# THE DETERMINANTS OF ADOPTION, AND IMPACT OF IMPROVED SORGHUM VARIETIES IN THE UPPER-WEST REGION, GHANA

BY

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# DECLARATION

I do hereby declare that except for references to other peoples work which have been duly cited, the work presented in this thesis: "THE DETERMINANTS OF ADOPTION, AND IMPACT OF IMPROVED SORGHUM VARIETIES IN THE UPPER-WEST REGION, GHANA", is the result of my original work.

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



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# DEDICATION

To my Parents, Na Jatoe-Moni Kangawee II and Kurimah Badingu Daana, for their support and guidance.

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To God be the glory!

# ABSTRACT

The production of sorghum, one of the most important food crops with multiple uses in the savanna zone of Ghana, has been bedevilled with several problems. The most important problems are low yields, lack of improved varieties and *striga* infestation. These problems led to research efforts at the Savanna Agricultural Research Institute to produce improved high yielding sorghum varieties that are adapted to the socio-economic and agroecological conditions of northern Ghana. This study set out to describe the adoption of improved sorghum varieties over the years; identify the various determinants of adoption, and intensity of use; and to identify the varietal traits or characteristics that are desired by farmers. Finally, the study also estimates the rate of return to sorghum research.

The Probit and Tobit models are used to identify the determinants of adoption and the intensity of use of improved sorghum varieties respectively. The logistic curve is used to describe cumulative adoption while the economic surplus model is used to estimate the rate of return to sorghum research. A characteristic S-shaped diffusion curve is obtained with an estimated rate of diffusion of 0.3% for the period 1988-1998.

It is found that age, available family labour, non-farm income, farmers perception about the varieties, farm size and farm type positively influence adoption while extension visits, the length of the fallow period and distance to the nearest purchase point for improved seed affect adoption negatively. Age of farmer, available family labour, farmers' perception about the varieties and farm size exert a positive influence on intensity of use while fallow period and the distance to the nearest purchase point for improved seed exert a negative influence. The estimated rate of adoption was 0.40 (40% of sampled farmers). The intensity of use, measured as the proportion of sorghum area under improved varieties, was 0.56 (56.33%) following a positive decision. It is found that farmers' choice of variety to plant depends on yield, maturity period, market value, taste and suitability for local dishes. The rate of return to sorghum research is estimated at 8%. Sensitivity analysis shows that increasing the rate of adoption to 1% of sorghum area would raise the rate of return to 109%.

For improved adoption and impact of improved Sorghum varieties, the study recommends the following measures:

(i) strengthening of research-extension-farmer linkages,

(ii) increased farmer education about the varieties,

(iii) improvement in infrastructure and input distribution networks,

(iv) active involvement of farmers in acquisition of inputs,

(v) increased sensitivity of research to farmer resource levels,

(vi) empowering farmers to engage in non-farm income generating activities and

(vii) a more concerted effort at technology transfer.

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# LIST OF ACRONYMS

| | |
|---|---|
| CIMMYT | International Maize and Wheat Improvement Center |
| CIP | International Potato Center |
| GTZ | German Agency for Technical Co-operation |
| IARCs | International Agricultural Research Centres |
| ICRISAT | International Crops Research Institute for the Semi-Arid Tropics |
| NAES | Nyankpala Agricultural Experiment Station |
| NARS | National Agricultural Research System |
| NGOs | Non-governmental Organisations |
| SARI | Savanna Agricultural Research Institute |
| SGA | Seed Growers Association |
| TFP | Total Factor Productivity |
| UWR | Upper West Region |
| WARDA | West Africa Rice Development Association |

# CHAPTER 1

# INTRODUCTION

## 1.1 Background

Sorghum (sorghum *bicolor (L) Moench*) commonly called "guinea corn" in West Africa, is an important food crop with multiple uses. Sorghum is an important and widely cultivated cereal crop in the Guinea savanna zone of Ghana. According to an Agricultural Census in 1986, it was grown on some 181 thousand hectares. Sorghum is only exceeded by maize in the Northern Region and by millet in the Upper East Region in terms of area cultivated with cereals (MOFA, 1997). The planting can be on the flat, on ridges or on mounds depending on the crop mixtures. Sorghum is planted between mid to end of May and early June in the Guinea savanna zone.

In Ghana, sorghum is produced in the Guinea Savannah zone, which occupies the three Regions of Northern Ghana. It is also grown to a limited extent in Brong-Ahafo, Volta and Greater Accra Regions. Traditionally, it is grown as a rain-fed crop in mixtures with other cereals and legumes. It is only in the Upper West Region that sole crops of sorghum are common (Schipprack and Mercer-Quarshie, 1984).

Although sorghum production is most prevalent in Northern Ghana the Upper West and Northern Regions are the major producers of the crop. The Upper West Region ranks second in the production of sorghum (MOFA, 1997). In fact, the Upper West Region is in the heart of the area often described as the "cereal basket" of the country, which produces the national supply of sorghum and millet as well as groundnut and cowpea (Terbobri et al, 1998). Table 1 shows sorghum production statistics for the region over the period 1989-1998.

