SUSTAINABILITY OF MAIZE-BASED CROPPING SYSTEMS IN NORTHERN GHANA

BY

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DECLARATION

I do hereby declare that except for references to other people's work which have been duly cited, the work presented in this thesis: "SUSTAINABILITY OF MAIZE-BASED CROPPING SYSTEMS IN NORTHERN GHANA", is the result of my original research.

This work has never been presented either in whole or in part for any other degree of the University or elsewhere.

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To: Tieresong and Angbanmwine.

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ABSTRACT

This study was carried out in Northern Ghana with the objective of assessing the sustainability of five maize-based cropping systems in the area. The cropping systems are maize-cowpea rotation, maize-cowpea relay intercropping, maize-cowpea mixed intercropping, sole maize continuously cropped and maize-sorghum-groundnuts mixed intercropping. The study also sought to establish any variability in the cropping systems of Northern Ghana, strategies adopted by farmers to increase crop yield as well as the cost-effectiveness of the strategies adopted.

To achieve the objectives above information on existing cropping systems was obtained through a structured questionnaire interview with 60 farmers selected from 6 villages (Kpongu and Sing in the Upper West region, Wiaga and Dullugu in the Upper East region and Woribogu and Cheshegu in the Northern region). Data on crop yields and quantities of inputs were obtained from records of the Savanna Agricultural Research Institute (SARI) while prices of inputs and crop products were obtained from the Ministry of Food and Agriculture, Policy Planning Monitoring and Evaluation Department's statistics. Existing cropping systems were compared to those found in the literature to establish the variability of cropping systems in the study area. Strategies adopted by farmers to increase crop yield were also established from the structured interviews. Partial budget anaysis was used to assess the cost-effectiveness of strategies adopted by farmers to increase crop yields while Total Factor Productivity (TFP) indices were calculated to assess the long run sustainability of the cropping systems under consideration.

Results of the study indicate that cropping systems in Northern Ghana vary across locations. The results also reveal that strategies adopted by farmers to increase crop yields are cost-effective in the short run. However, in the long run three out of the five cropping systems under study are not sustainable when natural resource flows (the level of soil nitrogen) are considered. Without considering natural resource flows, none of the systems was found to be sustainable. In order to achieve sustainable crop production, bullock traction should be used for land preparation to reduce labour requirements. There should be appropriate intercropping of cereals and legumes as well as rotation of cereals with legumes. Extension education should be improved mainly through radio broadcast in local languages. Through radio broadcast farmers that cannot be reached during farm or home visits can benefit from extension education.

TABLE OF CONTENTS

Declaration		i
Dedication		ii
Acknowledgment		iii
Abstract		iv
Table of contents		v
List of tables		vi
List of acronyms		viii
CHAPTER 1:	INTRODUCTION	
1.1	Background	1
1.2	Problem statement	8
1.3	Objectives of the study	11
1.4	Justification of the study	12
1.5	Organisation of work	12
CHAPTER 2:	LITERATURE REVIEW	
2.1	Major crops grown in Northern Ghana	15
2.2	Cropping patterns in Northern Ghana	16
2.3	Crop production management systems in Northern Ghana	19
2.4	Sustainability in Agricultural Production	21
2.4.1	The concept of sustainability	21
2.4.2	Measurement of sustainability	23
2.4.3	Application of TFP in measuring sustainability	29
2.5	Synthesis of issues from the literature	33
CHAPTER 3: METHODOLOGY		
3.1	Theoretical framework	36
3.2	Data requirements	40
3.3	Data collection methods	41
3.4	Data analysis	42
CHAPTER 4: RESULTS AND DISCUSSION		
4.1	Variability of cropping systems in Northern Ghana	46
4.1.1	Major crops grown in Northern Ghana	46
4.1.2	Variability of cropping patterns and cropping sequence	48
4.1.3	Crop production management systems	51
4.2	Constraints to crop production in Northern Ghana	51
4.3	Strategies adopted by farmers to increase crop production	53
4.4	Cost-effectiveness of Strategies adopted by farmers	58
4.5	Assessment of the sustainability of maize-based cropping systems	60
CHAPTER 5: CONCLUSION AND RECOMMENDATIONS		
5.1	Conclusions	71
5.2	Recommendations	73
5.3	Suggestions for future research	74
	Literature cited	
	Appendices	

LIST OF TABLES

Table 1.1: **Contribution of Northern Ghana to Annual National Production of Major cereals** 2

Table 1.2: **Ranking of the regions of Ghana by output of major cereals** 3

Table 1.3: **Proportion of livestock produced by Northern Ghana (1984 to 1994)** 4

Table 1.4: **Yields of selected food crops (average for 1991 to 1996)** 10

Table 2.1: **Regional distribution of the means of land preparation in Northern Ghana** 20

Table 4.1: **Relative importance of crops grown in Northern Ghana based on the percentage of sampled farmers growing each crop** 47

Table 4.2: **Relative frequency of Farmers Responses to Crop Production Constraints** 53

Table 4.3: **Frequency of strategies used by farmers to increase crop production in Northern Ghana** 55

Table 4.4: **Additional resources required by strategies adopted to increase crop production** 57

Table 4.5: **A partial budget of adopting manure application in sorghum-millet production in Northern Ghana** 59

Table 4.6: **A partial budget of adopting fertiliser application in maize production in Northern Ghana** 59

Table 4.7: **Nominal prices (¢/kg) of outputs** 61

Table 4.8: **Nominal prices (¢/unit) of inputs** 62

Table 4.9: **Quantity of labour input (man days/ha) used (land preparation to harvesting)** 62

Table 4.10: **Quantity of output (kg/ha) produced under experimental conditions** 63

Table 4.11: **Quantity of output (kg/ha) produced under farmers' practice (Maize-sorghum-groundnuts intercropped)** 63

Table 4.12: **Resource flow for five maize-based cropping systems in Northern Ghana** 65

Table: 4.13: **Profitability ratios for five cropping systems in Northern Ghana** 67

Table 4.14: **TFP indices for five Maize-based Cropping Systems in Northern Ghana (natural resource flows considered)** 68

Table 4.15: **TFP indices for five Maize-based Cropping Systems in Northern Ghana (natural resource flows not considered)** 69

LIST OF ACRONYMS

ASA:	American Society of Agronomy
CGIAR:	Consultative Group on International Agricultural Research
EESR:	Extra Early Streak Resistant
FSR:	Farming Systems Research
GTZ:	German Agency for Technical Cooperation
ICRA:	International Centre for Development-Oriented Research in Agriculture
IITA:	International Institute of Tropical Agriculture
MOFA:	Ministry of Food and Agriculture
NAES:	Nyankpala Agricultural Experimental Station
NGOs:	Non-Governmental Organisations
NR:	Northern Region
OECD:	Organisation for Economic Cooperation and Development
SAM:	Sustainability Assessment Map
TAC:	Technical Advisory Committee
TFP:	Total Factor Productivity
UER:	Upper East Region
UWR:	Upper West Region

CHAPTER 1

INTRODUCTION

1.1 Background

Northern Ghana (comprising Northern Region, Upper East Region and Upper West Region) has a land area of 97,700 square kilometres. This constitutes 40percent of the total land area of Ghana (MOFA, 1997). The area falls within the Guinea and Sudan Savanna vegetation zones of the country. The average annual rainfall of the area ranges from 900 mm to 1,111 mm. The rainfall period starts in April and ends in October, followed by a dry season from November to March. Dominant naturally growing tree species in the area include: shea nut *(Butruspermum spp)*, dawadawa (*Parkia spp*), ebony (*Diospiros mespiliformis*) and baobab *(Adansonia digitata)*.

The soils of Northern Ghana are predominantly Savanna glysols and Savanna ochrosols from sand stone parent material (Donhauser et al, 1994). Sand and gravel contents are generally high in the top layer of these soils. The soils are generally low in nitrogen, while the available phosphorus poses the most serious limitation to crop production. Potassium is usually available in sufficient quantities (NAES Annual Report, 1987/88).

The economy of Northern Ghana is predominantly agricultural. The majority of households rely on subsistence agriculture (crop and livestock production) for their livelihood. The area produces the bulk of the nation's cereals. The contribution of Northern Ghana to national annual production of major cereals is shown in Table 1.1 below for the period 1992 to 1996.

Table 1.1: **Contribution of Northern Ghana to national annual production of major cereals, 1992 to 1996**

Cereal	Contribution of Northern Ghana (percent of National production)				
	1992	1993	1994	1995	1996
Maize	19.2	22.9	23.8	21.0	17.1
Rice	55.7	56.4	58.9	64.4	62.5
Millet	100.0	100.0	100.0	100.0	100.0
Sorghum	97.7	97.9	98.5	98.7	98.6

Source: Computed from Annual Sample Survey of Agriculture 1992 to 1996.

A ranking of the regions of Ghana by output of major cereals indicates that the Northern region tops in the production of rice, sorghum and millet. The Upper West region ranks third in the production of rice, sorghum and millet, while the Upper East region ranks fourth in the production of rice and second in the production of each of sorghum and millet (MOFA, op cit.). Table 1.2 below gives a ranking of the regions of Ghana by output of major cereals.

Table 1. 2: **Ranking of Regions of Ghana by output of major cereals**

Region	Maize	Rice	Sorghum	Millet
Northern	3	1	1	1
Brong-Ahafo	2	4	-	-
Eastern	1	5	-	-
Ashanti	4	7	-	-
Central	5	10	-	-
Western	7	6	-	-
Volta	6	3	4	-
Upper West	8	8	2	2
Greater Accra	9	9	-	-
Upper East	10	2	3	3

Source: Agriculture in Ghana. Facts and Figures. 1997.

Major crops grown in the area include: maize, yam, sorghum, millet, rice, cowpea as subsistence crops, and groundnut and cotton as the main cash crops. Cropping systems in a particular area are defined by crops that occupy a larger cultivated area relative to other crops in cultivation in the area. Where crops are planted in mixtures, the crop having the highest relative population density in the plant stand defines the cropping system. On this basis, cropping systems in Northern region are mainly yam- and maize-based; in the Upper West and Upper East regions they are mainly sorghum, millet- and cowpea-based.

Frequent crop mixtures practised in the area include: maize-sorghum-cowpea, cassava-sorghum-cowpea sorghum-groundnut and yam-millet-bambara groundnut. Other crop mixtures are early millet-late millet-cowpea. Main sole crops are cotton, groundnut, rice and maize.

Where yam is grown, it is usually the first crop after fallow. The fallow period last between 2 and 5 years (Baur, 1993; Abatania 1990; Rufai 1985). Northern Ghana also contributes significantly to livestock production in the country. The area produces over 70percent of the nation's annual output of cattle, 37percent of sheep, 43percent of goats, 47percent of pigs and 31percent of poultry. Table 1.3 below gives the proportion (percent) of livestock produced by Northern Ghana over the period 1984 to 1994. Data for 1995 onwards was not available at the time of compiling this report.

Table 1.3: **Proportion of livestock produced by Northern Ghana, 1984 to 1994**

Year	Percentage of total national production				
	Cattle	Sheep	Goats	Pigs	Poultry
1984	75	37	40	46	32
1985	76	39	45	45	28
1986	77	44	47	51	40
1987	78	43	45	45	34
1988	77	35	40	49	31
1989	78	32	42	42	30
1990	77	38	45	53	32
1991	77	38	44	53	30
1992	76	37	44	45	28
1993	75	34	43	46	27
1994	74	34	40	46	25
Average	**76.4**	**37.4**	**43.2**	**47.4**	**30.6**

Source: Computed from statistics of the Veterinary Services Department Livestock Statistics Unit, Ministry of Food and Agriculture 1995.

