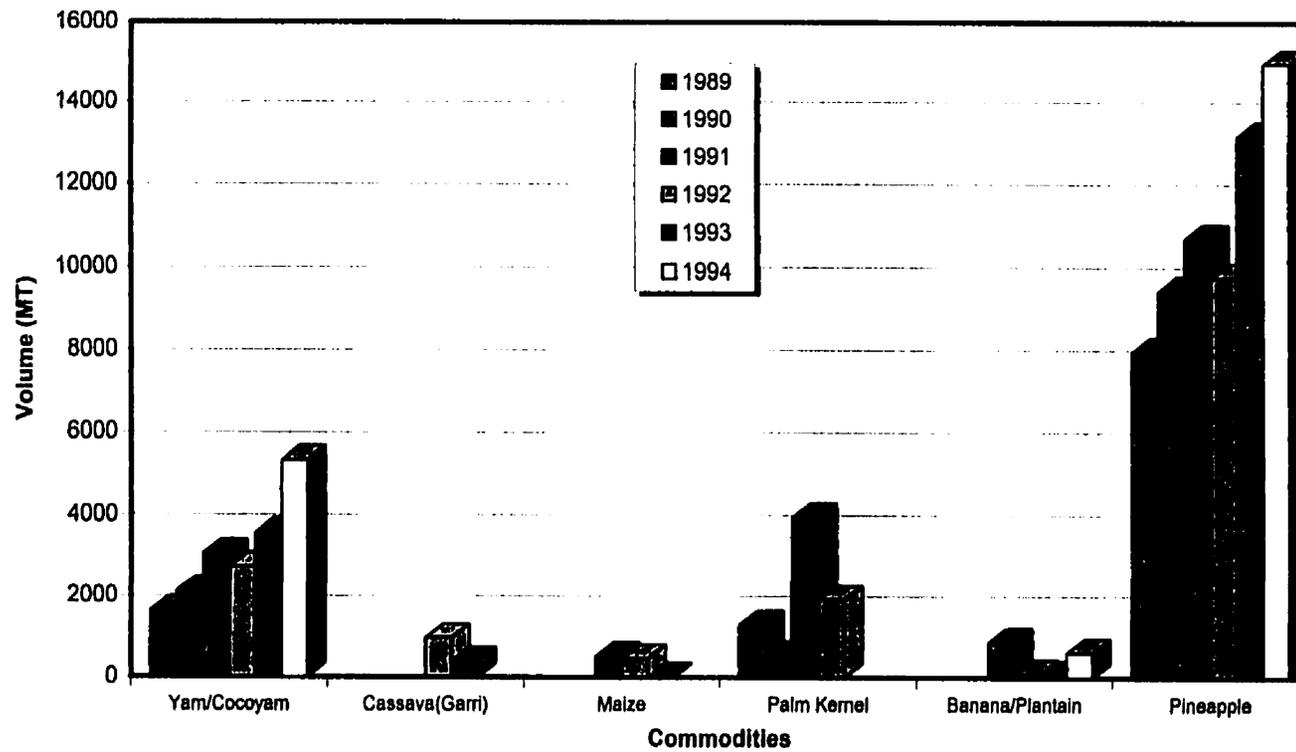
The government uses different strategies to keep food prices low at the expense of the farmer. To attract foreign capital investment in manufacturing, the government keeps urban wages low by dictating a low minimum daily wage. The government then compensates the low wages of urban workers by offering lower food prices to farmers. At one time or another, the government has used different strategies to ensure lower food prices in the urban centers by offering lower prices to the farmer. From the late 1960s until 1983 the strategies included policies that controlled and fixed low prices for food crops (Amanor 1995:47; (section 1.444). Since 1983, the government has replaced its controlled and fixed pricing policy with a flexible pricing one where price levels are determined by supply and demand. At the same time, the government has liberalized trade to include the importation of food crops, such as rice, from European and South East Asian countries. The cheaper food imports drive down the prices of local staples since farmers have to compete on the local market with farmers from agriculturally advanced countries whose production processes are heavily subsidized. Thus, even though the producer prices are now better, compared to the 1970s when they were controlled (section 6.11), the farmers still receive lower prices than they would have if there were no food imports. The lower the prices farmers receive for their food crops, the more farmers have to produce in order to afford their basic needs. But the more they produce, the more the forces of supply and demand lower the food prices within the framework set up by the government. Caught up in a cycle

where increased production means lower incomes that sometimes do not pay for the cost of the production, farmers produce just enough to feed themselves. Price interventions that keep food crop prices down also keep the farmers poor, thus inhibiting their ability to invest in any long-term adaptation strategies. The combined results of food imports and transfers from agriculture to help other industries, in the form of cheap food for urban dwellers, constitute the main impediments to the development of food crop agriculture in the country (Schiff and Valdes 1992:41). The strategies used by the government may be good for urban industries but do not provide the right incentives to farmers to produce more in order to ensure badly needed self-sufficiency in food.

#### 6.34 Lack of Markets for the New Crops

Closely related to the lower prices for food crops is the problem of marketing the new cash crops. The absence of markets slows down farmers' interest in experimenting in the production of new crops because the willingness to adapt new crops to environmental change is also determined by the availability of market outlets for the new crops that will be cultivated in the new environment (section 1.444). Farmers complained that since 1993, prices of cassava, cocoyam, plantain and maize had been declining relative to the cost of their production because of increased production without markets for these crops. Since there are no adequate storage facilities nor any processing facilities for most of the crops highly perishable after harvest, farmers are forced to sell crops very cheaply at the harvest season because there is a glut on the market (section 1.444). The lack of markets within and outside the country for the crops that replaced cocoa and coffee, therefore, discourages farmers from investing their energy in experiments that seek to increase production of these crops. When food markets are so unreliable, small farmers tend to

**Figure 6.8. Volumes of some Major non Traditional Agricultural Export Commodities, 1989-1994 (MT)**



Source: Based on data in ISSER 1994: Table 5.12

return to subsistence farming instead of finding ways to increase production (Lele and Agarwal 1989). Some success has been achieved by the government in finding foreign markets in Europe, North America and North Africa for these so-called *non-traditional agricultural export commodities*<sup>11</sup>, but it is still an uphill battle (ISSER 1994:77; Figure 6.8).

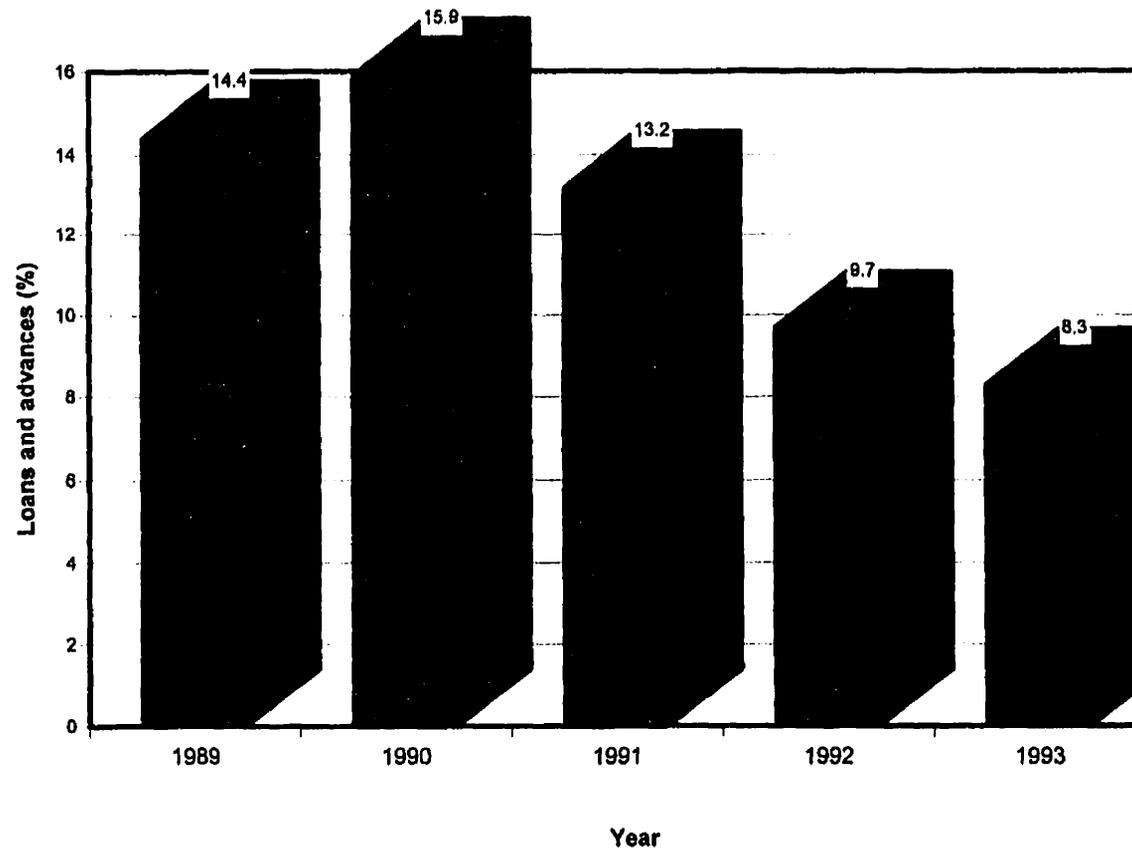
### 6.35 Insufficient Agricultural Credit

The majority of small-scale farmers, who produce the bulk of the nation's food, need fertilizer and improved seed varieties and other tools to be able to increase production. Yet most of them cannot afford these inputs from their own resources. Agricultural credit to these farmers is, therefore, a very important requirement for organizing effective farm production. Nevertheless, the proportion of government and private bank loans and of advances to the farmers has been on the decline for several years even though the total loans and advances from the banks have been increasing (Figure 6.9). In 1992, while actual loans and advances from commercial banks to the agricultural sector increased by about 20.3%, the loans declined as a proportion of the total loans granted, by 25 percentage points. And in the case of the private banks, actual loans and advances to the agricultural sector increased by about 16.6%. But as a proportion of the total, they declined by about 4.3 percentage points compared with 1991. Similarly, the amount of loans and advances from banks to the agricultural sector increased from 14.7 billion in 1992 to about 17.3 billion in 1993; however, as a proportion to the total loans and advances to all sectors of the economy, they declined from 9.7% to 8.3% (ISSER 1992:92; 1993:89). These figures show that agriculture occupies a declining position on the priority lists of the private financial institutions and the government. Successive governments in Ghana have

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<sup>11</sup> *Traditional agricultural export commodities* are the established agricultural export commodities, such as cocoa and coffee. New crops such as pineapple, maize and yam that are gaining importance as export crops are referred to as the *non-traditional agricultural export commodities* by the Ghana Export Promotion Council.

**Figure 6.9. Percentage of Loans and Advances to the Agricultural Sector of Total Commercial and Secondary Banks 1989-1993**



**Note:**

The total amount of loans advances from the banks to the agricultural sector has increased over the years but have declined as a proportion of the total loan to all sectors of the economy.

Source: Based on Data in ISSER 1993: Table 5.22; 1994: Table 5.28

neglected the small-scale farmers in the distribution of resources over the years – a neglect that has hindered the successful adaptation of indigenous agricultural systems to current challenges (section 1.44). The lack of adequate financial assistance to the small-scale farmers explains the farmers' inability to purchase fertilizers, high yielding seeds, and other items needed to alleviate the effects of the changing agro-ecosystem. By emphasizing agribusiness without equal attention to the small-scale sector, the government is failing to appreciate the full benefits and potential of the traditional farming methods in the agro-ecological environments of the FSTZ.