Agricultural production in Northern Ghana is confronted with a number of constraints. The most serious constraints, in the opinion of farmers, include the erratic rainfall pattern, inherent low soil fertility, lack of farm credit and low product prices (NAES Annual Planning Sessions Reports, various issues; Abatania et al, 1994). Inadequate housing for livestock and the incidence of pest and diseases of livestock also constitute severe constraints to agricultural production in the area.

SARI (formerly NAES), has over the years developed or released a number of technologies to overcome the constraints and increase crop production in the area.

Some of the technologies developed or released include short duration varieties of cowpea (Bengpla), sorghum (kapala) and maize (NAES EESR) to address the constraint of erratic rainfall. Planting can be staggered with these varieties because of their short maturity period. Replanting can also be done in situations where severe drought damages a particular crop. An improved fallow system using *callopogonium* as a cover crop and agroforestry techniques using *grilicidia* and *acacia species* in hedge rows have been developed to take care of the low fertility status of the soil. Appropriate crop rotation and intercropping systems of legumes and cereals have also been developed to address the constraint of low soil fertility.

The constraint of lack of farm credit is better addressed by NGOs, particularly Technoserve which is currently operating an inventory credit scheme in the Upper West region. Cotton producing companies in Northern Ghana also extend some credit facilities to farmers for cotton production with limited extension to cover food crop production.

Through extension activities of the Ministry of Food and Agriculture (MOFA) and some NGOs (Action Aid, Tamale Archdiocese Agricultural Project and the Presbyterian Church of Ghana Agricultural Programme) these technological packages have been introduced to farmers in the study area. The purpose of these extension activities is to ensure that farm households are able to produce enough food for their own consumption, as well as increased farm income and a general improvement in their standard of living.

The crop production technologies developed so far are based on the traditional inter-cropping systems prevalent in the area. This is in line with principles of the Farming Systems Research (FSR) approach in operation at SARI, which emphasises a context-based and problem-oriented approach to research among other requirements. This approach ensures the sustainability of production systems through the technologies developed. Sustainability is a concept that advocates the judicious use of productive resources in a way that benefits present and future generations while at the same time ensures environmental quality.

An important study of some of the traditional maize-based cropping systems was carried out on station at Nyankpala over the period 1984 to 1987 to assess the interrelationships and interactions between maize and cowpea with regard to the utilisation of water and nutrient supply (Hardter, 1989). The experiment examined the production of maize under the following cropping systems:

1. Sole cropped maize
2. Maize-cowpea relay intercopping
3. Maize-cowpea mixed intercropping
4. Maize-cowpea rotation

The results show that maize in particular responded sensitively to the different treatment levels: maize yields were highest in the crop rotation system and lowest in the mixed cropping system. There was no difference in maize yield between relay intercropping and sole maize cropping. In both cropping systems, however, yields were lower than crop rotation. The results suggested that maize benefited from the preceding cowpea crop, whereas it competed with cowpea for growth factors in the mixed cropping system. There was no competition between maize and cowpea in relay intercropping, which was due to the late planting of cowpea.

Yields of sole cropped cowpea (in rotation with maize) were higher than in the mixed and relay cropping systems. In contrast to maize, cowpea did not suffer from competition for growth factors with maize in the mixed cropping system. This was suggested by the comparatively high per plant yields of mixed cropped cowpea. Nitrogen application had no effect on cowpea yields in the intercropping system, whereas nitrogen applied to the preceding maize significantly reduced cowpea yields.

From the results stated above, supplementary nitrogen application had different effects on the output of maize and cowpea in the cropping systems studied. This has implications for the long run sustainability of the cropping systems even though the long run sustainability of the systems was not considered in Harter's study. The study however provides a good database for assessing the sustainability of the cropping systems studied. Sustainability of a cropping system in this context means determining whether the cropping system can produce the same or a higher output in the long run while maintaining environmental quality. A formal definition of the concept of sustainability is provided in Chapter 2.

1.2 Problem Statement

Increased human population over the years has put pressure on the demand for farm land in Northern Ghana. This has resulted in continuous cropping with a high intensity of land use. Fallow periods in the area are less than five years (Donhauser et al, op cit.). However, it has been stated elsewhere that a minimum fallow period of 8 years is required for regeneration of soil fertility in the tropics (Tshibaka, 1989). Intensity of cropping is measured by the R-value which is an indication of the intensity of land use. The R-value is the ratio of the number of cropped years to the sum of the number of cropped years and fallow years (Ruthenberg, 1980). A high R-value implies that the land is continually cropped. An average R-value of 0.7 has been calculated for Northern Ghana (Langyintuo et al 1995), this implies land in the area is continually cropped. In the Upper East region in particular, this value is as high as 0.9. With these high levels of cropping intensity, and given the soil conditions in the area, crop yields can be sustained or increased only if there is supplementary nutrient input coupled with improving the moisture-conserving property of these soils. Soil nutrient supplementation can be achieved through the use of organic manure or chemical fertilisers. However the reality of the situation is that the quantities of organic manure available are insufficient while chemical fertilisers are hardly used because of liquidity constraints of farmers. Available statistics on manure production and cultivated area suggest that 1.3 Mt/ha - 2.2 Mt/ha of manure is applied in Northern Ghana (Langyintuo et al, ibid.). The recommended rate of application for organic manure in the area is 8 Mt/ha (Anane-Sekyi, 1994). This means that the cropping systems being practised have implications for sustainability of crop production. Average annual yields of major crops in the area are below the corresponding national average yields and far below the achievable yields. Table 1.4 below gives some yield figures for selected crops.

Table 1.4: **Yield of selected food crops (average for 1991 to 1996)**

Crop	Yield (Mt/Ha)		
	National	Northern Ghana	Achievable*
Maize	1.5	1.3	5.0
Rice	3.0	1.4	3.0
Millet	0.9	0.7	2.0
Sorghum	1.0	0.8	2.0
Cassava	11.3	9.9	28.0
Yam	11.7	8.7	20.0

Source: Computed from MOFA, PPMED statistics 1991 1996.

* Indicates yields that have been achieved in isolated cases due to more effective extension and other logistic support.

Thus the problem being addressed by this study is how crop production in Northern Ghana is being sustained with the increasing cropping intensity. In particular the study will address the following specific questions:

1. What variability exists in the cropping systems of Northern Ghana?
2. What are the constraints to crop production in Northern Ghana?
3. What strategies are being adopted by farmers to increase crop yields and sustain crop production in Northern Ghana?
4. Are the strategies cost-effective in increasing crop yields?

5. What can be done to improve the situation for sustainable crop production in Northern Ghana?

1.3 Objectives of the study

For people depending directly on agriculture (mainly crop production) for their livelihood, fluctuating crop yields pose a major limitation on the realisation of a major objective - food for the family. Finding a cropping system that will ensure good yields at all times will take them several steps towards the realisation of this goal. Research activities at SARI are geared towards the development of technological options that will help farm households in Northern Ghana to realise this goal. Technologies emanating from research activities are meant to augment those from farmers indigenous knowledge. The broad objective of the study is to find out if the present traditional cropping systems in Northern Ghana are sustainable. The study has the following specific objectives:

1. To find out if there is variability in the cropping systems of Northern Ghana.
2. To find out the constraints to crop production in Northern Ghana
3. To determine the strategies adopted by farmers to increase crop yields in Northern Ghana.
4. To assess the cost-effectiveness of strategies currently being adopted by farmers to increase crop yields in Northern Ghana.
5. To make recommendations for achieving sustainable crop production in Northern Ghana.

1.4 Justification of the study

Despite several efforts at improving crop production in Northern Ghana through the cropping systems, not much has been done to assess their sustainability. The importance of the concept of sustainability is very much appreciated in research at SARI. However, no quantitative measurement has been attempted. The Technical Advisory Committee (TAC) of the Consultative Group on International Agricultural Research (CGIAR) has recommended that research at international centres which are designed to generate agricultural innovations should be planned and conducted with sustainability in mind. This recommendation is applicable to national agricultural research programmes as well. Despite the widespread concern about sustainability of agricultural systems, there is little guidance in the literature on what practical methods are to be used for measuring sustainability and economic viability of a production system (Ehui and Spencer, 1990). This study will contribute to the practical measurement of the sustainability of cropping systems in Northern Ghana.

1.5 Organisation of the study

The study is organised into five chapters. In chapter one a background of the study is given. It gives a brief description of the study area together with the objectives of the study, the justification for it and the organisation of work.

Chapter two deals with literature review. In it, literature on cropping systems in Northern Ghana, the concept of sustainability and the measurement of sustainability is reviewed. This provides a basis for establishing changes in the cropping systems over time, as well as a choice of a method of assessing the sustainability of the cropping systems under study.

In chapter three the methodology that has been used in the study is described. It covers the data required, the method of data collection and the analytical methods used.

Chapter four which forms the nucleus of the study presents the findings of it together with a discussion of such findings.

The fifth and last chapter contains the conclusions and recommendations made on the bases of the findings of the study.

CHAPTER 2

LITERATURE REVIEW

This chapter reviews literature on cropping systems in Northern Ghana. The purpose of this review is to establish any variability in the cropping systems in the study across locations and over time. Literature on the importance of sustainability, definitions of the concept of sustainability and its measurement and applications is also reviewed. This gives an understanding of the concept of sustainability and helps in deciding on what approach to use in measuring sustainability in this study.

The cropping systems of any location are described by the major crops grown in that area together with the management system used in the production of those crops. Several factors influence the crops that are grown in any geographical location. The most important among these are the rainfall pattern, soil nutrient status and the prevalence of pests and diseases of crops. These factors except rainfall pattern are influenced by the management practices used in crop production. These management practices in turn are influenced by population pressure on land. Rainfall pattern is important in relation to soil moisture content for crop production. In this case, management practices can influence soil moisture content, for example through mulching and agroforestry practices.

2.1 Major Crops Grown in Northern Ghana

There is a wide range of crops under cultivation in Northern Ghana. The major crops under cultivation in this area include maize, sorghum, millet, rice, groundnut, yam, cassava and cotton (Abatania, op cit.; Zegeye, 1990). There is variability in the crops grown in different parts of Northern Ghana. This variability across locations is influenced by a complex of factors: rainfall amount, soil fertility status, access to market for products, food habits and food security (Runge-Metzger and Diehl, 1993). Rainfall is the most important factor influencing choice of crops grown in different parts of Northern Ghana. In the Upper East region which receives an average of 890 mm of rainfall per annum, short maturity varieties of crops such as millet, sorghum, cowpea and groundnut are grown. Crops such as maize, yam, cotton and rice which require high soil moisture levels (influenced by rainfall amount and distribution) are found in the Upper West and Northern regions. These areas receive over 1000 mm of rainfall per annum which is adequate for the cultivation of these crops (Donhauser et al, op cit.). However, some amount of rice is grown in the Upper East region under irrigation and in valley bottom lands where soil moisture levels are adequate for the crop. Average yield of rice under irrigation is higher than that under rainfed conditions in this region (Kwotuah, 1990). The difference in yield is attributable to differences in soil moisture levels of the two production systems.

Like rainfall, soil fertility status also affects the choice of crops grown in a particular locality. Yam which requires very fertile soils for cultivation is usually the first crop after the fallow period. Therefore yam is not cultivated in the Upper East region where soil fertility is very low and land is hardly fallowed. The crop is grown mostly in the Bimbilla area of the Northern region where fallow periods are long enough to restore soil fertility. Some amount of yam is also grown in the Upper West region.