#### 6.4 SOCIAL ADAPTATION TO ENVIRONMENTAL CHANGE

Agro-ecological change has repercussions for the socio-economic systems of a people (Carney 1996:165; Bebbington 1996:98; Campbell 1984:34; Watts 1983). This observation is confirmed by this study, which among other things also shows that human activities influence the environment just as the environment influences the social systems of the people (section 2.31). The livelihood of farmers in the study area is so intertwined with farming that changes in the agricultural system, due to environmental change, have consequences for their social institutions as well. Changes in the social structure that have occurred as a result of the effects of environmental change on farming include changes in the land tenurial system, changes in gender roles, and changes in the income distribution.

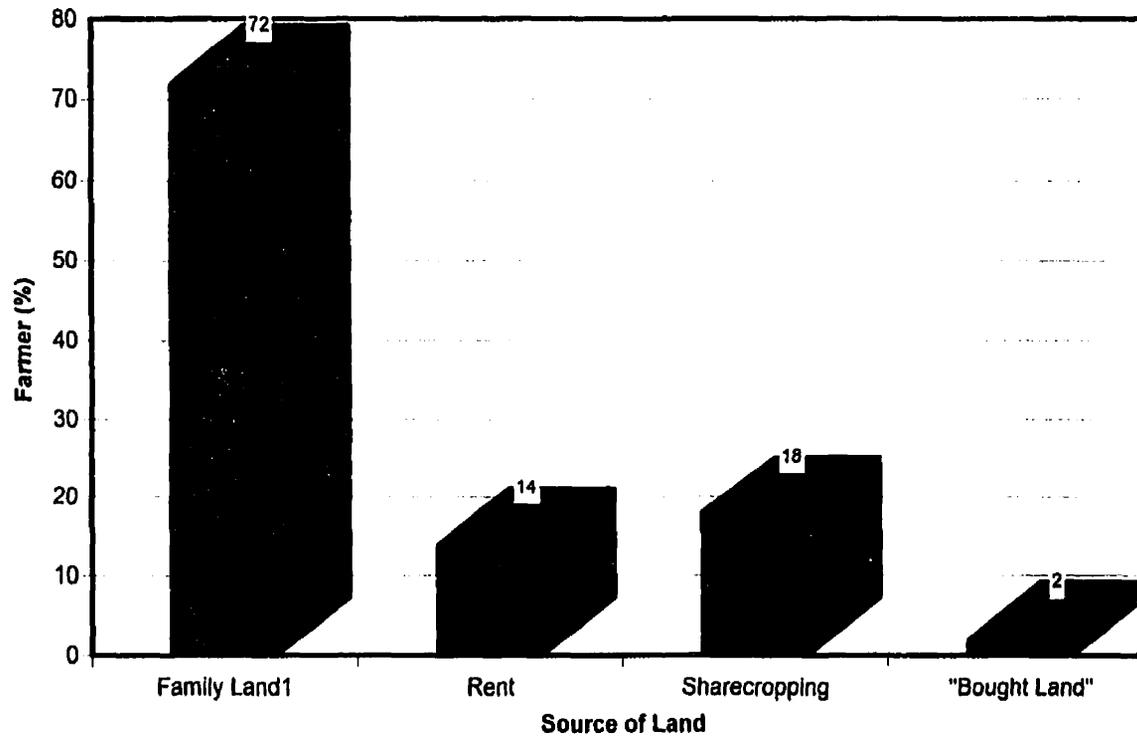
##### 6.41 Changes in the Land Tenure System

The land-holding system in every farming community shapes agricultural production, the distribution of wealth and the development of the soils (Dunning 1970). The destruction of cocoa and coffee farms in the 1980s forced a redistribution of land in the study area. Older people who once owned cocoa plantations but do not have the physical or financial

resources to farm now rent out the land to anyone who has the human and financial resources to obtain produce out of the land. The land is rented out for a specified number of years at a fixed yearly amount of money, or on an agreed-upon crop sharing ratio, usually 1:2 or 1:3 (section 1.434). Members of cocoa farming families now have more family land to farm since the land previously used for cocoa is now available for food production (Figure 6.10). In these ways more people, especially immigrant farmers who have relocated from the Northern Region of the country (section 1.431), have access to land. Of those interviewed, 36% have access to more land than before. Forty-two percent maintained the same amount of land while 22 % have a decrease in their land holding because they had rented out their land on a long-term basis (Figure 5.4). There is a relationship between how much land is at the disposal farmers they perceive their agricultural performance (Table 6.10). There are no recorded outright land purchases, since it is still taboo to sell land which is communally owned. It was discovered in the interviews, however, that some have developed subtle ways of getting around this taboo and other community regulations by engaging in deals that are similar to outright land sale. Formerly, it was permitted to rent land to strangers only in special cases. But now, it is a very common practice, and a shrewd way of dealing in land sales. For example, there were cases where people had rented out their land for as long as 30 years with conditions similar to a complete land sale. It seems that in the evolving land tenurial system one can rent land for as long as the owner wants on the condition that there is no outright sale of the land.

The price paid for land rent is based on the size of the land, how long the land has been fallowing, and the number of years the land is leased out. Land rent costs range from C60,000 to C100,000 (US \$400 - US \$660) per five years, for a hectare of land that has been in fallow for more than five years. If the same size of land has been in fallow for four

Figure 6.10. Sources of Land for Farming



Note

- 1 Family land refers to land that one gets (free of charge) from father, brother, sister, or any member
- 2 Some of the farmers who have access to family land also rent or do share cropping to supplement their incomes

Source: Author's Survey 1996.

**Table 6.10. Agricultural Performance of all Farmers Classified by Accessibility to Land**

		Agricultural Performance		
		Better-off	Worse-off	Total
Accessibility to Land	Increased	O: 30 E: 23.9	O: 6 E: 12.1	36
	No Change	O: 29 E: 26.5	O: 11 E: 13.5	40
	Decreased	O: 6 E: 14.6	O: 16 E: 7.4	22
	<b>Total</b>	<b>65</b>	<b>33</b>	<b>98 *</b>

O = observed frequency; E = expected frequency

**Note:**

\* Two female farmers said there had been no change in their agricultural performance.

1. Null hypothesis ( $H_0$ ): Accessibility to land and agricultural performance of farmers are independent  
Alternate hypothesis ( $H_A$ ): Accessibility to land and agricultural performance of farmers are not independent.
2. Test at 0.5 level of significance.
3. Reject null Hypothesis if  $\chi^2 > 5.991$  (value for 2 degrees of freedom ); otherwise accept the null hypothesis.
4. **Since  $\chi^2 = 20.04$  exceeds  $\chi^2_{05} = 5.991$ , reject  $H_0$  and accept  $H_A$ . That is, accessibility to land and agricultural performance of farmers are not independent (Appendix 8g).**

Source: Author's Field Research 1996.

years or less, it is rented for C40,000 - C70,000 (US \$300 to US \$460) for five years. Most of those tenants who had rented land said that they were able to recover the capital used to rent the land from the first and second year produce and then make a profit in the subsequent years. This may partly explain why as many 83% of those who have increased access to land are also think they are better-off now than before (Table 6.10).

With the redistribution of land comes the redistribution of wealth. Before the introduction of tree crops, income from the land was fairly distributed since all members of a family had equal access to the family land. During the cocoa era some family members established private ownership over portions of the family land because they had permanent tree crops on the land (section 3.221). With the destruction of the tree crops, however, the land has returned to the entire family and all members of the extended family have access to the land for food farming and, hence, a share in the income from the land.

These induced changes in the land tenure system could, however, lead to further land degradation. In sharecropping and land renting, the tenants are not very particular about maintaining the soil since they will have to give the land over at the end of a period. Instead, the land is continuously cultivated for all of the four or five years that it is rented it, since leaving it to fallow means losing income. The land owner who depends on the income from the land is ready to rent it out again as soon as the land is redeemed to whoever is willing to glean a livelihood from the exhausted land. This practice begins a cycle of land degradation.

Also, when land is leased to immigrant farmers from the savanna zone (section 1.431), they use farming techniques and tools that are effective in the savanna zone but which are not suited for the FSTZ environment. For instance the hoe is very effective farming tool in the savanna zone because it is used to dig out the roots of the grass vegetation to control its rapid growth. However, when the hoe, instead of the cutlass, is

used to clear weeds in the FSTZ, it disturbs the soil root mat, makes the topsoil prone to erosion, and eliminates the forest tree seedlings.

In spite of these drawbacks in the evolving land tenure system, the changes in the system show that the traditional system of land allocation is capable of responding to socio-economic changes. When cocoa and coffee were introduced in the 1900s, as cash crops, permanent cultivation and private ownership of the land was allowed. After the destruction of the cocoa farms, however, the land became accessible to all members of the family though the former owners tend to have more access to the fallow land than other members of the family. Likewise, the land tenure system is adjusting to recent environmental changes by allowing easier access of land to non-family members. Thus, far from being a static set of customary rules, it can be said that the communal system of land ownership is capable of changing, even if imperfectly, in response to the environmental and socio-economic changes. These observations, which confirm the study made earlier by Gyasi (1994), are contrary to many expert opinions that hold that the traditional communal land tenure system is incapable of adapting fast enough to change (Anyane, 1962; Migot-Adholla et al., 1990).

The land tenure system has changed in response to socio-economic needs, but there is no clearly defined land-use policy in the area. Consequently, the uses for the land are dictated by the needs of the farmers – cash, and food for subsistence – and not necessarily by what the land is most suitable for. Further, the communal ownership ensures land availability to all members of a community, most of whom depend directly on the land for survival (section 1.434), but there are no mechanisms in the tenure system to ensure the use of the land on a sustainable basis. To maintain a sustainable use of the land and its resources, the land must be managed to provide for the societal needs of the community without compromising its ecological quality. This management calls for either an

adjustment of societal needs to broadly-defined environmental carrying capacities or an increase in carrying capacities to meet societal needs (Bryan 1994:3). Finding this balance is an issue that farmers will have to grapple with in both the short and long-terms, and for which they will need the studies and recommendations of experts.

The sustainable use of the land also calls for a land reform that ensures access to land by all, while protecting the ecological quality of the land. For example, the vast expanse of land accessible to all members of the extended family can be divided among the smaller family units so that each family unit has exclusive rights over its share of the land (including the right to sell). Each family is thus excluded from all other land belonging to the other families. Not only will such a reform keep the traditional value of land availability for all members of the community, but it will also encourage the sustainable uses of the land since every member of the community will be restricted to only a limited piece of land with no free access to other land. The restriction will ensure cautious uses for the land.

#### 6.42 Gender and Environmental Change

Another transition in the socio-economic structure due to environmental change is in the role of the sexes in income generation. In the redistribution of land discussed above, women tend to have easier access to family land than men because of the prevailing matrilineal system of inheritance which distributes all family property through females (sections 1.434; 1.435). In addition to having easier accessibility to land, women have several advantages in the present environmental crisis. For example, women cultivate more crops than men because traditionally women have been associated with food crops while men concentrated on the main cash crops (cocoa and coffee). Of the food crops that have become the main cash crops, men have opted for maize production because, unlike

other food crops, it has a shorter-gestation period and thus brings faster income. Furthermore, unlike the other crops which are harvested throughout the year, maize is harvested in bulk and sales bring in lump income similar to the sale of cocoa. Since maize cultivation is very labor-intensive, men are able to harvest more maize since relative to the women the men are able to cultivate a larger area<sup>12</sup>. That women do most of the house chores such as cooking, water collection, caring for children etc. also explains why they have less acreage under cultivation than men.

Although women cultivate smaller land areas than men, they grow more crops on their farms than men, who tend to be more interested in mono-cropping. Women prefer to cultivate longer-gestation crops such as cassava, plantain, yam and cocoyam. Unlike maize, these crops do not provide a lump sum of money at harvest time since they do not all mature at the same time and thus they provide food and income throughout the year. These crops did not have a market during the cocoa era but now they have a relatively vibrant market in the urban areas. Since food crops have become cash crops in the area, it means that the women, who now control most of the food crops, are earning more money than the men who have neither cocoa farms, nor cultivate food crops. This explains why more women think that they are financially better-off now, while more men think that they are worse-off than before (Figure 6.2). The realities of the times are forcing some men to cultivate some of what have been traditionally considered as "women's crops" but it is a slow and painful transition for them. In a society where men have always wielded the

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<sup>12</sup>A consequence of increasing the annual acreage under cultivation is a shortening of the fallow period. Even though it is the men who cultivate large acreage, both men and women equally suffer the effects of the shortening fallow periods. Since the land is owned by the family, any member of the family can cultivate any part of the land that is lying idle at any time. Consequently, women cannot protect *their land* from the men since no member of the family privately owns any piece of land.

economic power, this change in fortunes, due to the changes in the environment, is likely to have other repercussions in the social set-up in the future.

## 6.5 CONCLUSION

In spite of the apparent effectiveness of farmers' adaptation strategies, the farming system faces some formidable problems imposed by government policy, socio-economic structure, rapid population growth, and the prevailing trends in the biophysical environment.

The main response to rainfall trends in the study area has been the selection of drought-resistant crops rather than the provision of irrigated fields. The problem with this type of adaptation is that since there is a limit to the resistance of crops to drought many of the crops in the region will not survive the limited amounts of rainfall forecast for the future. Attention should therefore be focused on millet and sorghum because these crops have the potential to survive the challenges posed by the agro-environmental changes (section 6.21).

Similarly, the responses to vegetation and soil degradation have been palliative rather than attacking the root cause of the degradation – the excessive pressure on the agro-ecosystem due to rapid population growth. While most of the responses such as crop rotation, managed fallow and plantation crop combination are effective in the short-term, they cannot ultimately sustain soil fertility and prevent a further degradation of the vegetation if the fallow system breaks down. There is the hope, however, that composting would provide a cheap and affordable source of fertilizer in the future.

Though the adaptation strategies appear to be successful at present, the ability of these strategies to respond to projected environmental changes is arguable. If current trends in the agro-ecological environment persist these same responses cannot increase production. On the other hand, one cannot assume that farmers' adaptive responses will

remain static as the agro-ecological environment changes since the farming strategies are dynamic and have been evolving in response to variations in the agro-ecosystem for millennia. While there have been important developments, there cannot be an enduring success in the adaptation process, without affordable environmentally benign fertilizers and irrigation. The next chapter, the concluding chapter, is devoted to a discussion of these and other strategies which can be implemented to support farmers' efforts to alleviate the effects on food production of the biophysical environmental changes.

## **7.0 DISCUSSIONS, CONCLUSIONS AND RECOMMENDATIONS**

### **7.1 DISCUSSIONS AND CONCLUSIONS**

Using the FSTZ as a case study, this research has sought to answer the question of whether traditional farming methods can increase food production in the face of changing agro-ecological environment. The first three chapters put the research into perspective by evaluating the socio-economic and environmental context of food production in Ghana and the FSTZ, and by suggesting that traditional farming methods, tempered with the appropriate modern methods, are a better alternative to an imported farming package. The rest of the thesis analyzes the agro-ecological problems in the study area, examines the strategies farmers are using to respond to agro-ecological challenges, assesses the potential of traditional farming methods to respond effectively to problems posed by the environmental challenges in the region, and evaluates the implications of the ecological changes for the socio-economic conditions of farmers in the FSTZ. The question to be answered is, what does the exploration of the thesis objectives (section 1.1) suggest about the adequacy of the traditional farming methods to increase food production? That is, what conclusions can be drawn from the thesis about;

- the trends in the agro-ecological environment and their implications for FSTZ agriculture;
- the farmers' responses to the environmental trends ;
- the successes or otherwise of the adaptive responses; and
- the socio-economic implications of environmental change?

(a) What are the trends in the FSTZ agro-ecological environment?

The thesis has been developed on the assumption that the FSTZ agro-ecosystem has been transformed from a high resiliency/low sensitivity ecosystem to a low resiliency/high sensitivity one (Figure 2.2) and that farmers are adapting to these changes. The basic framework for analysis is a farmer-agro-environment interaction model in which the combined effects of natural biophysical variation and farming activities transform the FSTZ agro-ecology. The changes in the agro-environmental conditions in turn induce adaptations in the farmer's strategies, and these further transform the environment. These responses are, however, structured by a complex interaction of political, social, economic and biophysical variables. As long as the farming pressures do not increase, the agro-ecological system remains in a state of equilibrium. However, increasing population pressure and natural factors, such as drought causes changes in the agro-ecosystem, and force the farmers to adopt newer ways (intensification) of dealing with environment so as to increase production.

The analysis of the trends in the main agro-ecological variables – rainfall, soil and vegetation cover – that influence FSTZ agricultural production confirm changes in the ecosystem (Chapter Four). Since 1930, the average annual rainfall has been on a steady decline. During the same period, temperature has been on the increase, causing increased evapotranspiration and decreased soil moisture content in the farming season. The indigenous vegetation, which was rich in biodiversity, has been replaced by a fire-climax vegetation of an impoverished nature with fewer plant species. The trend in vegetation cover is towards a more savanna-type of vegetation with weeds that are more aggressive and drought-resistant than the indigenous species. While the soil quality in the region has not degenerated significantly from its original condition, the increasing population pressure, shortening fallow periods and the nutrient requirements of the crops cultivated in the area

require that the natural soil nutrients are supplemented with chemical and/or organic fertilizers to ensure a sustained crop yield. Though the changes in the agro-ecological do not reflect a severe degradation that destroys agriculture in the region, they confirm the assumptions that the FSTZ agro-ecosystem has undergone a major transformation, and that the system has become more sensitive and less resilient to farming activities, than it was during the cocoa and pre-cocoa era (Figures 2.2; 2.3).

The changes in the FSTZ agro-ecosystem are more than a transition from a forest to a savanna ecosystem, or transition from the cultivation of tree-crops to savanna and forest-savanna food crops. The transition from a high resiliency/low sensitivity to a low resiliency/high sensitivity agro-ecosystem in the region also means that the constraints on farmers, as to what they can and cannot cultivate, are more limited now than before. Previously, the farmers could cultivate both tree crops and food crops but now they no longer have the option to cultivate tree crops. There are other benefits such as timber, fuelwood, various wild foods, medicines and game that the previous ecosystem provided but most of which have ceased to exist or are in very limited supply because the ecosystem cannot recover its previous condition.

These major changes made farmers respond in a more radical way to the degradation in the agro-ecosystem. They changed their crops from perennial tree crops to annual food crops and adopted new farming methods to mitigate the effects of the environmental changes. In spite of the transition from a high resilience/low sensitivity status to a low resiliency/high sensitivity one, the farmers affirm that production is on the increase. The ability of the FSTZ farmers to increase production in very trying environmental conditions confirms the conclusions of other studies that observed that farmers in Africa are able to increase production in conditions that are susceptible to degradation (Matlon 1987; Turner et al. 1991; 401-435). For example, high population densities have been

sustained in parts of Nigeria and West Africa on soils thought to be especially constraining to cultivation than almost anywhere else in the subcontinent (Kates et al. 1991). The farmers in the FSTZ have demonstrated similar ability by improving their conditions, through farming, in very trying agro-environmental conditions. This observation indicates that where farmers have extensive knowledge about the environment that they manage, environmental problems can be confronted successfully. As the agro-ecological conditions are changing, the FSTZ farmers are also adapting their farming strategies in ways that makes it possible for them to sustain agricultural production.

(b) How are farmers responding to the environmental trends ?

The adaptations that farmers have embarked on in the FSTZ consist mainly of the use of traditional methods with a minimum of modern methods. The cultivation of relatively shorter-gestation and drought-resistant crops is the main response to the increasing temperatures and declining rainfall amounts, while the bush fallow remains the dominant method for soil and vegetation regeneration. Traditionally, the fallow system and the complex cropping patterns have permitted relatively stable food production. However, with population growth rates exceeding 3% per annum, there simply is not enough land for the farmers to turn to any more should they seek to abandon one farm for another. Even if there were more land, the increase in the pace of economic development is such that the nation can ill-afford to allow a large percentage of the potential farmlands to lie fallow for any length of time. Most farmers in the region do not use fertilizer because the average soil quality on most farms is high enough to support the crops grown in the area. On some farms, however, the continued pressures on the land, has resulted in diminishing returns—a threshold level that has pushed the farm owners to embark on intensification and the use of fertilizers. The implication is that the threshold of demand for fertilizer and other capital

inputs for intensification must be met before investment in these technologies are deemed necessary by the farmers. The population density (30 persons/km<sup>2</sup>) in the FSTZ is not high enough to exert pressure on farm lands to warrant full agricultural intensification. However, the shortening fallow periods and the increasing number of farmers who are practicing continuous cultivation in the region portend the beginning of a transformation to agricultural intensification in the region.

These findings support the conclusions of similar studies done in Cameroon, Tanzania, Senegal, Kenya and Malawi. When Lele and Stone (1989) examined the agricultural change in these countries, they concluded that agricultural growth in these countries is slow because of low population density. These observations and the low application of fertilizer in the FSTZ, due to a low population-land ratio, partly confirm Boserup's thesis that increased population growth leads to increased agricultural intensification and productivity. Evidence from other parts of Africa, for example, among the Tiv of Nigeria, the Jos Plateau Region in Nigeria, and the Matengo of Tanzania, also show that population increases can play a forcing role for agricultural intensification and productivity (Pingali et al. 1987; Netting et al 1980; Benneh 1972).

In response to rainfall and temperature trends, the farmers have turned to more drought resistant crops, and substituted less-demanding, higher-yielding, or greater-density cultivars for traditional ones. In this respect, the farmers in the FSTZ are following a long tradition in sub-Saharan Africa of substituting for traditional crops, such as has occurred in West Africa where cassava has replaced yams, and in Rwanda and Uganda where Bananas and white potatoes have replaced finger millet (Hyden et al. 1991:403). This case study provides an insight into how a variety of crops with different tolerance levels are being used and can be used to sustain food production in the face of environmental change. The analysis of crop/environment relations in sections 5.21 and

6.21, suggests that the adoption of new crop species that are better adapted to the new environment should be developed to replace crops that are not viable in the new environment. In the FSTZ, food crops are managed in order to obtain food or profit, or a combination of both goals. The typical scene is a small family farm growing a wide range of subsistence and cash crops in a variety of mixed cropping patterns. The farmers have elected to grow specialized crops that are adapted to increasing temperatures, declining rainfall and soil fertility not because such conditions are favorable to the crops but because the farmers know that the crops will yield moderately in the circumstances while other crops would fail. Similarly, when a farmer plants two or more crops together in an intercropping pattern, the expectation is that neither will yield as well as it would if grown separately.

Farmers responses to environmental change are not limited to on-farm strategies. Other forms of economic diversification such as off-farm employment, and livestock rearing are taking place in response to the changing biophysical conditions. Also farmers are providing education for the younger generation to prepare them for off-farm jobs; many young people continue to migrate from rural to urban areas and other countries, because they think they do not have a future in agriculture. These off-farm responses influence farm level adaptations, especially with respect to population-land ratio.