In other cases access to market outlets determine the crops grown in different parts of Northern Ghana. For example, in parts of the area where cotton thrives, the crop is grown mainly because of the ready market for seed cotton.

2.2 Cropping Patterns in Northern Ghana

Intercropping is the predominant cropping pattern in Northern Ghana (Abatania, op cit.; Runge-Metzger and Diehl op cit.). Cereal -legume mixtures occupy the largest share of the annual cultivated area in the farming systems of Northern Ghana (Baur, op cit.). It is only in the areas around Tumu in the Upper West region, Cheshegu in the Northern region and Navrongo in the Upper East region that sole crops constitute more than one quarter of the cropped area. In particular, rice and cotton are hardly intercropped. Rice is mostly grown in valley bottom lands. These lands experience seasonal flooding which makes them unsuitable for the production of other crops. Cotton on the other hand is grown under high levels of pesticide application which will not be possible in intercropped situations. This explains why rice and cotton are grown as sole crops.

Farm households consume a range of crops that come from their own production. Farmers want to obtain each type of crop while the prepared land area is too small to be divided into plots for various crops. Most farmers in Northern Ghana rely on family labour supply for land preparation. This is as a result of lack of funds for hiring labour or tractor services for land preparation. More so, there is a very short period of time for land preparation. Crops are grown under rainfed conditions. There being only one rainy season in the area of about five months, most crops have to be sown within the first two months from the onset of the rains. This therefore requires that land preparation be completed within two months. Farmers therefore plant intercrops in an attempt to obtain the range of crops that they need. In areas around the Upper East region, population pressure on land has reduced individual land holdings to sizes that cannot be subdivided for sole cropping. With a population density of 125 persons per square kilometre, over 80 percent of the population of the region has less than 2 hectares of land holding. The national average population density is 72 persons per square kilometre.

Cereal-based intercropping is more important in the Sawla area of the Northern region and the densely populated areas in the Upper East region where also legume-based intercropping is more common than anywhere else. Cereals constitute the bulk of the diet of households in these areas (Fey, 1992).

This explains why the cropping patterns are cereal-based. In the Bimbilla area root- and tuber-based intercropping clearly dominates. The most common crop mixtures found in the cropping pattern include: maize-sorghum; maize-rice; groundnut-maize-sorghum; yam-maize; maize-millet; yam-rice and yam-millet (Ibrahim, 1984).

Cropping patterns also change according to land use types. In general, three zones of different land use intensities are established, known as the ring cultivation system (Norman *et al.* 1981). Around the homestead, compound farms are nearly permanently cultivated (Runge-Metzger, 1988). There is less variability in species cropped on compound fields in comparison to bush fields (ICRA and NAES, 1993). In the medium populated areas compound farms are covered by tobacco-based mixtures and sole crop maize. Maize is more responsive to soil nutrient levels than other crops. Compound fields receive household organic waste as well as animal droppings and are relatively more fertile than bush fields. Farmers plant sole maize to get the best out of these fields. Animals usually feed on crops grown on compound fields, destroying them in the process. Tobacco is however not eaten by animals. For this reason, farmers prefer to plant this crop on compound fields in areas where it is grown. Bush farms are those located more than 3 kilometres away; there are farms that are more than 20 kilometres away.

2.3 Crop Production Management Systems in Northern Ghana

Most farmers in Northern Ghana produce their crops under a traditional system of management. In this system, crops are produced under rainfed conditions using recycled planting materials. There is little or no use of purchased external inputs such as chemical fertilisers, herbicides and pesticides. Under this system of management, the hoe and cutlass are the main tools of cultivation. These are the main tools used in crop production elsewhere in Ghana (Gyasi, 1997). Other means of cultivation are bullock traction and mechanical power (use of tractors).

Regional differences exist in the use of the three means of cultivation mentioned above. In the Northern and Upper West regions, the hoe and cutlass as a means of land preparation is more important. This is followed by bullock traction and mechanical power in order of decreasing importance. In the Upper East region the situation is quite different. Here bullock traction, hoe and cutlass and tractor power in the order of decreasing importance are the means of land preparation. It must be noted here that the use of bullock traction and tractor power are mainly for purposes of land preparation and haulage of farm produce. All other operations including land preparation are carried out with the hoe and cutlass. In a few instances however, bullock traction is used in weed control. The use of mechanical power is constrained by limited availability of tractors and consequently high fees charged for ploughing services. Table 3.1 below gives the regional distribution of the means of land preparation in Northern Ghana.

Table 2.1: **Regional distribution of the means of land preparation in Northern Ghana**

Means of land preparation	Distribution of use		
	NR	UWR	UER
Hoe and cutlass	55.7	83.2	27.3
Bullock traction	29.0	14.4	57.5
Tractor Power	15.3	2.4	15.2
Total	100.0	100.0	100.0

Source: Runge-Metzger, A. and Diehl, L. (Editors) (1993). Farm Household Systems in Northern Ghana. A Case Study in Farming Systems Oriented Research for the Development of Improved Crop Production Systems.

The regional distribution of means of land preparation above also reflects the type of seedbed used in each region. In the Northern region, as a result of root and tuber crop cultivation a lot of mounding is done with the result that the hoe becomes more important as a means of land preparation, as the other means are not used in mounding. Similarly, in the Upper West region where cereals and legumes as well as root and tuber crops are grown on mounds the hoe and cutlass are even more important. In the Upper East region, crops are mostly planted on ridges or on the flat. To facilitate and speed up land preparation, bullock traction and tractors are used. However, owing to the fragile nature of the soils in that region tractor traction is not encouraged with the result that bullock traction becomes more important, accounting for 57.5% of land preparation.

2.4 Sustainability in Agricultural Production

In this section, definitions of the concept of sustainability is listed as found in the literature. Following this the need to quantify sustainability and how to do so is discussed. Finally, the application of approaches found in the literature in the measurement of sustainability is discussed.

2.4.1 The concept of sustainability

The concept of sustainability as used in agriculture has been defined in various ways by different authors. The OECD (1995) quotes Reptto's definition of sustainability as "a development strategy that manages all assets, natural resources, and human resources as well as financial assets, for increasing long-term wealth and well-being" According to the OECD the value of natural resources should not be measured only with regard to their capacity to produce tangible goods, but also with regard to the various non-marketed environmental benefits they provide. Trzyna and Osborn (1995) define sustainability with reference to development as the complex of activities that can be expected to improve the human condition in such a manner that the improvement can be maintained. Conway (1986) states that some definitions of sustainability focus on system resilience, or the ability of an agricultural system to maintain its productivity when subjected to stress or perturbation. Sustainability in the agroecology sense is enhanced through system diversity (Larry, 1992). The diversity of enterprises over time and space fosters the recycling of nutrients, increased efficiency in the use of moisture, nutrients and sunlight and the reduced incidence of weeds, pests and diseases (Alttieri, 1987).

Young and Burton (1992) define sustainability with reference to development as a process that meets the needs of present generations without compromising the ability of future generations to meet their own needs. Sustainability is also thought of as the idea of maintaining some overall equilibrium between resource use and availability (Pierce, 1993). The American Society of Agronomy defines a sustainable system as "one that over the long term, enhances environmental quality and the resource base on which agriculture depends; provides for basic human food and fibre needs; is economically viable and enhances the quality of life for farmers and society as a whole" (ASA, 1989). There is no conflict in the opinions expressed in these definitions. A synthesis of the definitions and an understanding of the concept indicates that a sustainable system is one that seeks to maximise present benefits while conserving resources (particularly natural resources) for future generations to use.

The concept of sustainability is widely used in agricultural literature. However, one core problem with regard to this concept is the development of appropriate analytical tools to measure a system's performance over time. So far in the literature, qualitative statements are made about the effect of agricultural activities on the environment and sustainability. This is particularly the case of literature on agricultural sustainability in Ghana. In these assessments sustainability is ranked subjectively (e.g. Benneh, 1972;

Benneh et al, 1996). It is important that measurable parameters are defined to describe the sustainability of agricultural systems.

2.4.2 Measurement of sustainability

There are a number of approaches to the measurement of sustainability. These approaches are based on the definition and understanding of what constitutes sustainability. One such approach views agricultural sustainability as food self-sufficiency (Douglass, 1984). In this approach, estimating the future demand for food is the essential first step in achieving sustainability. Once these estimates are available the next step is to assess supply capacities of the production system so as to estimate the supply of economically useful agricultural resources, and their productivities. Thinking economically about agricultural resources in the future leads to the conclusion that the supply of foodstuffs can always be increased at some cost. Physical limits of resources almost never bar increases in the output of particular products or sectors of an economy as long as society is willing to incur the economic and/ or environmental costs of recruiting the resources from other potential uses.

There is another group of people who trace their understanding of agricultural sustainability primarily to the insights of ecologists rather than economists. These people see environmental costs rather differently. The ecological view of sustainability arises from the belief that nature in the long run imposes limits on humankind's collective capacity to provide food for the world. This group therefore views sustainability in terms of food self-sufficiency just like the first group. The limits imposed are physical in nature because they are imposed by a finite supply of natural resources and by the limited capacity of our physical environment to absorb waste. In this view another measure of agricultural sustainability, therefore, is the sustained yield capacity of renewable agricultural resources. To maintain the long-run productive capacity of land for example, farmers need to maintain the depth of topsoil as well as a favourable root zone for plants, and they need to insure other physical, chemical and biological conditions for the growth of plants.

A system's performance may be quantified in different ways. Economists are concerned with the conditions of profit maximisation and the discounted value of future returns from current investment and technology choices. Ecologists look at stability and resilience in terms of material and energy balances, interactions among tropic levels, regulating feedback mechanisms, and biodiversity. Agronomists seek to harness solar, soil and water resources to optimise crop yields in relation to input requirements. Farmers are concerned with maximising their return on labour, land and capital depending on the socio-economic and policy environment in which they operate.

Two measures of performance that link the perspective of farmers and scientists are the efficiency with which inputs are used to produce a desired output and the total output which is determined by yield per unit area (Cassman and Pingali, 1995). The ratio of output to a single input is the partial productivity of that input; for example, crop yield is the partial productivity of the land input for the crop in question. Single factor or partial productivity is a misleading measure of gains in productive efficiency since it does not allow for factor substitution. A broad economic index of output/input efficiency is the Total Factor Productivity (TFP). TFP is defined as the ratio of the total value of all output produced by the system and the total value of inputs used by the system during one cycle of the system. Lynam and Herdt (1989) propose the use of TFP as an appropriate measure of output by which to determine sustainability. By constructing an index of TFP, it is possible to assess objectively the productivity performance of the system over time. In some approaches to measuring sustainability only state variables are quantified. In others both control and state variables are quantified. State variables are descriptors of the quality of the environment or of specific resources while control variables are those that directly influence the level of state variables. For example, the control variable "tillage practice" influences the state variable "soil depth remaining after erosion". There is usually a cause-effect relationship between state and control variables. When only state variables are measured, considerable doubt can remain about the causes of observed changes. There seems to be little discussion in the literature as to whether sustainability should be measured discretely or continuously. If sustainability is thought of as discrete, then in theory at least, an agroecosystem can be described as being sustainable or not. Measuring sustainability then comes down to ascertaining which of these two states prevails. If sustainability is seen as continuous; however, it is possible to ascertain different degrees of sustainability, opening the way to comparisons between systems. Among the levels of measuring sustainability are the regional level, at which the sources of growth in agricultural productivity are compared with the expected growth in the demand for agricultural products (Byerlee and Sidiq, 1989; Rosegrant and Pingali, 1991) and the plot level, at which changes in yields and total factor productivity are explained in terms of changes in the levels of inputs, technical change, and changes in resource quality (Lynam and Herdt, 1988).