Agricultural adaptation in the FSTZ is also responding to, and are constrained by socio-economic and political factors which affect farm level adaptation. There are inadequate markets for both purchased inputs and the disposal of produce. Overall market development in the region, as in other parts of sub-Saharan Africa, is threatened less from within than from without (see Turner et al. 1991:416-417; World Bank 1989). For instance, trade liberalization in the country has opened up agriculture to competitive pressures from subsidized first-world production and large scale agribusiness both in the worlds economy

and within the internal markets of the of the sub-region. Nationally, currency devaluation and inflation have led to rapid price increases in fertilizers, and other farming inputs. These transformations increase the pressure on the FSTZ small-scale farmer to increase productivity, lower costs, increase competitiveness and use inputs much more efficiently in technical and economic terms. Both off-farm and on-farm responses to environmental change in the FSTZ are mediated by political and socio economic conditions. Consequently, any discussions about adaptive strategies to the agro-ecological environment must be expanded beyond provision of farm level techniques to include the political and socio-economic factors that affect the local farmer. Included in these factors are the identification of niche markets; provision of good roads to food producing areas, breeding of productivity-enhancing seeds; provision of education, credit and off-farm jobs; export some labor and receive remittances without undermining agriculture. My assumption is that the more of these options farmers have at their disposal, the greater the prospect for viable agricultural development.

(c) Have the adaptive responses been successful?

The difficulty in answering this question reflects the complex interaction of the environmental and socio-economic variables that influence adaptation (see Figure 2.4). The answer reflects how international monetary policies (IMF), national economic policies (SAP), and political decisions together combine with farm-level adaptations to improve the socio-economic well-being of the farmer. Most of the farmers believe that they are better-off now than they were in the pre-1983 period. Indicators, such as better housing, community development, and increased income from farming activities point to the fact that the living conditions of the farmers have improved relative to the pre-1983 period. Since the main economic activity of the farmers is food production, one can infer that the better

conditions of living, relative to the pre-1983 period, are a result of the adaptive strategies adopted since 1983. However, it is difficult to attribute these successes solely to the changes farmers have made at the farm-level since 1983 because there are other socio-economic and political variables that shape and are shaped by the farmers' adaptive responses (Figure 2.4).

Among the socio-economic variables that have shaped the outcome of the adaptations is the relative land availability for food cultivation since 1983 compared to the pre-1983 period. Since most of the cocoa and coffee farms were destroyed by fire in 1983 most of the lands that were under cocoa/coffee cultivation are now used for food production (section 6.222). Yield per unit land area was already low before the farms were destroyed because most of the cocoa/coffee plants were very old. As a result, the income from the same unit area cultivated with food crops tends to be higher now than the income from cocoa/coffee. Another reason for the better conditions of living could be the positive growth in the Ghanaian economy growth (due to the SAP policies planned and executed by the IMF and the Ghana Government) since 1983 relative to the negative growth in the decade before 1983 (section 6.11).

These and other socio-economic factors which affect farmers' adaptive strategies could be responsible for the positive perception farmers have of their performance. For these reasons the determination of the success of the farmer's adaptive responses has been limited to a chain of explanations and relationships rather than by a rigorous statistical measure of the success or otherwise of the specific adaptations. It can only be concluded that farmers are adapting to the environmental changes that affect agricultural activities, and that most farmers think they are better-off now as a result of the adaptations. It has to be acknowledged, however, that while other factors might have helped improve the living conditions of farmers, the general well-being that farmers in the area are experiencing now

could not have been achieved if farmers had not made the many on-farm adaptations in response to the effects of environmental changes on production. The socio-economic conditions provided the right environment for the success of the adaptations (measured by improved living conditions) rather than these conditions being the cause of the success (section 2.31).

So far, the indigenous traditional farming methods appear to have increased production (as reflected in the improved living conditions of the farmers) in spite of environmental changes; however, the challenges posed by the negative trends in the agro-ecosystem make it imperative that the farmers adopt appropriate modern technologies to complement the traditional indigenous farming technologies. Modernization does not necessarily mean a replacement of the traditional system with imported capital-intensive methods of farming; it means starting with affordable low-cost short-term, and pragmatic responses that work from contemporary contexts towards longer-term solutions that are already inherent in the farmers' strategies. It is expected that through various steps, the agricultural intensification process will transform the low-yielding subsistence agriculture into high-yielding commercial agriculture, until the farmers eventually adopt advanced technologies based on the appropriate mechanization. The task therefore is not to resist modernization, but to control it towards this end.

This case study suggests that farmers in the FSTZ are reluctant to experiment with technologies that involve 'high' economic cost and whose chances of succeeding are feared to be low. For example, farmers shy away from the use of fertilizers and many improved cultivars because the chances of failure in the use of these technologies are high due to natural risks such as rain failure. Similar observations have been made in other parts of Africa such as Kenya (see Hyden et al. 1991:414). The adoption of modern methods other than those the farmers are used to therefore requires that the associated

natural risks are minimized so that the chances of succeeding are higher. For example, since the fear of crop failure, due to lack of rains, is the main stumbling block to the use of fertilizers and improved seeds, provision of water for irrigation will encourage farmers to use fertilizers and improved seed varieties.

- (d) What are the socio-economic implications of farmers' response to environmental change?

In outlining the social and historical processes of changing land-use strategies in the FSTZ, this research reveals that more than the environment is being transformed. As environmental change transforms land use in the community, so the social relations that controls access to and use of land in the community are also being transformed (Figure 2.4). The gender division of labor made the men wield economic power prior to 1984 with cash crop (cocoa/coffee) under male control and women's work largely oriented to food production. With food crops emerging as cash crops since 1984, the same division of labor keeps food production, which is considered as *women's work*, in the hands of females. The men, who depended on cocoa, on the other hand, have no established substitute for cocoa/coffee and have lost their economic power relative to the women. With the destruction of the cocoa/coffee farm most of the land that was used for cocoa cultivation returned to the extended families to be used for food production, hence limiting further the land that cocoa owners controlled. Because men no longer wield the economic power, which added to their status as leaders of their families and the communities, women who now wield more economic power than before want to assume more prominent roles in a traditionally male-dominated community. Though it is too early to determine the full implications of these social transformations for the community, it is known from other

studies that changes in gender roles can bring about conflict in the community (Carney 1996:165; Jackson 1993; Guyer 1984).

Another socio-economic implication of the case study is the population-resource imbalance which is beginning to show up in shorter fallow periods and continuous cropping. These conditions can tempt one to reach a Malthusian conclusion for the region when the region is seen in isolation from its broader national, regional and international context. However, when the rapid population growth is seen within its the broader political and socio-economic context, then it needs not be a problem in the region, at least for now. The political, and economic decisions can be used to minimize the pressure on agricultural land. For example, the government can make more funds available for agricultural intensification to meet food demand. Provision of other inputs such as irrigation will make it possible to have cropping throughout the year to increase production to meet the growing food demand. Training people for off-farm jobs is another way to ease the pressure on agricultural land. While it is important to train people for off-farm jobs it is important to acknowledge that the FSTZ farmlands have not exceeded their carrying capacity. The population densities (per km<sup>2</sup>) in some areas in Africa such as Mable in Uganda, Ukerewe in Tanzania, and Gitarama in Rwanda, are 261, 270, and 335 respectively (Kates et al. 1991:24). In these areas the rapid agricultural growth is attributed to the high population density (Turner et al. 1991). Compared to these areas the population density in the FSTZ – - 30 persons per km<sup>2</sup>— is very low (Table 1.1), and the low density may even hinder agricultural intensification (Lele and Stone 1989; Boserup 1965). Thus, while the rapid population growth rate of 3% in the FSTZ is leading to shorter fallows, there is no indication that degradation of a severity that destroys agriculture has occurred in the region. On the bases of the Boserup's (1965) thesis, it can even be argued that the shortening fallows due to a rapidly growing population, and market integration are the beginning of a process that

is leading to continuous cultivation and agricultural intensification in the FSTZ. Thus, population growth and the associated shortening fallows cannot be seen simply as the inherent driving force to environmental degradation in the FSTZ, but as a process that may lead to increased production.

#### 7.11. CONCLUSION

Farmers' responses to environmental changes in the FSTZ of Ghana, have not changed radically from the dominant traditional practices in the region. Farmers have adapted indigenous technologies and crops more than they have adopted new technological packages, and have made incremental changes to their land capital rather than wholesale transformations. Farming is still rain-fed at a time when rainfall amounts are declining and becoming increasingly unreliable. The fallow system remains the main method of soil regeneration, though the system is breaking down under population pressure, a condition which is likely to lead to continuous and intensive use of the land. In response to the negative effects of the changes in the agro-ecological environment, farmers have developed and are developing a wide range of traditionally-based farm management strategies and off-farm strategies. The core of the farm level strategies includes changes in land use patterns, animal rearing, new techniques of soil-nutrient regeneration, and selective cultivation of crops which are better adapted to the changing environment. The farmers adopt these strategies, most of which are risk-averse, because of the considerable environmental constraints the farmers face. Other responses include diversification into off-farm trades, emigration, and education which prepares young people for off-farm jobs. Thus, the adaptation to environmental change in the FSTZ is being addressed not only in terms of farm level agricultural adaptations such as intensification, but also within a broader national, international and socio-economic context. In this respect the use of the pluralistic

model for the examination of the principal questions of this study is vindicated since the framework offers a useful guide for the analysis of the linkages between farmer-environment interaction, and the broader socio-economic factors that influence these interactions (Figure 2.4).

Most of the farmers' adaptations are not particularly unique or unanticipated. The surprising discovery, however, is that the farmers are able to use these unsophisticated methods to increase production, as most of the farmers believe they have. The farmers' claim is supported by their improved personal conditions of living and the self-help infrastructural developments in the community. These suggest that the research and the development of these simple affordable techniques, in combination with selective use of irrigation, fertilizer and improved seeds, may hold the key to increased food production in the face of environmental change. Sustained food production in the long-run would require that the current farming strategies in the FSTZ are complemented, but not replaced, with modern technologies that are compatible and affordable. In this regard, patterns of technologies which the farmers have selected and refined in harmony with the local environment and the socio-economic realities need to be fostered and built upon, while those which seem wasteful should be discouraged and new ones introduced.

The conception that the local technologies cannot feed the growing population in the face of the projected changes in the environment, ignores the West African farmers' ability to manage resources in very trying environments. It is noteworthy, for example, that cotton production in Ghana reached a record level in 1983, a year of unprecedented drought (Pickering 1988). This research has also shown that in the face of decreasing rainfall and the negative trends of other biophysical variables pertinent to agriculture, farmers have managed to improve their conditions of living over the pre-1983 conditions. The exceptional production of cotton, and food under very trying agro-environmental

conditions demonstrates that farmers are not hopelessly set in their ways.

In saying this, I do not pretend that I have a firm answer to the question that this thesis has tried to answer: can local farming technologies increase food production in face of the current environmental trends and population pressures. What this research shows, however, is that the FSTZ farmers have shown great ingenuity and resilience in adapting their agricultural system to unfavorable environmental conditions, and to the larger socio-economic conditions in the face of population pressure. The farmers have been able to improve their conditions of living and sustained themselves even if only marginally through agricultural intensification and strategies that have the potential to be developed further. These indicators show that farmers are capable of sustaining agricultural growth in the face of environmental and socio-economic changes. While the current environmental trends pose formidable problems for farmers in the FSTZ, there is no reason to doubt the farmers will continue to adapt their methods in response to the environmental changes, as they have done for millennia.

Questions about whether current strategies can increase production in the faces of projected environmental challenges are based on the false assumption that local technologies and the socio-economic conditions of the people are incapable of further adaptation to the changing conditions. To consider that, in the normal course of events, things would be getting worse rather than better would be blinding oneself to recent great strides in food production in Asia. Further, the longer the time horizon of any forward looking exercise in food production, the more difficult it becomes to define the effects of environmental changes on food security. For one cannot know with certainty the future state of the socio-economic variables, such as technology, population dynamics, and the overall economic development of a people. Yet all these variables must be factored into the overall environmental change equation before one can determine, with any degree of

certainty, the capacity of a people to respond to projected impacts of the changes. Consequently, it makes sense to say that if Ghana were to be as technologically developed as it is today fifty years from now, then its food security will be doubtful in the event of environmental change. But Ghana could be in a better socio-economic position to respond to the shocks of environmental change assumed in some reference scenarios. It is in this context that the potential of farmers' adaptation strategies in the FSTZ should be viewed.

## 7.2 RECOMMENDATIONS

Most of the recommendations and research proposals listed in this section follow from the discussions in the previous chapters, and from farmers' own proposals during field seminars. In their suggestions farmers distinguished between what they could do themselves and what external assistance they would need to support their activities. Measures that farmers can implement on their own include the execution of new farming strategies that are practical, affordable and can be achieved with local resources. These include the conducting of basic experiments at the farm-level with vegetation cover, soils and new crop varieties. Measures that would require assistance from external sources range from a wide variety of government-financed crop research through provision of specialized skills which prepare people for off-farm jobs to construction of rural food processing industries and storage facilities. Those listed here are selected for their relevance to the delicate agro-ecological conditions and the socio-economic conditions of the farmers in the FSTZ.

### 7.21 Emphasize Specialized Crops

The changing agro-environment makes emphasis on those crops which survive better in the new environment a major component of the adaptation process in the FSTZ.

As rainfall patterns and vegetation cover in the FSTZ assume the characteristics of the savanna ecological region (sections 4.2; 4.16), it will be worthwhile cultivating savanna crops in the area. Savanna crops tend to be more drought-resistant than the forest savanna crops. Crops such as millet, sorghum, dry land rice, cowpea (*Vigna unguiculata*), Bambara Groundnuts (*Vigna subterranea*), groundnuts (*arachis hypogaea*), which are indigenous to the savanna region, could replace plantain, cocoyam and yam as the major crops in the FSTZ.

#### 7.22 Cultivate Wild Edible Plants

Research has documented a wide variety of nutritious edible plant species that grow in the wild of the FSTZ and other areas in Ghana (National Research Council 1996; Abbiw 1990). These wild species, which hitherto have been harvested in the wild only in times of famine, could be cultivated as food crops. A number of leaf and legume species that are fast-growing, highly nutritious and abundant in the wild are rich sources of protein (Abbiw 1990:34). Some of them are already used in the study area as spinach and salad. Among these legumes and leaf species are Kooko (*Colocasia esculenta*), Chaya (*Cnidossolus aconfolius*), Bameha (*Averva tomentosa*), Bonwen (*Vernonia amygdalina*), Hunhon (*Laportea aestuans*), Banfa-banfa (*Crassocephalum rubens*) and Bitinamusa (*Feretia apodanthera*).

Similarly, there are about 60 species of wild-cereals, including the native rice (*Oryza glaberrima*), that are still gathered for food in West Africa (National Research Council 1996:3). The different types of this rice species mature extremely quickly and will fit into seasons and situations where other cereals fail. Another cereal barely known outside certain remote settlements in West Africa is the finger millet (*Eleusine coracana*). It yields satisfactorily on marginal lands. Its tasty grain is remarkable for its long storage life. Fonio

*(Digitaria exilis* and *Digitaria iburua*) is another indigenous cereal that is probably the world's fastest maturing cereal (National Research Council 1996:6). It is particularly important as a safety net when other foods are in short supply. The crop grows well on poor, sandy soils. Its short gestation period makes it possible for farmers to have a couple of harvests in one farming season. Forged in the searing savannas and the Sahara, these resilient crops would be vital for extending cereal production onto the ever-more-marginal lands in the FSTZ.

### 7.23 Improve Farm Management Practices

Alternative farm management practices should be explored as short-term and long-term measures. Some of the practices which can help farmers in the study area include the following:

- (a) **Multicropping and interplanting practices:** Mixed cropping is more beneficial in the changing agro-environment than monocropping because mixed crops have high resilience to weather fluctuations, discourage pest attacks, conserve soil moisture and protect the soil from erosion (section 3.11).
- (b) **Crop rotation:** Farmers can make conscious efforts to alternate regular crops such as maize and cassava with leguminous and nitrogen-fixing crops. For example, leguminous crops can be incorporated into a system of crop rotation in which a carefully selected number of food crops which make different demands on soil nutrients are alternated in successive farming seasons. This system will not only allow for a continuous cultivation of the same field, but will also ensure that all the nutrients in the soil are utilized effectively without exhausting the soil.

- (c) Farmers can improve the capacity of the shallow soils to retain moisture by increasing plant residue on the soil during the farming season. Substantial amounts of plant residue can be available on the farms if farmers cease the practice of burning plant litter that is cleared as weeds. Farmers can also use the abundant saw-dust from the timber mills both as compost and as mulch on their farms.
- (d) Formal and traditional agroforestry can both be used to establish and maintain vegetative cover to replenish soil nutrients, check excessive evapotranspiration, and to provide fuelwood.
- (e) As the environmental conditions in the FSTZ are no longer favorable for cocoa/coffee cultivation, farmers in the study area may consider giving up cocoa and coffee cultivation, and give emphasis to food crop production. Unlike cocoa and coffee, food crop can serve the dual purpose of providing food for home consumption as well as a cash crop.
- (f) A number of farmers can pull their financial and labor resources together to dig wells in an area on their farms accessible to each of them. Farmers who have farms near streams can make even bigger dams by sinking deeper and bigger wells near or on the stream beds to collect water during the rainy season. These dams, which are fed by rain during the rainy season, can be used if rains cease at a critical stage in crop growth.

#### 7.24 Develop Policies and Programs to Reduce Impact

Since the success of farm-level management strategies is also dependent on political and

socio-economic factors, farm level management strategies have to be complemented by strategic off-farm government policies and research directed to producing positive results for farm level adaptations. These policies may include some of the following:

- (a) Agricultural policy makers can focus more on the small-scale farmers who produce the bulk of the nation's cash and food crops. It is imperative that the government help the small-scale farmer to break the web of social and economic dependency that develops between smallholders and wealthier members of the farming community. This dependency can be broken by recognizing smallholder farmers' co-operatives and using them to channel farm inputs and financial assistance directly to the farmers.
- (b) Alleviation of existing constraints such as those of price distortions, indirect and direct taxation of food crop farmers, and limited accessibility to credit facilities are some off-farm policies that can be implemented to increase production at the farm-level. Food items may be imported only when necessary and not as a means to lower the prices of locally produced staples. If food prices have to be determined, the government can conduct cost-of-production studies on the major agricultural crops and livestock to formulate realistic prices that encourage rather than discourage production.
- (c) The government can make credit available to farmers as an incentive to respond to the environmental challenges. These credits can be made in the form of bank loans towards specific projects that are fundamental for the success of food crop farming. For example, credit can be given for dam construction. Since the main scourge of farmers is the lack of irrigation water, the provision of dams will decrease the chances of crop failure.

If crop failure diminishes then defaults in loan repayment will also diminish significantly.

(d) In the context of land subdivision and degradation, programs that emphasize education and help young people to acquire specialized skills for off-farm jobs can be introduced into the rural areas. Agro-based factories that uses these skills and that will need the farmers' produce as raw materials can be built in the rural areas. These factories will create off-farm jobs for some of the rural population. Such off-farm jobs can reduce pressure on the agricultural land.

(e) Much of the degradation in soil and vegetation has occurred as a result of the population growing at a rate that is faster than the ecosystem and the level of agricultural technology can support. While adaptation strategies have increased food production, demand for food is increasing at a faster rate. The question is not so much whether food production will increase in the face of agro-environmental changes, as whether the agro-system will have the capacity to meet the needs of a rapidly growing population. As a result, responsible family planning programs should be made a major part of the agricultural adaptation package. This program should aim to have the population growing at a rate which prevailing farming technology and the agro-ecosystem can support, and eventually to stabilize the population. The question of how many people a hectare of agricultural land in the FSTZ and other areas in Ghana can support using prevailing and projected technologies is beyond the scope of this research. However, such knowledge is essential for long-term agricultural and family planning policies.

## 7.25 Research Needs

### (a) Crop-Related Technologies

Since specialized crops are one of the farmers' main adaptation strategies in the

FSTZ there is the need to devote more human and financial resources to crop-related technologies such as genetic engineering. In view of increasing temperatures and declining rainfall amounts, such technologies can be used to develop shorter-gestation, drought- and heat-tolerant crop varieties from which the farmers might choose, depending on the needs on their farms.

(b) **Making Mechanized and Continuous Cultivation Possible**

Since the extreme reliance on human labor is an impediment to increased food production (section 6.31), it is imperative to research how machinery can be used on the shallow soils in study area without degrading the soils. Similarly, since the fallow system of farming is breaking down under population pressure, there is an urgent need to research into the manner in which the delicate soils in the region can be made to sustain the continuous, intensive system of farming which is gradually replacing the fallow system.

(c) **Development of *Chromolaena odorata* and Compost as Fertilizers**

The need for further research into the potential use of the *C. odorata* weed and the composting of organic waste as fertilizers cannot be overemphasized, since these may be the main sources of affordable fertilizer for most smallholder farmers in the near future. While acknowledging that the *C. odorata* is a nuisance to all crops, some farmers have observed its fertilizing effects. This observation by the local farmers is supported by research which concluded that the weed has the potential to be developed as green manure to raise soil fertility (Gyasi et al. 1995; Abbiw 1993; Van der Meulen 1977; Litzenger and Ho Ton Lip 1961). Soil analysis done during this research also showed that the *C. odorata* weed regenerates soil nutrients faster than soils following under other vegetation cover. Since the weed grows rapidly, especially on degraded lands, it will be

readily available for whatever uses are determined to be advantageous. Similarly, there should be further research into more efficient ways of processing rural household refuse into compost and the possible conversion of urban waste into compost for farmers in the rural areas.

(d) Since insufficient and unreliable rainfall are the main scourge of food production in the FSTZ, it is time that steps are taken to solve the water problem. It is impossible to provide extensive irrigation systems in the near future; however, research should be able to offer simple but effective ways to harness rain water, underground water and water, from the streams and rivers for the purposes of irrigation.

(e) While the communal land tenure system is flexible enough to adapt to socio-economic changes, the tenure system does not have mechanism that enforces the sustainable use of the land. There is a need, therefore, to research a land reform that not only enforces sustainable uses for the land, but also gives access to all members of the community as their tradition requires.

(f) The socio-economic adjustment to environmental change confirms the findings of some previous research that concluded that environmental change shapes, and is shaped by socio-economic and political conditions of a people (Campbell 1984; Hewitt 1983; Waddell 1977; White 1974). The implications for society of the new role women play in the families, and the economic power they wield in a traditionally male-dominated society should be studied carefully. Also, studies on agricultural production in some parts of Africa indicate that in the event of agricultural intensification, as it is beginning to happen in the FSTZ, women in particular seem to be at a disadvantage with respect to access to new

technologies and input (Mackintosh 1989; Stamp 1989). This does not appear to be the case in FSTZ, at least now. However, it is worth studying how the new technology and other inputs necessary for intensification are distributed between and among men and women, and what policies can be implemented to ensure equal access to resources by all.