Approaches to measuring sustainability are heavily conditioned by how the word sustainability itself is understood. However, some general issues are common across all possible approaches. These issues include predicting the future, the time frame, state versus control variables, continuous versus discrete measurement and the level of measurement. Larry (op cit.) sees the measurement of sustainability as implying drawing conclusions, or at least stating probabilities about future events. Forecasts contain uncertainty but some are more uncertain than others. The degree to which sustainability can be measured depends on the ability of analysts to predict the future accurately.

The problems of measuring sustainability are exacerbated by different time frames that apply to different sustainability issues. Some are best studied over the medium term, within a time frame of five to twenty years. These include problems such as soil nutrient depletion, build up of weeds, pests and diseases. Other problems are best studied in the longer time frame, twenty to hundred years (slower rate of land degradation e.g. soil erosion, salinisation and desertification). Still some problems are studied over very long time frames. These include issues concerning the ultimate sustainability of agriculture (Larry, op cit.).

The measurement of sustainability may be quantitative or non-quantitative. Proponents of non-quantitative approaches seem to reject the notion that sustainability can or should be measured. MacRae et al. (1989) argue that quantification tends to distort the research process, inducing researchers to choose quantifiable (but less relevant) variables at the expense of other non-quantifiable (but conceptually more important) ones. They are especially skeptical of numerical modeling of biological systems, arguing that the internal consistency of these models does not compensate for their lack of realism. However it is never possible to deal with any problem (not just sustainability problems) in all its real-world complexity. Scientists "have to simplify to survive" (McCall and Kaplan, 1985). In addition, the experience of farming systems research suggests that it is often possible to quantify and model complex biological systems without unacceptable loss of realism (Harrington, 1992).

While most proponents of sustainable agriculture would probably not agree that measuring sustainability is utterly impossible and that trying to measure it is a bad idea, many however, would be content with "directional measurements". A directional measurement is one that measures only the direction of change in the sustainability of a system, not the magnitude of that change. Directional measurements are most attractive when it is felt that a proportional relationship exists between control and state variables. The assumption is that the sustainability of an agroecosystem is changed in rough proportion to those practices felt to most strongly influence the system's future productivity (and/or its ability to deal with stresses and perturbations). For example, an agroecosystem suffering from gradually declining levels of soil nutrients is thought to become more sustainable in rough proportion to the amount of nutrients that, through appropriate interventions, can be generated or recycled within the system or applied from external sources.

There are two approaches to the quantitative measurement of sustainability. The first deals with the use of sustainability assessment maps (SAM). Essentially, a SAM consists of a diagram in which each of the important dimensions in a compound problem is represented by an axis (Clayton and Radcliffe, 1996). Measurement of change or indications of priorities are then mapped onto these axes. The resultant profile can be used to represent the current situation. Possible future scenarios or outcomes from the situation are then used to generate further profiles. These profiles are then differentiated, which highlights the trade-offs inherent in each possible choice.

The second quantitative approach to the measurement of sustainability makes use of index numbers in comparing one situation to another. In this approach total factor productivities are calculated for an agricultural production system for a number of periods. Setting the index equal to 1.0 in one period, this can be compared with the indices in future periods. If the index in future periods is greater than or equal to that in the current period then the system is said to be sustainable. The system is said to be non-sustainable if the index decreases over time.

The use of TFP has been recommended against the use of partial factor productivities because with TFP, changes in output are related to changes in all inputs, while partial factor productivities tend to mask the effect of many of the factors accounting for productivity growth. There are two approaches to the measurement of TFP: the growth accounting (or index-number) approach which involves the development of indices of outputs and inputs and the computation of non-parametric factor productivity measures; and the econometric (or parametric) approach, which is based on econometric estimation of the production function or (through duality relations) the underlying cost or profit function.

2.4.3 Application of TFP in measuring sustainability

Ehui and Spencer (op cit.) have measured the sustainability and economic viability of farming systems in Nigeria by using the approach of total factor productivity proposed by Lynam and Herdt. Analysing a set of data available at the International Institute of Tropical Agriculture (IITA) they conclude that sustainability and economic viability indices are sensitive to the incorporation of natural resource stocks and flows. They observe that where changes in soil nutrient status are substantial, the productivity measures provide markedly different results from conventional total factor productivity approaches. The calculation of total factor productivity requires complete information on the input-output relationships. Special attention has to be given to the level of technology which is applied because, there is always the danger that technological change may mask the process of environmental degradation of an agricultural system.

A concept closely related to the notion of technological change is that of productivity growth (Rayner and Welham, 1995). If technical change increases the effectiveness by which a given input combination is transformed into output, then there is said to be an increase in productivity of the bundle of inputs or aggregate input. Productivity measurement attempts to provide a number or score over time of output in relation to inputs used; that is, it assesses movements in output/input ratios. Productivity is said to increase when larger quantities of output are produced from the same quantities of inputs or when the same amount of output is produced from smaller quantities of inputs.

Cassman and Pingali (op cit.) analysing a set of long-term farm-level data for rice production in Asia observe dramatic increases in yield following the rapid adoption of modern rice varieties and management practices in the 1960s. Yields continued to increase in the second decade following adoption but in the most recent decade, yields have been stagnant or declining. However, yield trends alone do not tell the whole story because farmers continually modify their management practices as new technologies become available and in response to government policies and markets. Based on 1990 prices for inputs and outputs in each year in the Philippines Cassman and Pingali calculated TFP trends for the rice cropping system. The trends show that productivity increased steadily until the early 1980s followed by slight decline through the l990s.

Traxler et al (1995) analysed data obtained from long term experiments at Auburn University, Alabama, to study the long term productivity of cotton under organic, chemical and no nitrogen fertilizer treatments. The experiment was carried out over the period 1896-1992 with the following treatments:

1. Continuous cotton with no nitrogen and no winter legume;
2. Continuous cotton with winter legume used as green manure; and
3. Continuous cotton with annual application of l 34 kg/ha of nitrogen.

Cotton productivity was assessed from different perspectives. The first perspective is provided by a set of conventional indices which ignore the negative external costs associated with erosion and the use of agricultural chemicals. Finally, a TFP index is calculated which allows the performance of the winter legume and 134 kg/ha of Nitrogen treatments to be compared to the no nitrogen-no legume plot. From their findings Traxler et al conclude that none of the systems shows a linear trend in TFP over the life of the experiment. Productivity cycles are present in all three systems despite an over all positive trend. The presence of productivity cycles implies that productivity increases and decreases in a regular manner over the period of the experiment. The system with neither an organic input or a chemical source of added nitrogen was found to be less productive than the other systems. This system compares more poorly when external costs such as regulatory costs for pesticide use, adverse health effects and damage to the natural environment resulting from pesticide use as well as soil loss due to erosion are considered. Organic and chemical sources of nitrogen were found to have similar productivity impacts.

The introduction of the mechanical cotton picker was found to be the single most dramatic event to affect productivity. The positive impact of this technology is powerful enough to offset the negative impact of many other changes in the system.

In a multi-crop comparison in Missouri, Brown et al (1 995) used an input/output ratio and the TFP approach to compare the sustainability of maize- and wheat-based cropping systems under different management systems. Data for this study was obtained from a long-term experiment (1950 - 1989). The study involved the use of farmyard manure and different crop sequences or rotations. From the input/output ratios and TFP trends Brown et al conclude that crop production is sustainable in continuous culture. Sustainability of maize grown in rotation was found to be influenced by variability in red clover hay output as well as weather-induced wide swings in maize yields. TFP index calculations indicate that total factor productivity increased over the 40-year period, stabilising over the last decade of the study period. Crop production during the four-decade period maintained the productivity of the soil. This was indicated by both yields and soil organic matter when balanced nutrition was used.

2.5 Synthesis of Issues from the Literature

Literature on the cropping systems of Northern Ghana indicates that there are variations in the systems across locations mainly due to rainfall soil conditions. It is however not known if the systems vary over time. It is necessary to find out what the present cropping systems are. This can be compared with information available in the literature to establish any variability over time.

The literature has so far indicated the wide application of total factor productivity measures in determining the sustainability or otherwise of an agricultural system. Changes in TFP over time result from changes in socio-economic and the biophysical environment. Evaluating TFP trends after specifying constant prices for inputs and outputs eliminates fluctuations due to changes in market conditions but does not account for changes in the policy environment or changes in biophysical resource base which may influence the quality and efficiency of inputs used by farmers. Thus monitoring the TFP trend line based on constant prices indicates that the efficiency of input use has changed but does not explain why the change is occurring.

In cases where a decline in TFP results from a reduction in the quality of the biophysical resource base to support crop growth, it is the job of biological and physical scientists to quantify the effects of crop production on soil quality and pest pressure, and to understand the processes responsible for the changes. Partial factor productivities based on the key biophysical constraints become important here, as they can be monitored in a given environment to indicate the trend line for biological efficiency. Relevant indices include input/output ratios for nutrients, grain yield per unit of water input as from rainfall and irrigation, or an energy ratio based on the calorific value of all outputs.

There are two views on the measurement of sustainability. One view supports the quantitative measurement of sustainability while the other suggests a non-quantitative approach. The latter view argues that less important but easily quantifiable variables may be included in the analysis while excluding more important but unquantifiable variables. This study will side with the view that supports the quantitative measurement of sustainability. It is true that it is impossible to include all variables that influence the performance of a production system in order to assess its sustainability. However, it must be appreciated that some variables have greater influence on the system than others. In this case, quantitative measurement of the sustainability of the system through stepwise inclusion of relevant variables in the model would lead to an identification of the most important factors that influence the performance of the system.

While it may be impossible to quantify certain variables that influence a production systems, it should be possible to quantify these variables indirectly by quantifying the effects that they have on the performance of the system. While it is not easy to quantify the aesthetic value that a community places on a flower garden for example, it is possible to estimate the cost of establishing a similar flower garden if the site for the present one is proposed for crop production. In assessing the sustainability of the crop production system, the cost of establishing the new flower garden including the cost of maintaining it would be treated as a measure of the influence of aesthetic values on the system.

There is no information in the literature on the measurement of sustainability in Northern Ghana although this has been done in other countries. This study will contribute to filling this information gap by assessing the sustainability of five maize-based cropping system in Northern Ghana.

CHAPTER 3

METHODOLOGY

The study is divided into two parts. In the first part, farmers' efforts at ensuring sustainable crop production is examined. In the second part, sustainability of cropping systems is assessed using secondary data. The data was obtained from on-station experiments conducted at Nyankpala as well as on-farm farmer managed sources. The aim is to establish the link between what farmers do and the results of the on-station experiments. Five maize- and cowpea-based cropping systems have been chosen for this study. These systems are representative of the cropping systems in Northern Ghana. The choice of systems was influenced by the availability of data for the application of the model specified below for the study.

3.1 Theoretical framework

The TFP index approach discussed in chapter two above has been adopted in determining the sustainability of five maize-based cropping systems in this study. There are a number of index number approaches to the computation of a TFP index. These include the Laspeyres, Pasche index, Fisher index and the Tornqvist index. Index numbers calculated using the first three index number approaches have been shown to be inexact except under conditions of a linear production function in which all inputs are perfect substitutes (Christensen, 1975; Diewert, 1976). For a mathematical specification of these three index number approaches, see Varian (1978) and Monga (1995).