In this research, I have tried to identify the trend in the agro-ecological environment and the implications of the trend for food production in the FSTZ. I have also highlighted some of the simple but effective methods that the smallholder farmers are using to alleviate the negative effects of the changes in the agro-environment. The importance of developing and using the traditional farming methods to mitigate the negative impacts of agro-ecological changes, and some of the affordable ways to improve the traditional methods have also been emphasized in the research. The recommendations and research needs suggested in the thesis by no means exhaust the list of potential strategies that could be used for the successful adaptation to the agro-ecological changes in the FSTZ. Those listed here are the needs arising from this research and discussions with farmers in one representative farming community in the general study area. Other adaptations and new technologies that have been successful in other tropical areas with similar agro-ecological characteristics as the FSTZ could be studied for their possible modification and implementation in the study area. While the socioeconomic conditions in the different countries in West Africa may be different from what pertains in the study area, the biophysical implications of this research may be used to guide agricultural policies in the FSTZ in the West African sub-region. There could be ongoing research, together with monitoring of each of the farmers' strategies as they are implemented, to determine which ones should be encouraged, which ones should be discouraged, and what new ones could be introduced to enhance the on-going agricultural adaptation to environmental change in the FSTZ of Ghana.

## APPENDIX 1

### Some Local Terms and their Meanings.

- Akan:** The local dialect of the Akan people of Ghana. About 70% of the people of Ghana speak this dialect. It is also spoken by the Akan tribe in Côte d'Ivoire.
- Abunu or Dibi maminnibi:** Literally it means *divide into two*. It is a sharecropping arrangement under which the stranger farmer may be required to give up half of the produce as payment for the use of the land.
- Abusa:** Literally it means *divide into three*. It is a sharecropping system in which a third of all the produce from the land may be demanded by the landlord as payment for the use of the land.
- Dokotoo:** Food crops, usually perennial food crops such as plantain and cocoyam, which are left in the fallow or harvested in the fallow
- Kontomire:** Fresh and tender cocoyam leaves. They are used as spinach.
- Nto:** A cash rental tenure in which the tenant pays a cash rent equivalent to 10% of total annual produce from the land.
- Ntufuo:** A name given to one or two year old food crop field on which grows perennial crops such as cassava and cocoyam. These crops may be interplanted with maize and some leguminous crops for two or three consecutive farming seasons before the land is left to fallow.
- Proka** It is a farming method in which the cleared weeds on a new field are used as green manure instead of being burnt.

## APPENDIX 2.

## Common, Scientific, and Local Names of Plants Referred to in this Thesis

Scientific Names	Local Names	English Names
<i>Aerva tomentosa</i>	<i>Bameha</i>	-
<i>Alstonia boonei</i>	Sinduro	-
<i>Antiaris toxicaris</i>	Kyenkyen	Bark Cloth Tree
<i>Arachis hypogae</i>	nkatee	Groundnuts
<i>Ceiba petendra,</i>	Onyina	Silk Cotton Tree
<i>Chromolaena odorata,</i>	Acheampong	Siam Weed
<i>Colocasia esculenta</i>	Kooko	Eddoes
<i>Corynanthe pachyceras</i>	Pamprama	-
<i>Crassocephalum rubens</i>	Banfa-banfa	-
<i>Discoglyprena caloneura</i>	Fetefre	-
<i>Disoscorea species</i>	Bayere	Yam
<i>Elaeis guineensis</i>	Abe	Oil palm
<i>Feretia apodanthera</i>	<i>Bitinamusa</i>	-
<i>Ficus capensis</i>	Nwadua	
<i>Fruntumia elastica</i>	fruntum	West African Rubber Tree
<i>Hildegardia barteri</i>	Akyere	-
<i>Harungana madagascariensis</i>	Okosoa	-
<i>Heteropogon contortus</i>	Too	Spear Grass
<i>Imperata cylindrica</i>	Lalang	Lalang
<i>Kalanchoe integra</i>	Aporo	-
<i>Laportea aestuans</i>	Hunhon	-
<i>Mangifera indica</i>	Amango	Mango
<i>Manihot esculenta</i>	Bankye	Cassava
<i>Milicia excelsa</i>	Odum	Iroko
<i>Momordica charantia</i>	Nyanya	African Cucumber
<i>Momordica foetida</i>	Sopropo	-
<i>Musa paradisiaca</i>	Brodee	Plantain
<i>Musanga cecropiodes</i>	Dwuma	Umbrella Tree
<i>Nesogordonia papaverifera</i>	Danta	-
<i>Panicum maximum</i>	Hwede	Guinea Grass

<i>Pennisetum americanum</i>	Ewio	Millet
<i>Pennisetum purpureum</i>	Sre	Elephant Grass
<i>Paspalum conjugatum</i>	Asamoa Nkwanta	-
<i>Ricinodendron heudelottii</i>	Wamma	-
<i>Rottbellia exalta</i>	Nkyenkyemaa	-
<i>Smilax kraussiana</i>	Kokra	-
<i>Sorghum bicolor</i>	Atoko	Sorghum
<i>Tabernaemontana crassa</i>	pepae	-
<i>Talinum triangulare</i>	Fan	Water Leaf
<i>Theobroma cacao</i>	Kokoo	Cocoa
<i>Trema orientalis</i>	Sesea	-
<i>Vernonia amygdalina</i>	Bonwen	Bitter Leaf
<i>Vigna unguiculata</i>	Cowpea	Cowpea,
<i>Vigna sibirica</i>	Adua apatram	Bambara Bean
<i>Xanthosoma mafaffa</i>	Mankani	Cocoyam
<i>Zea mays</i>	Aburo	Maize

**APPENDIX 3****QUESTIONNAIRE FOR FARMER RESPONSE TO ENVIRONMENTAL CHANGE****SECTION A: BACKGROUND INFORMATION**

1. Age: \_\_\_\_\_ 2. Sex: : Male \_\_\_\_\_ Female \_\_\_\_\_
  
3. How many years have you been a farmer?  
\_\_\_\_\_ years
  
4. What is the highest level of formal education you have completed? (check one).
  - Elementary school/Junior secondary
  - Senior Secondary school.
  - Trade School.
  - No education
  
5. Under what tenure is this farm operated? (Check one)
  - Owner-manager
  - Sharecropping
  - rent land

## SECTION B: FARM CHANGE AND DECISION MAKING

6. Indicate how management practices have changed on your farm between 1982 and 1995?

Management Practices	Increased	Decreased	No Change
Ploughing			
Use of chemicals on crops (e.g. herbicides, pesticides, fungicides etc.)			
Improved seed varieties			
Use chemical fertilizers			
Number of crops cultivated			
Number of times cropping is done in a year			
Irrigation			
Use manure/compost			

7. What are the three most important reasons in regards to the changes you have identified in 6. (Please tick only three)

- Response to declining soil fertility  
 Response to declining rainfall  
 Response to declining yields  
 To increase production for market  
 Acquired new knowledge  
 Shortening fallow period  
 Other. Specify \_\_\_\_\_

8. What were your major and minor crops before and after 1983 ?

Year	Major crop	Minor crop
Before 1983		
After 1983		

9. Indicate which crops you cultivated on your farm before 1983, and which crops you have been cultivating since 1983.

Crop	Before 1983	After 1983
Cocoa		
Coffee		
Maize		
Plantains		
Cocoyams		
Cassava		
Palm Trees		
Beans		
Yams		
Rice		
Pepper		
Tomatoes		
Sorghum		
Millet		
Pineapples		
Onion		
Cola		
Other		

10. Which of the following best describes your attitude to cocoa cultivation ?

- My cocoa farm was destroyed by fire but I am not rehabilitating it  
 I replanted cocoa but it was destroyed by fire and/or died of drought.  
 I started cocoa cultivation only after 1983 bushfires  
 Never had cocoa farm  
 Other. (Specify) \_\_\_\_\_

11. Indicate the structural changes that have occurred on your farm since 1983.

Structural Change	Increased	Decreased	No Change	Not Applicable
Land area owned				
Land area rented				
Land area cultivated				
Land area leased to share cropping				
Capital Investments in farming				
Off-farm capital investment				
off-farm Income				
Livestock rearing				
Other				

12. What are the three most important reasons in regards to the changes you have identified in 11. (Please tick only three)

- Response to declining soil fertility
- Increase land availability
- Lack of financial resources
- To increase production for market
- To reduce dependence farming
- Other (Specify) \_\_\_\_\_

13. What is/are your source(s) of land for farming?

- Family land (father, mother, uncle)
- Rented land
- Bought land
- Sharecropping (*abunu* or *abusa*)
- Other. (Specify) \_\_\_\_\_

14. Indicate which of the following livestock, you raise and indicate how many if any.

Livestock	Yes	No	Number
Sheep			
Cattle			
Goat			
Chicken			
Rabbit			
Pigs			
Other			

### SECTION C: ENVIRONMENTAL CHANGE AND FARMER RESPONSE

15. What changes are you making on your farm in response to decreasing rainfall?

- Plant crops at first rains
- Plant more drought resistant crops
- Increase number of crops cultivated in farming season
- Cultivate more shorter-gestation crops
- Make farms in river valleys
- Irrigation
- Mulching
- Other. (Specify) \_\_\_\_\_

16. What Changes are you making on your farm in response to soil degradation?.

- No fertility problem on my farm
- Apply manure (composting)
- *Proka*
- Crop Rotation
  
- Increase acreage
- Use chemical fertilizers
- Use land rotation
- Other. (Specify) \_\_\_\_\_

17. What was the average fallow period you maintained on your farm in 1983 and in 1995?

Year	Length of fallow period
1983	
1995	

18. What changes are you making on your farm in response to changes in vegetation cover?.

- Alley Cropping
- Plantation Crop Combination
- Fallow Method
- Weed control
- Managed fallow
- None
- Other. (Specify) \_\_\_\_\_

19. From your experience as a farmer, what are the three most important things you think could be done to help farmers overcome the impacts of decreasing rainfall on agricultural activities?

- High yielding seeds
- Financial assistance
- Water for irrigation
- Chemical fertilizers
- Farming tools
- Other. (Specify) \_\_\_\_\_

#### SECTION D: ECONOMIC

20. How have the labour inputs on your farm in post-1983 period changed compared to to before 1983 ? (check only one)

- Increased
- Decreased
- No Change

21. Which of the following best describes your over all performance in agriculture today as compared to the situation before 1982? (check only one)

- Better-off
- Worse-off
- No change

**APPENDIX 4**  
**CODING AND SUMMARY OF QUESTIONNAIRE RESULTS**

1.	AGE.		2.	SEX	
	21-30	(5)		Male	33
	31-40	(24)		Female	67
	41-50	(20)			
	51-60	(24)			
	61-70	(18)			
	>70	(9)			
3.	YEARFARM				
	1-10	(11)			
	11-20	(31)			
	21-30	(24)			
	31-40	(15)			
	41-50	(16)			
	>50	(3)			
4.	EDUCATION				
	ELJSS	46			
	SSS	0			
	TRADES	0			
	NOEDUC	54			
5.	TENURE				
	OWNM	93			
	SHARECRO	7			
	LANDRENT	14			
	OTHER0				

## 6. MANPRACT

Management Practices	Increased	Decreased	No Change	NOT APPLICABLE
PLOUGH	1	0	0	0
CHEMIUSE	10	25	4	61
IMPSEED	21	1	0	78
NUMCROP	56	29	15	0
NUMTIME	6	7	78	9
IRRIGA	22	7	0	71
MANUCO	8	2	0	90

## 7. 3REASONS

SOILFERT	39
DERAIN	90
DEYIELD	60
MARKET	22
SHORTFA	89

## 8. MAJOMINOR

## MAJORBF83

COCOA	69
COFFEE	4
PLANTAIN	12
COCOYAM	2
CASSAVA	7
MAIZE	8

## MINORBF83

COCOA	5
COFFEE	3
PLAINTAIN	29
COCOYAM	23
CASSAVA	22
MAIZE	10
OTHER	8

## MAJORAF83

COCOA	23
COFFEE	0
PLANTAIN	30
COCOYAM	3
CASSAVA	13
MAIZE	31

## MINORAF83

COCOA	23
COFFEE	0
PLANTAIN	22
COCOYAM	8
CASSAVA	31
MAIZE	9
OTHER	7

## 9. CROPAFBF

CROP	BEFORE 1983	AFTER 1983
COCOA	74	26
COFFEE	7	3
MAIZE		97
PLANTAINS	41	97
COCOYAMS	24	100
CASSAVA	29	99
PALMTREES	12	34
BEANS	58	37
YAMS	69	74
RICE	12	5
PEPPER	69	57
TOMATOES	55	38
SORGHUM	0	1
MILLET	0	0
PPINEAPPLE	21	34
ONION	23	45
COLA	12	3
OTHER	46	17