Production functions are however generally assumed to be in a quadratic functional form. The Tornqvist index which is based on the quadratic logarithmic functional form is the most appropriate since it is consistent with a flexible production function which does not arbitrarily constrain the substitution possibility between inputs. Nevertheless, over a short period, a simple index such as the Laspeyres can often provide an acceptable approximation to a flexible aggregator function (Rayner and Welham, op cit.).

In the Tornqvist index approach, TFP is measured as the ratio of an index of aggregate outputs (Q) to an index of aggregate inputs (X):

$$TFP_t = Q_t / X_t \quad (1)$$

where t denotes time.

The index of aggregate outputs is computed as the ratio of outputs produced in period t to the outputs produced in the previous period (t-1), taking into consideration the revenue share of each output in total revenue:

$$Q_t = \Sigma(Q_{jt}/Q_{jt-1})^{(wjt + wjt-1)/2} \quad (2)$$

where

$w_{jt} = P_{jt}Q_{jt}/\Sigma P_{jt}Q_{jt}$ is the revenue share of output 'j' in total revenue in period t

w_{jt-1} = revenue share of output 'j' in total revenue in period t-1.

P_{jt} = the price of output 'j' in period t

Q_{jt} = quantity of output 'j' produced in period t

Q_{jt-1} = quantity of output 'j' produced in period t-1

$P_{jt}Q_{jt}$ = revenue of output 'j' produced in period t and

$\Sigma P_{jt}Q_{jt}$ = total revenue of outputs produced in period t

Similarly the index of aggregate inputs in period t is computed as:

$$X_t = \Sigma(X_{it}/X_{it-1})^{(Sit + Sit-1)/2} \qquad (3)$$

where

$s_{it} = r_{it}X_{it}/\Sigma r_{it}X_{it}$ is the cost share of input 'i' in total cost in period t

s_{it-1} = the cost share of input 'i' in total cost in period t-1

r_{it} = the price of input 'i' in period t

X_{it} = quantity of input 'i' produced in period t

X_{it-1} = quantity of input 'i' produced in period t-1

$r_{it}X_{it}$ = cost of input 'i' used in period t and

$\Sigma r_{it}X_{it}$ = total cost of inputs used in period t

Substituting for Q_t and X_t in equation (1) gives:

$$TFP_t = \frac{\sum (Q_{jt}/Q_{jt-1})^{(wjt + wjt-1)/2}}{\sum (X_{it}/X_{it-1})^{(sit + sit-1)/2}} \qquad (4)$$

From equation (2) above:

$$\Delta LnQ_t = \frac{1}{2}\sum (w_{jt} + w_{jt-1}) In(Q_{jt}/Q_{it-1}) \qquad (5)$$

Similarly, $\Delta LnX_t = \frac{1}{2}\sum (s_{it} + s_{it-1}) In(X_{it}/X_{it-1})$ (6)

Equation (4) then becomes:

$$\Delta LnTFP = \Delta LnQ_t - \Delta LnX_t \quad (7)$$

Now $\Delta LnQ_t =$ growth of aggregate output ($\dot{Q}$) in period t and $\Delta LnX_t =$ growth of aggregate input ($\dot{X}$) in period t.

Thus equation (7) implies that the growth in TFP is equal to the difference in the growth in aggregate output and growth in aggregate input: $T\dot{F}P = \dot{Q} - \dot{X}$.

Setting the index to equal 1.0 in a particular year and accumulating the measure according to equation (7) provides the conventional index of TFP. For a production system to be sustainable the TFP indices calculated for it must remain constant or show an increase over the relevant period of time. The individual TFP values could also be plotted against time and a TFP trend line determined. The trend line of a sustainable system would have a zero or positive slope.

A production system that is sustainable in the long run must be economically feasible in the short run. To put it another way, the system must be profitable in the short run. Short run profitability is determined using output/input (profitability) ratios given by:

$$\Pi_t = \frac{\sum P_{jt} Q_{jt}}{\sum r_{it} X_{it}} = \frac{R_t}{C_t} \quad (8)$$

where Π_t is the profitability ratio for period t, and the other expressions are as defined above. For short run profitability, $\Pi_t > 1$.

The model stated above is adopted from Traxler *et al* (1995) for this study. The same model has been used by Ehui and Spencer (op cit.) to assess the economic viability and sustainability of cropping systems in Nigeria.

3.2 Data Requirements

Both primary and secondary data were required to achieve the objectives of this study. Primary data required included information on major crops grown, cropping patterns and cropping sequence. Information was also required on changes over time in the crops grown, trends in crop yields from season to season as well as trends in yields from one cycle of rotation to another. Information on strategies adopted by farmers to increase crop yields and additional resources required to implement such strategies was required. Other primary data required were farmers' sources of information on improved agricultural practices and constraints to crop production.

Secondary data was collected on cropping systems in Northern Ghana. This information was compared with information on current cropping systems in establishing the variability of cropping systems in the study area. Secondary data was also used for an application of the model specified above. The data included yields (kg/ha) of crops per season, quantity of inputs used per unit area of land and the unit prices of inputs used as well as unit prices of outputs produced. The outputs produced were maize, cowpea, sorghum and groundnut.

Inputs used included chemical fertilisers, seeds (of maize, cowpea, sorghum and groundnut), hoes and cutlasses, knapsack sprayers, pesticides and labour.

3.3 Data Collection Methods

A structured questionnaire survey was conducted to obtain the primary data required. Two representative villages were selected in each of the three regions of Northern Ghana, resulting in a total of six survey villages. The villages selected were Kpongu and Sing in the Upper West region, Dullugu and Wiaga in the Upper East region and Cheshegu and Woribogu in the Northern region. Dullugu and Wiaga fall within the Sudan Savanna vegetation zone of Ghana while Kpongu, Sing, Cheshegu and Woribogu fall within the Guinea Savanna vegetation zone. While the annual average rainfall in Dullugu and Wiaga ranges from 900 mm to 1,000 mm the annual average rainfall in the other villages ranges from 1,000 mm to 1,111 mm. The choice of villages was influenced by accessibility, cultivation of the range of crops grown in the region, availability of enumerators (data collection agents) within the vicinity of the village and cooperation of village in previous surveys of a similar nature to the proposed survey.

A total of sixty farm household heads were interviewed. Ten household heads were selected in each village. To select the household heads in a particular village, a meeting of all household heads was organised through the village chief. The purpose of the survey was explained by the researcher during this meeting and the cooperation of the household heads solicited.

There after, a list of all household heads was compiled with the assistance of three volunteers from the village community. Ten household heads were then randomly selected from the list.

The interviews in the Upper West region and Northern region were carried out by trained enumerators while those in the Upper East region were carried out by the researcher with the assistance of an interpreter. Enumerator training took the form of a group discussion of the structured questionnaire and mock administration sessions. This was followed by a questionnaire pre-testing session in one of the selected villages (Woribogu). The enumerators were supervised by the researcher during the questionnaire administration. A copy of the questionnaire that was used in the interviews is shown in appendix 2.

The secondary data was collected from three main sources. Crop yields and quantities of inputs were obtained from records of the Savanna Agricultural Research Institute. Prices of inputs and outputs were obtained from statistics of the Ministry of Food and Agriculture's Policy Planning Monitoring and Evaluation Department. The daily wage of labour was obtained from Ghana Prices and Incomes Board, Accra.

3.4 Data Analysis

To achieve the broad objective of the study, assessing the sustainability of maize-based cropping systems in Northern Ghana, the model specified above has been used. Using the model, total factor productivity indices were calculated for five maize-based cropping systems to determine their profitability and sustainability.

When more than one crop is produced in a year, an implicit quantity index of total output for the system is derived by dividing the total value of all crops harvested by an associated price index. The price index is obtained by weighting the price of each crop by its share in total revenue.

An aggregate input index was calculated using quantities of labour, planting materials and implements. Labour in man days per hectare was valued at the minimum daily wage rate for each year. It is assumed here that family workers are valued at their opportunity cost and hence paid the same wage as hired workers. An implicit index of material inputs was calculated as the ratio of total expenditure on these materials to the material input price index. The latter was computed by weighting the price of each material input by its share in total cost of material inputs. Similarly an index of implements was computed as the ratio of total annual cost of capital inputs to the capital service price. To create an aggregate capital service price, the price of each farm tool was share-weighted in the same manner as for the aggregate material input price index.

Natural resource flows have to be considered in the computation of total factor productivities in order to determine the sustainability of a production system. The level of soil Nitrogen has been considered as natural resource flows in this study. In years that there are net negative Nitrogen flows, these are treated as costs to the production system under consideration. Similarly net positive Nitrogen flows are treated as benefits to the system. Nitrogen flows are valued at the price of chemical fertiliser (Urea). It is assumed that when there is a net negative flow of Nitrogen cost will be incurred in purchasing Urea fertiliser to restore the level of soil Nitrogen to the required level. In the same way a net positive flow will imply that cost will be saved to the tune of the value of net positive Nitrogen flow.

To achieve the first specific objective, information from literature on cropping systems in Northern Ghana has been compared with information from the structured interviews on current cropping systems. This establishes any variability in the cropping systems across locations and over time. Similarly, strategies adopted by farmers to increase crop yields in Northern Ghana were established through frequency tabulation of responses from the structured questionnaire interviews. This served to achieve the second specific objective.

To assess the cost-effectiveness of strategies currently adopted by farmers to increase crop production, a partial budget approach was used. This approach compares extra benefits to extra costs as a result of adopting a particular strategy. A strategy is said to be cost-effective if extra benefits exceed extra costs. Partial budgets of the most commonly adopted strategies have been drawn to assess if the extra benefits and extra costs of these measures justify their adoption. This serves to achieve the third specific objective. From the responses to the questionnaire interviews descriptive statistics (frequencies) were used to establish the constraints to crop production in the study area, thus achieving the fourth specific objective.

Based on the findings of the study, recommendations have been made for improving upon the situation for sustainable crop production in Northern Ghana, thus achieving the last specific objective.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Variability of Cropping Systems in Northern Ghana

The first objective of the study is to find out if there is variability in the cropping systems of Northern Ghana. In this section current cropping systems of Northern Ghana are presented as they were found from the structured questionnaire interviews. These current cropping systems are then compared with cropping systems that have been found in the literature to find out if there is any variability in cropping systems across locations and over time. Variability of the cropping systems is discussed in terms of major crops grown, cropping patterns and cropping sequence and management systems.

4.1.1 Major Crops Grown in Northern Ghana

Information from the questionnaire interviews reveal that a wide range of crops are currently cultivated annually in Northern Ghana. The major crops grown are: maize, sorghum, millet, rice, cassava, groundnut and cotton. Other crops grown are tobacco, soyabean, cowpea and bambara groundnut. There is some variability in the crops grown across locations. As discussed in the literature review, climatic and soil conditions are mainly responsible for the regional differences in the type of crops grown. Early millet is not grown in the Northern and Upper West regions because the flowering period of the crop coincides with rains in these regions. As a result, there is poor pollination leading to low yields. In the Upper East region yam and cassava are not grown because of soil conditions. Both crops are grown on mounds, while the soil depth in this region does not permit the raising of such mounds. It is noteworthy that maize is hardly produced in the Upper East region due to inadequate soil moisture and nutrient levels. Table 4.1 below shows the relative importance of crops grown in Northern Ghana based on the proportion of sampled farmers growing each crop.