## 10. ATTITUDE

NOREHAB	15
FIREDDROU	39
AFTFIRE	19
NOCOCOA	27
OTHER	

## 11 STRUCTURAL

STRUCTURAL CHANGE	Increased	Decreased	No Change	Not Applicable
LAND AREA OWNED	30	1	69	0
LAND AREA RENTED	14	0	2	84
LAND AREA CULTIVATED	60	28	12	0
LAND AREA LEASED TO SHARE CROPPING	14	0	2	10
CAPITAL INVESTMENTS IN FARMING	86	4	10	0
OFF-FARM CAPITAL INVESTMENT	18	43	3	36
LIVESTOCK REARING	25	3	70	2
OTHER				

## 12. 3REASONS2

SOILFERT	39
LANDAVAIL	90
FINANCIAL	60
MARKET	35
REDUDEPN	25
OTHER	51

## 13. LANDSOURCE

FAMILYLAND	72
LANDREENT	14
BOUGHTLAND	2
SHARECROP	18

## 14. LIVESTOCK

LIVESTOCK	YES	NO	NUMBER
SHEEP	71		313
CATTLE	1		10
GOATS	51		398
CHICKEN	2		1500
RABBIT	2		25
PIGS	2		18
OTHER	1		35

## 15. RAINCHANGE

CROPRAIN	53
DRYCROP	19
INCRECROP	100
SHORTCROP	21
VALLEYCROP	42
IRRIGATION	42
MULCHING	3

## 16. SOILCHANGE

NOPROB	6
COMPO	10
PROKA	22
CROTATION	83
INCREASE	60
CHEMICAL	17
LAROTATION	89

## 17. FALLOWLENGTH

1983		1995	
1YR	0	1YR	1
2YRS	0	2 YRS	20
3YRS	1	3 YRS	33
4YRS	7	4 YRS	21
5YRS	9	5 YRS	8
6YRS	18	6 YRS	7
7YRS	31	7 YRS	5
8YRS	21	8 YRS	2
9YRS	3	9 YRS	3
>10YRS	8	>10YRS	0

18.	VEGECHANGE	
	ALLEYCRO	3
	PLANTCRO	59
	FALLOW	89
	WEEDCONTRO	100
	MANAFALLOW	39
19.	AGRICIMPACT	
	HIIYIELDSEED	65
	FINANCE	90
	IRRIGATION	89
	CHEMFERTILIZER	32
	FARMTOOL	3
	OTHER	6
20.	LABORCHANGE	
	INCREASED	74
	DECREASED	15
	NO CHANGE	11
21.	PERFOMANCE	
	BETTEROFF	65
	WORSEOFF	33
	NOCHANGE	2

<b>Rainfall and Temperature Records for Wenchi and Sunyani</b>		<b>APPENDIX 5</b>							
<b>RAINFALL: WENCHI - 1931- 1995</b>									
	<b>1931</b>	<b>1932</b>	<b>1933</b>	<b>1934</b>	<b>1935</b>	<b>1936</b>	<b>1937</b>	<b>1938</b>	
Wenchi Annual Rainfall Total (mm)	1416.81	1251.71	1746.5	1611.63	1110.49	1425.7	1037.84	1382.27	
Wenchi Annual Rainfall Relative to 1961-1990 mean	164.23	-1.4	493.92	359.05	-142.09	173.12	-214.74	129.69	
Wenchi No. of Rainy Days per Year	112	96	99	126	100	99	75	86	
Wenchi Rainy Days Relative to 1961-1990 mean	-2	-18	-15	12	-14	-15	-39	-28	
<b>RAINFALL: SUNYANI - 1931-1995</b>									
	<b>1931</b>	<b>1932</b>	<b>1933</b>	<b>1934</b>	<b>1935</b>	<b>1936</b>	<b>1937</b>	<b>1938</b>	
Sunyani Annual Rainfall Total (mm)	1475.23	1108.95	1484.63	1366.52	1420.1	1280.41	1218.44	1673.35	
Sunyani Annual Rainfall Relative to 1961-1990 mean	265.38	-100.9	274.78	156.67	210.25	70.56	8.59	463.5	
Sunyani No. of Rainy Days per Year	87	77	99	98	100	82	93	94	
Sunyani Rainy Days Relative to 1961- 1990 mean	-14	-24	-2	-3	-1	-19	-8	-7	
<b>TEMPERATURE: WENCHI - 1952 - 1995</b>									
	<b>1952</b>	<b>1953</b>	<b>1954</b>	<b>1955</b>	<b>1956</b>	<b>1957</b>	<b>1958</b>	<b>1959</b>	
Wenchi Mean Yearly Temperature (°C)	25.4	25.6	25.8	25	25.2	25.7	25.1	25.4	
Wenchi Mean Yearly Maximum Temp. (°C)	30.3	30.3	30.6	30.1	30.1	30.4	29.8	30.2	
Wenchi Mean Yearly Minimum Temp. (°C)	20.7	20.8	20.9	20.7	20.4	20.9	20.8	20.6	
Mean Yearly Temperature Anomalies Relative to 1979-1995 mean (°C)	-1.4	-0.68	-0.48	-1.28	-1.28	-0.58	-1.18	-0.88	
<b>TEMPERATURE: SUNYANI - 1957 - 1995</b>									
	<b>1957</b>	<b>1958</b>	<b>1959</b>	<b>1960</b>	<b>1961</b>	<b>1962</b>	<b>1963</b>	<b>1964</b>	
Sunyani Mean Yearly Temperature (°C)	25	24.9	25.2	25	25.8	26.2	25.9	25.4	
Sunyani Mean Yearly Maximum Temp. (°C)	29.5	29.3	29.9	29.2	30.4	31.1	29.9	30.2	
Sunyani Mean Yearly Minimum Temp. (°C)	20.3	20.4	20.6	20.7	20.6	20.1	20.9	20.5	
Mean Yearly Temperature Anomalies Relative to 1979-1995 mean (°C)	-1.22	-1.33	-1.02	-1.22	-0.42	-0.02	-0.32	-0.82	
Source: Computed from climatic data from the Ghana Meteorological Services Department, Accra, 1996.									cont'd

1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953
1353.57	1344.68	1378.2	1053.85	1670.81	1212.34	1231.9	1208.28	1653.03	1194.62	1416.81	1073.04	1266.19	1283.46	1297.18
100.99	92.1	125.62	-198.73	418.23	-40.24	-20.68	-44.3	400.45	-57.96	164.23	-179.54	13.61	30.88	44.6
90	87	91	74	78	69	60	75	78	80	100	103	116	133	136
-24	-27	-23	-40	-36	-45	-54	-39	-36	-34	-14	-11	2	19	22
1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953
1418.84	1124.97	1257.55	1160.27	1626.11	1291.84	1778	1053.85	1438.91	1160.02	1307.59	1362.2	1207.01	1596.14	1235.46
208.99	-84.88	47.7	-49.59	416.26	81.99	568.15	-156	229.06	-49.83	97.74	152.35	-2.84	386.29	25.61
119	90	87	70	99	86	77	65	89	68	70	105	130	128	121
18	-11	-14	-31	-2	-15	-24	-36	-12	-33	-31	4	29	27	20
1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974
25.5	25.8	25.6	25.8	25.5	25.7	26.1	25.7	25.8	25.6	25.6	25.1	25.6	26.3	25.8
30.4	31	30.4	30.5	30.3	30.4	31.3	30.5	30.7	30.5	30.5	30.1	30.4	31.1	30.7
20.6	20.7	20.6	20.9	20.7	21	21.3	20.8	21	20.8	20.6	20.1	20.8	21.4	20.8
-0.78	-0.48	-0.68	-0.48	-0.78	-0.58	-0.18	-0.58	-0.48	-0.68	-0.68	-1.18	-0.68	0.02	-0.48
1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
25.8	25.95	25.58	25.44	25.38	25.9	25.4	26	26.3	25.6	25.6	25.3	26	26.2	26.4
30.1	31.1	30.5	30.6	29.7	30.5	30.2	30.6	31.4	30.3	30.5	29.8	30.7	30.3	31
21.1	21.4	20.5	20.2	21.1	21.1	20.6	21.3	21.3	20.7	20.6	20.7	23	21.3	21.7
-0.42	-0.27	-0.64	-0.78	-0.84	-0.32	-0.82	0	0.08	-0.62	-0.62	-0.92	-0.22	-0.02	0.18

cont'd





1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	Average	STDEV
1501	1496.5	1169.5	1251.1	1209.6	1759.7	1159.3	1308.3	1285.7	1212.6	902.3	1372.6	121.036	216.8642
248.42	243.92	-83.08	-1.48	-42.98	507.12	-93.28	55.72	33.12	-39.98	-350.28	120.02	3.86277	216.2572
92	107	108	110	97	125	90	113	91	81	93	125	106.8308	20.60686
-22	-5	-6	-4	-17	11	-24	-1	-23	-33	-21	11	-7.13846	20.60861
1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	Average	STDEV
1135.8	1319.1	1418.1	1499.5	1008.6	1305.5	1116.4	1149.9	1003.1	1080.1	881.7	1401.6	1258.137	219.7233
-74.05	109.25	208.25	289.65	-201.25	95.65	-93.45	-59.95	-206.75	-129.75	-328.15	191.75	48.27292	219.729
81	91	109	124	111	126	97	113	92	101	108	114	101.3077	17.953
-20	-10	8	23	10	25	-4	12	-9	0	7	13	0.815385	17.81893

APPENDIX 6															
Mean Monthly Precipitation and Evapotranspiration for Wenchl, 1931-1990															
	J	F	M	A	M	J	J	A	S	O	N	D	SUM	AVE.	STDEV.
Mean Monthly Precipitation: 1931-1960	8.54	43.6	99.95	147.74	167.61	194.08	91.02	71.88	186.63	217.87	78.55	21.68	1329.15	110.763	70.531
Mean Monthly P. E. 1931-1960	121	133	145	133	122	106	101	99	97	108	105	108	1378	114.833	15.6312
Mean Monthly Precipitation: 1961-1990	4.5	28.6	102.1	137.9	161.4	164.7	130.1	96.7	177.9	193.1	41.2	14.7	1252.9	104.408	67.2636
Mean monthly P. E. 1961-1990	138	126	151	144	138	122	114	114	111	117	117	118	1510	125.833	13.4559

Source: Computed from climatic data from the Ghana Meteorological Services Department, Accra, 1996.

**APPENDIX 7**

**Chemical Properties of Soils Under Different Vegetation Cover in Wamanafo**

Sample	Depth (cm)	pH	Organic C (%)	Total N (%)	Organic Matter (%)	Exchangeable Cations me/100			
		H <sub>2</sub> O 1:2.5				Ca	Mg	K	Na
Virgin Forest Soil	0 - 2	5.4	3.35	0.31	5.78	9.6	2.88	0.42	0.13
	2 - 20	4.7	1.07	0.13	1.83	2.72	0.48	0.14	0.09
	20 - 40	4.4	0.68	0.1	1.17	2.08	0.32	0.1	0.09
C. Odorata Soil	0 - 2	5.9	3.79	0.38	6.54	12.64	7.36	0.78	0.2
	2 - 20	5.8	2.73	0.25	4.07	8.16	3.36	0.35	0.13
	20 - 40	4.8	1.02	0.14	1.75	3.52	2.56	0.17	0.11
Plantain and Cassava Soil	0 - 2	6.3	3.33	0.28	5.73	18.4	3.68	0.69	0.22
	2 - 20	6	1.48	0.14	2.55	6.56	1.44	0.26	0.17
	20 - 40	4.7	0.58	0.11	0.99	3.52	0.96	0.14	0.11

cont'd

Source: Results of soil analysis conducted at Soil Research Institute, Kumasi 1996

Chemical Properties of Soils Under Different Vegetation Cover in Wamanafo							
Sample	Depth (cm)	T.E.B	Exchangeable Acidity (Al + H)	CEC (me/100g)	Base Sat. %	Available-Bray's ppmP	ppmK
Virgin Forest Soil	0 - 2	13.03	0.2	13.23	98.5	1.8	127
	2 - 20	3.43	0.8	4.23	81.1	2.15	36
	20 - 40	2.59	1.6	4.19	61.8	Neg.	20
C. Odorata Soil	0 - 2	22.99	0.3	23.29	98.7	2.15	133
	2 - 20	8.43	0.2	8.63	97.7	1.45	51
	20 - 40	4.73	1	5.73	82.2	0.35	25
Plantain and Cassava Soil	0 - 2	20.98	0.3	21.28	98.6	1.05	177
	2 - 20	12	0.2	12.2	98.4	0.35	75
	20 - 40	6.36	0.7	7.06	90.1	0.7	31

Source: Results of soil analysis conducted at Soil Research Institute, Kumasi 1996

**APPENDIX 8**

**National Average Wholesale Prices for Selected Food Commodities 1988-1994**

Year	Maize		Millet	
	Nominal Price (₱/kg)	Real Price (₱/kg)*	Nominal Price (₱/kg)	Real Price (₱/kg)*
1988	68.5	46.991	94.14	64.58
1989	53	39.6	114.67	85.7
1990	86.33	54.21	117.81	73.98
1991	94.34	77.36	154.43	126.63
1992	100.62	90.46	157.33	141.44
1993	110.72	90.57	185.22	151.51
1994	138.63	105.08	197.63	149.8
Year	Sorghum		Cocoyam	
	Nominal Price (₱/kg)	Real Price (₱/kg)*	Nominal Price (₱/kg)	Real Price (₱/kg)*
1988	76.38	53.4	51.39	35.25
1989	87.09	65.14	59.33	44.38
1990	97.28	61.09	87.74	55.1
1991	122.97	100.83	84.4	69.21
1992	133.43	119.95	100.19	90.07
1993	167.62	137.11	132.5	108.39
1994	164.39	124.61	176.01	133.42
Note:	* Real Prices are the nominal prices deflated by the respective annual rates of inflation.			

cont'd

**National Average Wholesale Prices for Selected Food Commodities 1988-1994)**

Year	Plantain		Yams	
	Nominal Price (¢/kg)	Real Price (¢/kg)*	Nominal Price (¢/tuber)	Real Price (¢/tuber)*
1988	32.87	22.55	194.78	133.62
1989	43.44	32.4	233.65	174.77
1990	69.31	43.53	301.02	189.04
1991	55.44	45.46	294.69	241.65
1992	66.81	60.06	290.7	261.34
1993	100.63	82.32	400.98	328
1994	121.24	91.9	533.1	404.09

Year	Cassava	
	Nominal Price (¢/kg)	Real Price (¢/kg)*
1988	29.49	20.23
1989	27.44	20.53
1990	46.97	29.5
1991	43.96	36.05
1992	44.48	39.98
1993	56.47	46.19
1994	63	47.75

Note:

\* Real Prices are the nominal prices deflated by the respective annual rates of inflation.

Source: ISSER 1992; 1993; 1994.

**APPENDIX 9****CHI-SQUARE CALCULATIONS**

The formula for chi-square Statistic is:

$$\chi^2 = \sum \frac{(o - e)^2}{e}$$

Where:  $\chi^2$  denotes the chi-square distribution  
o denotes the observed frequencies  
e is the expected frequencies: The expected frequency for each cell is obtained by total of the row to which it belongs by the total of the column to which it belongs and then dividing by the grand total for the entire table

The degree of freedom (df) for the chi square distribution is determined by;

$$(r - 1)(c - 1)$$

**(a) Chi-square Calculation for Table 6.1**

$$\begin{aligned}\chi^2 &= \frac{(55 - 48.4)^2}{48.41} + \frac{(18 - 24.6)^2}{24.6} + \frac{(10 - 16.6)^2}{16.6} + \frac{(15 - 8.4)^2}{8.4} \\ &= 0.9 + 1.77 + 2.62 + 5.19 \\ &= 10.48\end{aligned}$$

$$\text{Degree of Freedom} = (2-1)(2-1) = 1$$

**(b) Chi-square Calculation for Table 6.2**

$$\begin{aligned}\chi^2 &= \frac{(16 - 21.9)^2}{21.9} + \frac{(17 - 11.1)^2}{11.1} + \frac{(49 - 43.1)^2}{43.1} + \frac{(16 - 21.9)^2}{21.9} \\ &= 1.59 + 3.14 + 0.81 + 1.59 \\ &= 7.13\end{aligned}$$

$$\text{Degree of Freedom} = (2-1)(2-1) = 1$$

**(c) Chi-square Calculation for Table 6.3**

$$\begin{aligned}\chi^2 &= \frac{(16 - 9.8)^2}{9.8} + \frac{(13 - 14.1)^2}{14.1} + \frac{(4 - 9.1)^2}{9.1} + \frac{(13 - 19.2)^2}{19.2} + \frac{(29 - 27.9)^2}{27.9} + \frac{(23 - 17.9)^2}{17.9} \\ &= 3.92 + 0.09 + 2.86 + 2.00 + 0.04 + 1.45 \\ &= 10.36\end{aligned}$$

$$\text{Degrees of Freedom} = (2 - 1)(3 - 1) = 2$$

**(d) Chi-square Calculation for Table 6.5**

$$\begin{aligned}\chi^2 &= \frac{(18 - 13.9)^2}{13.9} + \frac{(3 - 7.1)^2}{7.1} + \frac{(47 - 51.1)^2}{51.1} + \frac{(30 - 25.9)^2}{25.9} \\ &= 1.21 + 2.37 + 0.33 + 0.65 \\ &= 4.6\end{aligned}$$

$$\text{Degree of Freedom} = (2-1)(2-1) = 1$$

**(e) Chi-square Calculation for Table 6.6**

$$\begin{aligned}\chi^2 &= \frac{(50 - 49.7)^2}{49.7} + \frac{(15 - 15.3)^2}{15.3} + \frac{(25 - 25.3)^2}{25.3} + \frac{(8 - 7.7)^2}{7.7} \\ &= 0.002 + 0.006 + 0.004 + 0.011 \\ &= 0.023\end{aligned}$$

$$\text{Degree of Freedom} = (2-1)(2-1) = 1$$

**(f) Chi-square Calculation for Table 6.7**

$$\begin{aligned}\chi^2 &= \frac{(11 - 11.3)^2}{11.3} + \frac{(6 - 5.7)^2}{5.7} + \frac{(54 - 53.7)^2}{53.7} + \frac{(27 - 27.3)^2}{27.3} \\ &= 0.04 + 0.02 + 0.002 + 0.003 \\ &= 0.03\end{aligned}$$

$$\text{Degree of Freedom} = (2-1)(2-1) = 1$$

**(g) Chi-square calculation for Table 6.10**

$$\chi^2 = \frac{(30 - 23.9)^2}{23.9} + \frac{(6 - 12.1)^2}{12.1} + \frac{(29 - 26.5)^2}{26.5} + \frac{(11 - 13.5)^2}{13.5} + \frac{(6 - 14.6)^2}{14.6} + \frac{(16 - 7.4)^2}{7.4}$$

$$= 1.56 + 3.08 + 0.24 + 0.46 + 5.07 + 9.99$$

$$= 20.4$$

$$\text{Degrees of Freedom} = (3-1)(2-1) = 2$$

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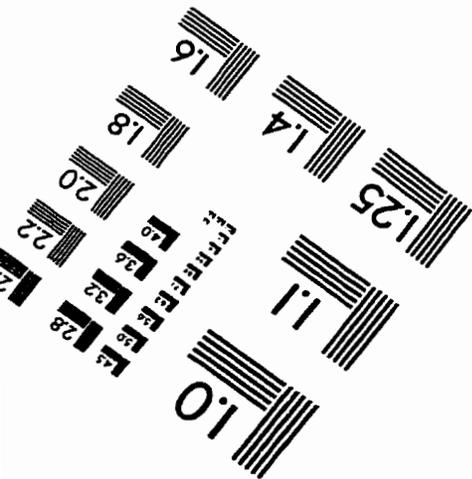
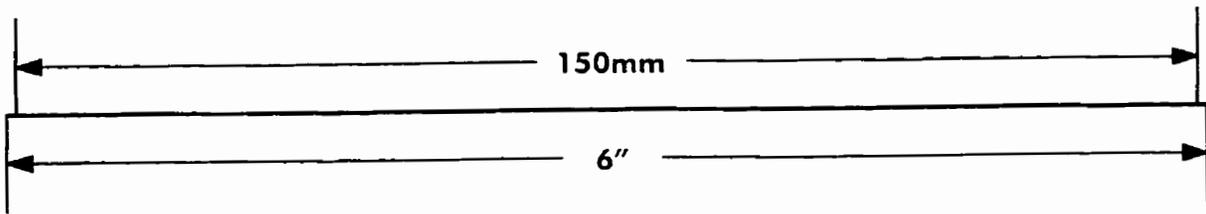
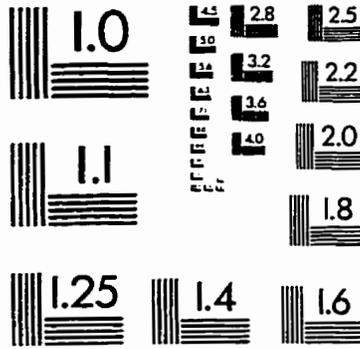
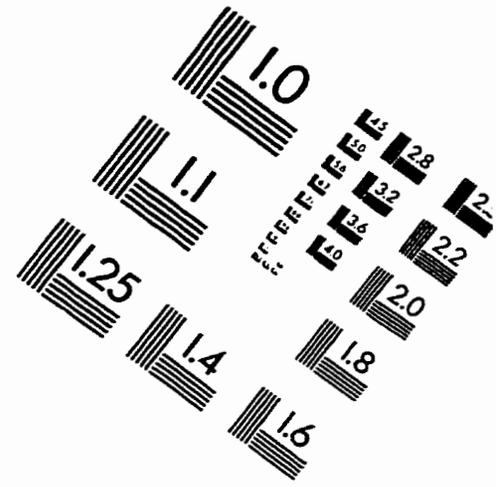
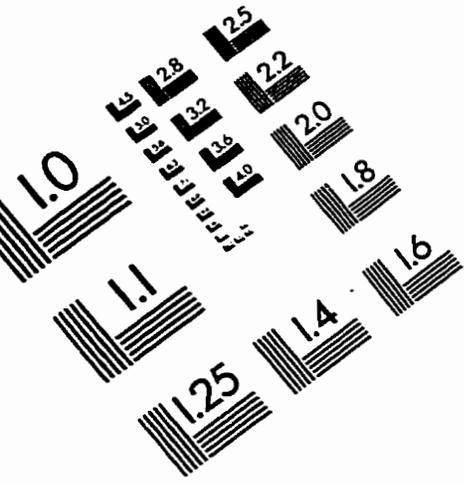
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