Table 4.1: **Relative importance of crops grown in Northern Ghana based on the percentage of sampled farmers growing each crop**

	Percentage of sampled farmers by region			
Crop grown	Northern	Upper West	Upper East	Total
Maize	31.7	33.3	0.0	65.0
Sorghum	30.0	33.3	33.3	96.6
Cowpea	21.7	28.3	26.7	76.7
Early millet	0.0	0.0	33.3	33.3
Late millet	16.7	21.7	31.7	70.1
Rice	25.0	15.0	8.3	48.3
Groundnut	30.0	25.0	23.3	78.3
Yam	31.7	31.7	0.0	63.4
Cassava	30.0	1.7	0.0	31.7
Bambara groundnut	8.3	0.0	18.3	26.6
Tobacco	16.7	0.0	0.0	16.7
Cotton	3.3	16.7	0.0	20.0
Soyabean	6.7	0.0	5.0	11.7

Source: Compiled from farmer interview responses, 1997.

The observation from the table above that none of the sampled farmers grow soyabean in the Upper West region is not exactly a true reflection of the situation in that region. It could be the case that the farmers selected for interview do not grow the crop. The same is true for the case of tobacco and cotton production in the Upper East region, although cotton production here is not as important as in the Northern or Upper West region.

4.1.2 Variability of cropping patterns and cropping sequence in Northern Ghana

Responses from the questionnaire interviews indicate that mixed cropping or intercropping is widely practised in the cropping systems of the study area. There are several crop combinations depending on the location. These vary across the three regions. The most prevalent crop mixtures include cereal-cereal, cereal-legume, legume-legume and root/tuber-cereal mixtures. Some crops are also grown as sole crops.

In the Upper East region, early millet-sorghum, early millet-late millet and groundnut-bambara groundnut-cowpea are common crop mixtures in the current cropping systems. In the Northern and Upper West regions, common crop mixtures include yam-maize, yam-millet, maize-sorghum, maize-sorghum-cowpea and cassava-sorghum.

Although there appears to be no difference between the present cropping patterns of Northern Ghana and those found in the literature, some of the farmers interviewed indicated there had been some change.

In the Northern region 19 out of 20 farmers indicated that crop mixtures had changed over the last 20 years. Up to four different crops could be grown on the same piece of land concurrently twenty years ago, the farmers noted. Farmers attribute the fact that they can no longer grow this number of crops together to declining soil fertility. Over the years, population pressure on land has resulted in continuous cropping or very short fallow periods (in situations where land is fallowed). Continuous cropping or short fallow periods without supplementary nutrient input leads to depletion of soil nutrients. Intercrop competition restrict the number of crops in a mixture under such depleted soils, hence the observed reduction in the number of crops planted in a mixture.

Farmers plant a definite sequence of crops on a piece of land from the time it is cleared until it is fallowed. The duration of the cultivation period is determined by yield levels. As long as economic yields are obtained farmers would continue to crop a particular piece of land.

In the Northern region responses from the structured interviews indicate that yam or yam in combination with millet is the first crop in the cropping sequence. Sorghum or sorghum in combination with legumes (cowpea, groundnut) is also not uncommon as the starting crop in the cropping sequence in this region. This is followed by a maize-sorghum mixture in the second and third year. Groundnut may be found as a third crop in the mixture during the second and third years. In the fourth year the land is planted with a millet-groundnut mixture, followed by cassava in the fifth year. The land is then fallowed for one to three years depending on the availability of land.

In the Upper West region, where compound fields are cultivated these are planted to almost fixed crop associations every cropping season. Typical mixtures include maize-sorghum, sorghum-cowpea and sorghum-groundnut. On bush fields yam or yam in combination with cereals is the first crop in the cropping sequence as observed in the Northern region. This is followed by a maize-cowpea and sorghum-cowpea mixture in the second and third years respectively. A mixture of millet and cowpea follows in the fourth year. The cultivation period is terminated at the end of the fifth year with sorghum-cowpea or groundnut.

In the Upper East region where there is so much land pressure, land is hardly fallowed. Here a mixture of early millet-late millet-sorghum-cowpea is grown annually on compound fields. On bush fields sorghum is the first crop in the cropping sequence. This is followed by late millet-sorghum mixture in the second year. A mixture of bambara groundnut-groundnut follows in the third year and the sequence is repeated during the fourth year. A particular crop mixture may be repeated in the following season if the current season yields are high. In such a situation the particular piece of land is assumed to be very suitable for the crop mixture in question.

Farmers recognise that growing the same crop or crop mixture on a particular piece of land year after year does not give them as much yield as when they grow them in some definite sequences. This provides a rationale for crop sequencing in Northern Ghana. Crop sequencing, if well planned can lead to a reduction of pest and disease incidence. Different crops have different rooting zones. Crop sequencing means that subsequent crops exploit different zones of the soil for nutrients as opposed to the preceding crop or crop mixture. The combination of these factors manifests in better yields than those that would otherwise be obtained under continuous cropping of the same crop or crop mixture on a particular piece of land.

Farmers in the study area indicated that the cropping sequence had not changed since their stay in the villages where they farm. Most of the farmers have been in these areas since birth.

4.1.3 Crop Production Management Systems

Although there is variability in the systems of crop production management practices across locations (regions) in Northern Ghana, there is little variation in these systems over time. The variability in management systems across locations has been discussed in chapter 2.

4.2 Constraints to Crop Production in Northern Ghana:

Climatic and biophysical factors pose the most serious constraints to crop production in Northern Ghana. Declining soil fertility was mentioned by 57 farmers (95 percent of the survey sample) as the most serious constraint to crop production. Another 52 farmers (87 percent) indicated that rainfall was the most serious constraint. The farmers stated that rainfall amounts and distribution were inadequate for crop production. The rainy season is late in starting and is characterised by dry spells during critical stages in the growth of crop plants. Farmers are known to practise continuous cropping, gathering and burning crop residue each year during land preparation. Such practices lead to depletion in soil organic matter and subsequent deterioration in soil physical properties, including moisture retention, hence the declining soil fertility reported by farmers. Striga infestation was the next constraint to crop production mentioned by farmers. Thirty farmers (50 percent) identified this constraint.

Other factors acting as constraints to crop production as mentioned by farmers are labour supply and liquidity constraints to meet the cost of farm inputs and services. Table 4.2 below presents the relative frequency of responses to crop production constraints in Northern Ghana. Although farmers did not refer to access to agricultural extension services as a constraint, the survey revealed that there is low extension contact with farmers. Only twenty-five farmers out of the sixty farmers interviewed indicated that they had contact with extension agents.

Table 4.2: **Relative frequency of Farmers Responses to Crop Production Constraints**

Constraint	Relative frequency (percent)
Declining soil fertility	95
Erratic rainfall pattern	87
Striga infestation	50
Labour bottlenecks	32
Liquidity	20

Source: computed from responses of structured interviews.

4.3 Strategies Adopted by Farmers to Increase Crop Production in Northern Ghana

Farmers' perception of sustainable crop production is one of constant or increasing physical crop output. This information was obtained from the structured questionnaire interviews. Strategies adopted by farmers to increase crop production are therefore directed at maximising physical crop output. In this regard, biophysical factors are very important in the choice of a measure to increase crop production.

In the light of the above considerations, the strategies adopted by farmers to increase crop production are those directed at influencing biophysical factors so as to maximise physical output. Given that crop production is carried out mainly under rain fed conditions, little effort is made to influence soil moisture levels.

The strategies adopted by farmers to increase crop production include the use of chemical fertilisers, application of manure (mostly animal droppings), incorporation of crop residue and compost application. Other strategies are crop rotation, early weeding and extra weed control. In terms of the number of farmers adopting each of these strategies, the use of animal droppings (mostly cow dung) is the most important; 50 percent of the farmers interviewed indicate that they use this strategy. The next strategy in order of importance is the use of chemical fertilisers; 25 percent of the farmers interviewed used this strategy. This is followed by early or timely weed control and next to it in order of importance is extra weeding. Table 4.3 below gives the frequency of strategies used by farmers.

Table 4.3: **Frequency of strategies used by farmers to increase crop production in Northern Ghana**

Strategy adopted	Number of responses	Percentage of sample
Manure application	30	50
Chemical fertilisers	15	25
Early weeding	9	17
Extra weeding	5	8.3
Incorporation of crop residue	4	6.7
Compost application	4	6.7
Other strategies	5	8.3
Total	**72**	**122.0**

Source: computed from responses of structured interviews.

It is important to note here that some of these strategies are used (adopted) together. This explains why the total number of responses(72) in Table 4.2 exceeds the number of farmers interviewed (60). Farmers indicated that the adoption of manure application invariably goes with early weed control or extra weeding. This is because the adoption of this strategy promotes vigorous growth of weeds as it does for crops. The use of manure may also introduce certain weeds hitherto not present on the particular field. If these weeds are noxious weeds their presence would call for early weeding or extra weeding.

Responses from the interviews conducted suggest that the strategies adopted by farmers to increase crop production have resulted in increasing crop yields. The average additional yield of sorghum obtained annually from the adoption of yield increasing strategies (manure and chemical fertiliser application mainly) is 375 kg/ha in the Northern region and 381 kg/ha in the Upper East region. Additional yields of 544 kg/ha of millet are also obtained in the Upper East region where manure application strategies are adopted in millet production.

Additional yields of 1240 kg/ha and 962 kg/ha of maize are achieved in the Northern and Upper West regions respectively as a result of adopting manure and chemical fertiliser application respectively to increase crop production. On a few occasions, yield increasing strategies are extended to legume crop production. Under such circumstances, up to 307 kg/ha of cowpea and 540 kg/ha of groundnut are realised as gains in yields. The adoption of these strategies in legume crop production is exclusively done in the Upper East region of the study area. Additional yield figures given above were obtained from farmers' memory recall, with regards to their experience in using these strategies.

The adoption of strategies to increase crop production requires the use of extra resources. This may be in terms of financial or material and human resources. For example, the use of animal droppings requires that these droppings are gathered and additional labour mobilised for more weeding. Responses from the structured questionnaire interviews indicated that where animal droppings were used, up to 5.25 Mt/ha of cow dung was usually applied every four years. The use of chemical fertilisers requires extra financial resources. In the case of chemical fertilisers, 5 bags (50 kg each) of compound fertiliser per hectare and 2.5 bags of Sulphate of Ammonia per hectare are used. In both situations and in the situation of other strategies such as compost application, extra weeding and crop residue management, extra labour resources are required. Table 4.4 below gives some information on additional inputs/resources required by each strategy.

Table 4.4: **Additional resources required by strategies adopted to increase crop production.**

Strategy	Additional inputs/resources	Quantity
Manure application	manure labour	5.25 Mt/ha 32 man days/ha
Fertiliser application	chemical fertilisers labour	5 bags (50kg) NPK + 2.5 bag SA/ha 34 man days/ha
Additional weeding	labour	20 man days/ha

Source: Compiled from structured questionnaire interview responses, 1996.

4.4 Cost-effectiveness of Strategies Adopted by Farmers

Given that extra labour and financial resources are required for the adoption of strategies to increase crop production, a partial budget analysis was carried out to compare the extra benefits and extra costs incurred in adopting these strategies. This analysis leads to a realisation of the third specific objective of this study. The use of chemical fertilisers and the application of manure have been considered for this analysis, as these two are the strategies frequently adopted by farmers.

Results of the partial budget analysis indicate that it is worth committing scarce labour resources to the adoption of manure application and chemical fertiliser use in Northern Ghana for purposes of increasing crop yields. Extra benefits of ¢42,333.03 and ¢4, 047.50 were obtained for the use of manure and chemical fertilisers respectively during the 1995 cropping season. Since the additional benefits exceeded additional costs it meant that these strategies should be adopted, where possible. Details of the partial budget analysis are shown in Table 4.5 and Table 4.6 below.

Table 4.5: **A partial budget of adopting manure application in sorghum-millet production in Northern Ghana**

Extra benefits/extra costs	Quantity	Unit price (¢)	Total value
Extra benefits			
Extra output of sorghum	417 kg	188.12	78,446.04
Extra output of millet	477 kg	179.37	85,559.53
Total extra benefits			**164,005.53**
Extra costs			
Manure	1750 kg	30.67	53,672.50
Extra labour	32 man days	1500	48,000.00
Total extra cost			**121,672.50**
Extra benefits less extra costs			**42,333.03**

Source: Prices from MOFA statistics; other data from structured questionnaire interviews.

Table 4.6: **A partial budget of adopting fertiliser application in maize production in Northern Ghana**

Extra benefits/extra costs	Quantity	Unit price (¢)	Total value (¢)
Extra benefits			
Extra output of maize	1125 kg	205.82	231547.50
Total extra benefits			
Extra costs			
compound fertiliser	5 bags	23,000.00	115,000.00
Ammonium sulphate	2.5 bags	15,000.00	37,500.00
Extra labour	34 man days	1,500.00	51,000.00
Total extra cost			**203,500.00**
Extra benefits - extra costs			**28,047.50**

Source: Prices from MOFA statistics; other data from structured questionnaire interviews.

Table 4.5 and table 4.6 indicate that the adoption of manure as a strategy to increase crop yields resulted in higher net benefits (¢42,333.50/ha) than the adoption of chemical fertilisers as a strategy (¢28,047.50). The use of chemical fertilisers definitely gives higher additional benefits than the use of manure. However, fertiliser use also attracts higher additional costs than manure use, with the result that net additional benefits are higher with the use of manure. Given that farmers have liquidity constraints the use of manure is a better option, provided adequate quantities of manure are available.

4.5 Assessment of the Sustainability of Maize-based Cropping Systems in Northern Ghana

A partial budget at a point in time indicates that the use of manure and chemical fertilisers in crop production in Northern Ghana are profitable; but sustainability is a long-term measure and must consider non-market resource flows.

Using the model outlined in chapter three for assessing the sustainability of a production system, Total Factor Productivity (TFP) indices have been computed to assess the sustainability of five maize-based cropping systems in Northern Ghana. The systems are:

1. Maize-Cowpea Rotation
2. Maize-Cowpea Relay intercropping
3. Maize-Cowpea Mix, continuously cropped
4. Sole Maize, continuously cropped and
5. Maize-sorghum-groundnut mixture, continuously cropped

The first four systems were managed under experimental conditions while the fifth system is the usual practice of farmers. The most important crop mixture in Northern Ghana is maize-sorghum-groundnut. Details of these cropping systems have been given in chapter three.

Before a discussion of the results, the data used for the TFP computations is presented. For the purpose of presentation the data has been classified into prices of outputs, prices of inputs, quantities of inputs used and quantities of output produced. The share of the cost of each set of inputs in total cost as well as the share of the value of each output in total revenue is also computed. The data is presented in Table 4.7 through Table 4.13 below.

Table 4.7: **Nominal prices (¢/kg) of outputs**

Year	Prices of:			
	Maize	Sorghum	Cowpea	Groundnuts
1984	9.89	12.19	43.08	53.20
1985	16.82	17.82	49.40	60.93
1986	23.75	24.00	66.51	66.25
1987	39.98	38.35	80.03	100.84

Source: Ministry of Food and Agriculture, Policy Planning Monitoring and Evaluation Department statistics (1995).

Table 4.8: **Nominal prices (¢/unit) of inputs**

Year	Prices of:						
	Labour (man day)	Urea (kgN)	Pesticide (litre)	Hoe (single)	Cutlass (single)	Maize seed (kg)	Cowpea seed (kg)
1984	35.00	14.05	1500	116	200	66.67	64.58
1985	70.00	14.05	2000	175	280	44.44	49.40
1986	90.00	23.33	2500	230	340	48.89	99.80
1987	112.50	40.48	3000	290	400	55.57	120.20

Source: Zegeye Hailu. (1990). The Adoption of Modern Farm Practices in African Agriculture. Nyankpala Agricultural Research Report No. 7. Verlag Josef Margraf Scientific Books, D-6992 Weikersheim, West Germany.

Table 4.9: **Quantity of labour input (man days/ha) used (land reparation to harvesting)**

Year	Labour input (man days) for:				
	MC-ROT	MC-REL	MC-MIX	M-MONO	Ma-So-Gn
1984	154	175	175	154	178
1985	136	157	167	136	178
1986	136	157	167	136	178
1987	136	157	167	136	178

Source: NAES Farm Management survey data (1990).

Table 4.10: **Quantity of output (kg/ha) produced under experimental conditions**

Year	Output of:							
	MC-ROT		MC-REL		MC-MIX		M-MONO	
	maize	cowpea	maize	cowpea	maize	cowpea	maize	cowpea
1984	2918		2790	227	2451	475	2967	-
1985		514	2325	297	2038	336	2459	
1986	3271		2526	60	2057	522	2573	
1987		956	2760	108	2057	492	2663	

Source: Rolf Hardter. (1989). Utilisation of Nitrogen and Phosphorus by Intercropping and Sole Cropping Systems of Maize and Cowpea on an Alfisol in Northern Ghana. Verlag Josef Margraf Scientific Books, D-6992 Weikersheim, West Germany.

Table 4.11: **Quantity of output (kg/ha) produced under farmers' practice (Maize-sorghum-groundnuts intercropped)**

Year	Output (kg/ha)		
	Maize	Sorghum	Groundnuts
1984	154	303	154
1985	196	248	122
1986	129	220	106
1987	142	470	218

Source: Runge-Metzger, A. and Diehl, L. (Editors). (1993). Farm Household Systems in Northern Ghana. Verlag Josef Margraf Scientific Books, D-6992 Weikersheim, West Germany.

As mentioned in chapter three, non-market resource flows play an important part in determining the sustainability of a cropping system. However the valuation of these resources has always been a problem. One reasonable approach is to consider the cost of replenishing such resources as their value if the possibility exists of replenishing them. The resource flows considered in this study is soil nutrient levels. The level of soil nitrogen is taken as a measure of non-market resource flows. As soil nitrogen is usually replenished through the application of chemical fertilisers, the cost of replenishing this nutrient through the application of urea is taken as its value.

Where there is a net negative flow of nitrogen, the situation is considered as a cost to the production system and the flow is treated as an input. On the other hand a net positive flow is considered a benefit to the production system and is therefore treated as an output. Table 4.12 below provides the resource flow over a four-year period (1984 - 1987).

Table 4.12: **Resource flow for five maize-based cropping systems in Northern Ghana**

Year	Resource flow (kg N/ha)				
	MC-ROT	MC-REL	MC-MIX	M-MONO	Ma-So-Gn
1984	-	-	-	-	-
1985	-20.8	3.7	-16.2	1.4	-
1986	-23.5	-17.0	-28.2	-33.9	-
1987	-	-	-	-	-

Source: Rolf Hardter. 1989. Utilisation of Nitrogen and Phosphorus by Intercropping and Sole Cropping Systems of Maize and Cowpea on an Alfisol in Northern Ghana. Verlag Josef Margraf Scientific Books, D-6992 Weikersheim, West Germany.

Resource flows were recorded for 1985 and 1986 for the experimental plots. From Table 4.12 above, resource flows are negative except for the maize-cowpea relay system and sole maize system which have positive resource flows in 1985. No data is available for the cropping system under farmers' practice. TFP indices of this system do not therefore take resource flows into account.

Other relevant information used in the TFP computations include the quantity of planting material used, quantity of pesticide and depreciation cost for the use of knapsack sprayers in cowpea production. In all experimental plots planted with maize whether as a sole crop or in combination with cowpea, 20 kg/ha of maize seed was used. Under Ma-So-Gn intercropping 10 kg/ha of maize, 10 kg/ha of sorghum and 15 kg/ha of groundnuts were used as seed during each cropping season. Cowpea was planted at the rate of 15 kg/ha in pure stands and 7.5 kg/ha in maize-cowpea mixtures and maize-cowpea relay systems. A litre of pesticide per hectare was used in cowpea production whether in pure stands or in combination with maize. One hoe and one cutlass per hectare per season has been used in the computations.

Although it is important that the productivity of a system is maintained in the long term, in the short run an agricultural system must at least meet its costs in order to survive. For that reason, the profitability (ratio of aggregated output values to input costs) of a system must be considered (Rayner and Welham, 1995).

Using the profitability equation specified in chapter three, profitability ratios have been calculated for each cropping system over the four-year period of the study. Except in the case of maize-sorghum-groundnuts intercropping system, all the profitability ratio values for each of the other systems are greater than unity. This means that the value of output is greater than the cost of production, a measure of profitability.

As shown in Table 4.13 below, MC-MIX is the most profitable system in 1984 followed by MC-ROT, M-MONO and MC-REL in that order. M-MONO is the most profitable system in 1985 and 1987 while MC-ROT is the most profitable in 1986. Ma-So-Gn is the least profitable system for all years.

Table: 4.13: **Profitability ratios for five cropping systems in Northern Ghana**

Year	Profitability ratios for:				
	MC-ROT	MC-REL	MC-MIX	M-MONO	Ma-So-Gn
1984	3.796	3.338	4.121	3.595	1.773
1985	1.624	3.196	3.108	3.452	1.070
1986	4.947	2.804	3.754	3.716	0.851
1987	3.481	3.961	4.206	5.234	1.985

Given that in the short term the cropping systems under consideration were found to be profitable, TFP indices were computed to assess their long term productivity. This achieves the broad objective of the study. The TFP computations are based on 1985 constant prices. Two sets of TFP indices were calculated. The first set of indices took natural resource flows into consideration. The level of soil Nitrogen was treated as a measure of natural resource flows. Even though Phosphorus and Potassium were mentioned in the introduction as limiting factors to crop production in Northern Ghana, these have not been taken into account. This is because their levels did not affect crop yields in the experiment that provided the database for this study. Information from the experiment suggests that adequate amounts of these nutrients must have been present in the soil over the four years period of the experiment. The experiment was started on a previously fallowed land. Fallow lands are known to have adequate amounts of Phosphorus and Potassium.

Results of the TFP calculations are presented in Table 4.14 and Table 4.15 below. It has been stated earlier that for a production system to be sustainable TFP indices for it must remain constant or show an increase over time.

Table 4.14: **TFP Indices for five Maize-based Cropping Systems in Northern Ghana (natural resource flows considered)**

Year	Total Factor Productivity Indices for:				
	MC-ROT	MC-REL	MC-MIX	M-MONO	Ma-So-Gn*
1985	0.318	0.372	0.623	0.289	0.384
1986	0.610	0.382	0.721	0.323	0.299
1987	0.343	0.390	0.683	0.350	0.643

* Resource flows were not considered for this system due to unavailability of data.

Table 4.15: **TFP indices for five Maize-based Cropping Systems in Northern Ghana (natural resource flows not considered)**

Year	Total Factor Productivity Indices for:				
	MC-ROT	MC-REL	MC-MIX	M-MONO	Ma-So-Gn
1985	0.318	0.372	0.631	0.278	0.384
1986	0.640	0.387	0.727	0.346	0.299
1987	0.337	0.385	0.669	0.343	0.643

The results presented above indicates that the systems of maize grown in rotation with cowpea (MC-ROT) and maize intercropped with cowpea (MC-MIX) are not sustainable whether natural resource flows are taken into account or not. The systems of maize grown in relay with cowpea (MC-REL) and sole maize continuously cropped (M-MONO) are found to be sustainable when natural resource flows are considered. However none of the systems is sustainable when natural resource flows are not taken into consideration. The system of maize-sorghum-groundnut intercropping is also found to be non-sustainable.

When natural resource flows are accounted for, all the cropping systems under the experimental conditions show an increase in TFP index between 1985 and 1986. Between 1986 and 1987, the systems of maize-cowpea rotation and maize-cowpea mix intercropping both show a decline in TFP index. The systems of maize-cowpea relay intercropping and sole maize however continue to show an increase in TFP index between 1986 and 1987. Table 4.11 indicates that there was consistent negative net natural resource flows for maize-cowpea rotation and maize-cowpea mix intercropping systems in 1985 and 1986. In the case of maize-cowpea relay and sole maize positive net natural resource flows in 1985 were followed by net negative flows in 1986. Net positive resource flows may therefore be responsible for the result that maize-cowpea relay and sole maize cropping systems are sustainable.

Table 4.14 illustrates that when natural resource flows are not accounted for trends in TFP indices between 1985 and 1986 are similar to trends with resource flows accounted for, except in the maize-sorghum-groundnut system. This system shows a decrease in TFP index between the two years (1985 and 1986). The four experimental systems show a decrease in TFP indices between 1986 and 1987 while the farmers' practice of maize-sorghum-groundnut intercropping shows an increase in index over that period.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Crop rotations involving maize and cowpea have been recommended on agronomic grounds as a way of stabilising food production in Northern Ghana. This was done against the background that the cultivation of intercrops leads to interplant competition resulting in yield reduction. An assessment of the long term productivity of the cropping systems shows that maize-cowpea relay intercropping and sole maize continuously cropped are sustainable. On the other hand maize-cowpea rotation, maize-cowpea mixed intercropping as well as maize-sorghum-groundnut mixed intercropping are not sustainable.

From the trends in TFP indices and natural resource flows it can be said that net negative resource flows are responsible for the non-sustainability of maize-cowpea rotation, maize-cowpea mix intercropping and maize-sorghum-groundnut intercropping systems in Northern Ghana. Although data on resource flows for the maize-sorghum-groundnut system was not available for analysis, the effect of resource flows suggest that net negative resource flows may be responsible for its non-sustainability. The fact that these systems are maize-based means that legume crops (that are supposed to improve the nutrient status of the soil) are planted at low densities. In effect these legumes do not return the expected amount of soil nutrients either through fixation or mineralisation of legume crop residue.

Hardter (1989) acknowledged the need to plant cowpea at higher population densities than those used in the experiment in order to fully utilise the beneficial effects of large amounts of cowpea residue during the succeeding cropping period. Thus planting cowpea at higher population densities in rotation or in mixed intercropping with maize may move these systems towards sustainability.

Planting a at higher plant population densities however implies the need for additional seed and labour to plant the additional seed. Providing for additional seed may not pose any problems as farmers usually obtain seed from their own stocks. However, the need for additional labour would be a problem as farmers experience labour bottlenecks during production.

Continuous cropping of sole maize and maize-cowpea relay intercropping hold some promise for sustainable crop production in Northern Ghana. There are however implications for recommending these systems to farmers. Both systems require purchased inputs in the form of chemical fertilisers for maize and insecticides for cowpea. As much as 80 kg N/ha in the form of urea was used in the experiment that revealed these systems to be sustainable. However, farmers in the study area who use chemical fertilisers apply less than 80 kg N/ha for reasons of liquidity constraints. The results also imply that farmers who grow maize and cowpea in rotation, maize-cowpea mixture and maize-sorghum-groundnut would have to take steps to forestall the soil nutrient imbalances which make these systems non-sustainable.

5.2 Recommendations

The recommendations that follow are made in the light of the findings and conclusions of this study. It has been stated that the cropping systems of Northern Ghana have opportunities for being sustainable with implications for additional resources in the form of planting materials, labour and financial resources. Labour has the highest cost share in all five cropping systems assessed (Appendix 1). The share of labour in total cost ranges from 50% to over 70%. As the case is, if labour-saving devices are adopted it will greatly enhance the sustainability of the cropping systems. In the light of this the use of bullock traction for land preparation and weed control which are labour-intensive is recommended.

The advantages of crop rotation and intercropping can be realised through a planned rotation of intercrops. Cereal-legume mixtures which are very popular in the study area may be rotated with sole legume crops where these are grown. The legume crop residue that remains after harvest need to be worked into the soil to fully realise the benefits of legume cropping during the succeeding cropping season. Besides, legumes have to be planted at high densities to provide adequate quantities of residue to improve soil fertility.

Information from the structured questionnaire interviews indicate that there is poor agricultural extension contact with farmers. Yet good extension contact is very necessary so as to enable farmers employ modern agricultural practices that will increase output at lower cost. If extension education is improved through radio broadcast in local languages, home and farm visits the productivity of the cropping systems and hence their sustainability would be enhanced.

On the basis of the sustainability of the cropping systems investigated, it is recommended that farmers of Northern Ghana should plant sole crop maize or maize-cowpea in relay.

5.3 Suggestions for future research

The database for assessing the sustainability of agricultural production systems in Ghana is very weak. Crop yields at the district, regional or national level are reported on the basis of sole crops whilst intercropping widely practised in Northern Ghana in particular. Data on soil nutrient levels in relation to crop yields are difficult to come by. In this regard there is a need for the initiation of long term experiments to build up a comprehensive database for assessing the major cropping systems of Ghana and Northern Ghana in particular. Such a database will include information on:

Quantities of inputs used, quantities of main products produced, quantities of byproducts produced, levels of major crop nutrients in the soil at the beginning and the end of each cropping season. The prices per unit of input used and output produced are also relevant. These should be available on an annual basis.

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Appendix 1A:

Revenue and cost shares used in the computation of TFP indices for Maize cowpea rotation system (1984 to 1987)

Year	Revenue share		Cost share			
	Crop output	Resource flow	Materials	Labou r	Implements	Resource flow
1984	1.000	0.000	0.208	0.709	0.083	0.000
1985	1.000	0.000	0.203	0.748	0.049	0.004
1986	1.000	0.000	0.184	0.779	0.036	0.003
1987	1.00	0.000	0.309	0.645	0.046	0.000

Appendix 1B:

Revenue and cost shares used in the computation of TFP indices for Maize-cowpea relay intercropping system (1984 to 1987)

Year	Revenue share		Cost share			
	Crop output	Resource flow	Materials	Labour	Implement s	Resource flow
1984	1.000	0.000	0.397	.0547	0.056	0.000
1985	0.999	0.001	0.260	0.694	0.046	0.000
1986	1.000	0.000	0.305	0.656	0.039	0.000
1987	1.000	0.000	0.341	0.625	0.034	0.000

Appendix 1C:

Revenue and cost shares used in the computation of TFP indices for Maize-cowpea mix intercropping system (1984 to 1987)

Year	Revenue share		Cost share			
	Crop output	Resource flow	Materials	Labour	Implements	Resource flow
1984	1.000	0.000	0.409	0.533	0.058	0.000
1985	1.000	0.000	0.268	0.671	0.047	0.014
1986	1.000	0.000	0.296	0.635	0.040	0.030
1987	1.000	0.000	0.354	0.611	0.035	0.000

Appendix 1D:

Revenue and cost shares used in the computation of TFP indices for Continuous sole cropped maize system (1984 to 1987)

Year	**Revenue share**		**Cost share**			
	Crop output	Resource flow	Materials	Labour	Implements	Resource flow
1984	1.000	0.000	0.301	0.660	0.039	0.000
1985	0.999	0.001	0.168	0.794	0.038	0.000
1986	1.000	0.000	0.173	0.744	0.035	0.048
1987	1.000	0.000	0.214	0.752	0.034	0.000

Appendix 1E:

Revenue and cost shares used in the computation of TFP indices for Maize-sorghum-groundnut mix intercropping system (1984 to 1987)

Year	Revenue share		Cost share			
	Crop output	Resource flow	Materials	Labour	Implements	Resource flow
1984	1.000	0.000	0.135	0.824	0.042	0.000
1985	1.000	0.000	0.089	0.879	0.032	0.000
1986	1.000	0.000	0.081	0.887	0.032	0.000
1987	1.000	0.000	0.100	0.870	0.030	0.000

Appendix 2: Sample Questionnaire

SUSTAINABILITY OF MAIZE-BASED CROPPING SYSTEMS IN NORTHERN GHANA

QUESTIONNAIRE FOR INDIVIDUAL FARMERS

GENERAL INFORMATION

Village: District: Region:

Name of farmer: Age: Sex:

Educational level:

Marital status: [ ] Single [ ] Married

[ ] Divorced [ ] Widowed

Size of household - males: females:

Location of farm(s): [ ] Compound

[ ] Bush

[ ] Both bush and compound

Main off-far income generating activity: ....

For how long have you been farming in this village?

No. of years: ....

CROP PRODUCTION

1. What crops do you grow?

	Compound field	Bush field
Main subsistence crops		
Main cash crops		
Other crops		

2. How many acres of land do you cultivate every year? ....

3. What area of land do you fallow every year? ....
   Length of fallow period: ....

4. How did you acquire the land on which you farm?

   [ ] Inherited from a family member
   [ ] Acquired through village chief
   [ ] Appropriate don my own right

5. What expenses did you incur (cash/kind) in acquiring the land: ....

   ....

6. What expenses do you incur every year for use rights of the land? ....

   ....

7. List four main constraints to crop production on your farm (start with the

   most serious to the least serious): ....

   ....

CROPPING SYSTEMS AND CROPPING PATTERNS

8. What crops do you normally grow on newly cleared land? ....

9. Over the last twenty years has there been any change in the crop mixtures that you plant?

   State the change: ....

10. What is the sequence of crops grown on a newly cleared piece of land

    until it is fallowed? ....

    ....

11. Has this sequence always been the same since your stay in this village?

    If no, indicate the changes: ....

12. Do you grow any new crops that you did not grow in the past? Name

    them: ....

    ....

13. Why did you decide to grow these crops? ....

14. Are there any crops you used to grow that you no longer grow? Name

    them: ....

    ....

15. Why do you not grow them any longer? ....

SUSTAINABILITY ISSUES

16. What has been the trend of crop yields on you major food crop fields

    (in the last 10 years) from season to season?

    [ ] Increasing [ ] Constant [ ] Decreasing

17. What accounts for the observed trend above? ....

    ....

18. What has been the trend of yields on your major food crop fields from

one round of rotation to the other?

    [ ] Increasing [ ] Constant [ ] Decreasing

19. Can crop yields be increased? [ ] Yes [ ] No

20. If no, why? ....

    ....

21. If yes, how? ....

....

22. What measures do you take to ensure that yields do not decline on this field? (list measures as alternatives or as measures to be applied together):..

....

23. What is the source of information with regard to (22) ? ....

....

24. How much more does it cost you to implement these measures? Give additional inputs required and the cost involved.

Input required	Amount (quantity)	Cost per season	Labour input

25. What constraints do you face in carrying out the measures in (22) above?...

....

26. Have these measures been effective at injcreasing your crop yields?

[ ] Yes [ ] No

27. How much more yield do you get from the measures each year? No. of bags per acre: ....

28. Give the yield of by-products: ....

RESEARCH-EXTENSION-FARMER LINKAGE

29. Does any body come to talk to you about your crop production activities? [ ] Yes [ ] No

30. Which organisation do they come from? ....

31. What do they talk about in crop production? ....

....

32. Have you heard of Nyankpala? [ ] Yes [ ] No

33. What do they do there? ....

Make any comment you have on this interview: ....

....

....