Table 1:Sorghum Production Statistics for the Upper West Region 1989-1998

| *Year* | *Output (MT)* | *Area cultivated (Ha)* | *Yield (MT/Ha)* | *As % of National Output* |
|---|---|---|---|---|
| 1989 | 49000 | 75700 | 0.65 | 22.8 |
| 1990 | 53942 | 64217 | 0.84 | 39.7 |
| 1991 | 58776 | 74400 | 0.79 | 24.3 |
| 1992 | 63434 | 73816 | 0.86 | 24.9 |
| 1993 | 102900 | 73500 | 1.40 | 31.3 |
| 1994 | 108944 | 78098 | 1.39 | 33.6 |
| 1995 | 109498 | 84200 | 1.30 | 30.4 |
| 1996 | 110413 | 88000 | 1.25 | 31.2 |
| 1997 | 106623 | 89230 | 1.19 | 32.1 |
| 1998 | 116461 | 94410 | 1.23 | 34.7 |

Source: Derived from PPMED statistics

A considerable amount of the sorghum produced is consumed directly as human food. The grain is mainly used in preparing *koko*[1], *tuo zaafi*[2] (TZ), and *maasa*[3] The leaves provide fodder for farm animals while the stalks are used in fencing, roofing, as fuel and

[1] Porridge prepared from dough/fine flour.
[2] Prepared by stirring and addition of flour to porridge until it is cooked and viscous; served with soup.

for weaving baskets and mats. In addition, the ash from burnt sorghum stalks provides potash for soap making, a cottage industry for some rural women (Songsore and Denkabe, 1995).

Above all, sorghum is utilised in the production of a local opaque beer known as *pito*. *Pito* brewing, an important cottage industry for women in Northern Ghana has assumed greater commercial proportions throughout the country. This can be seen in the rise in the number of *pito* bars in all major towns in Southern Ghana. Besides, it has been established that sorghum is usable and has been used in malting and brewing clear lager beer in Nigeria, Eastern and Southern Africa, Mexico, Germany and Belgium (Atokple, 1992), and hence could become an import substitute in the brewing industry in Ghana. The crop also enters into considerable inter-regional trade between the Upper West region and southern Ghana.

The production of sorghum and other crops in the Upper West Region is in the hands of small-scale resource-poor farmers, whose farms on the average hardly exceed 2.0 hectares per household. Majority of the people in this area live in rural homesteads, where the production of crops and livestock is their main source of livelihood. These subsistence/ peasant farmers use little external input (such as improved seed and chemical fertilizers) and often sell the little surplus of production in excess of household consumption needs to supplement household income.

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[3]Cake prepared from fermented dough.

Despite the importance of sorghum in the Upper West Region, and the country at large, production of the crop is hampered by several edaphic, physiological and biological factors culminating in extremely low output per unit area. Depending on the year, average yields range between 600 and 1400kg/ha in the Region (Table 1). These yields are rather low as compared to the achievable 2 Mt/Ha reported by Abatania (1999). Specific constraints include declining soil fertility, lack of improved varieties, and *striga* infestation (Terbobri et al., 1998). These constraints triggered the inception of the sorghum (and millet) improvement programme at the Nyankpala Agricultural Experiment Station (NAES), now the Savannah Agricultural Research Institute (SARI), over three decades ago.

**1.2 Sorghum Production and Improvement in Ghana**

The most common land races of sorghum in Ghana are Guineense, Caudatum and Bilocor. However, the loose panicled Guinea type (also known as Belko type in Ghana) with white corneous grain is the most widely cultivated and most widely adapted of all the races (Frolich and Buah, 1991). These races are very tall, highly photoperiod sensitive and late maturing. The evidence suggests that there has been considerable selection for good weathering and storage qualities (Harlan and de Wet, 1972). The hard and corneous seeds suffer little or no damage from insects even under the most primitive storage conditions. Mould damage is also reduced under wet conditions probably due to the open pendulous panicles and gaping glumes.

Farmers grow mostly the tall photoperiod sensitive cultivars and risk of complete crop failure exists should the rains stop early, since these cultivars often flower very late.

However, these types are preferred because their long stalks are used for fencing, building and making baskets, hats and barns. They also have good seed quality, that is, hard, vitreous endosperm (Frolich and Buah, 1991). Farmers usually retain large and uniform panicles with large grains for use as seed stock for the next planting season. Farmers generally are interested in stable grain yields and consequently, cultivate a mixture of two or more cultivars on the same piece of land.

The grain yield of traditional sorghum varieties is very low. It ranges between 600 and 1400kg/ha. However, with the use of improved varieties and better production practices, average yields can be pushed to between 2000 and 3000kg/ha (Frolich and Buah, 1991).

### 1.3 Problem Statement

Since the early 1960s, developing countries, assisted by foreign donors, have invested resources to strengthen their agricultural research systems. Agricultural Economists have often supported this strategy, arguing that technological innovations in agricultural production drive the development of the agricultural sector, which in turn contributes to the development of the general economy (Mellor, 1966; Eicher and Staatz 1984).

In Ghana, one such example is the Savanna Agricultural Research Institute (SARI), with support from the Ghana Government and the Federal Republic of Germany through the Deusche Gesellschaft fur Technische Zusammenarbeit (GTZ). An important component of the research mandate of SARI is the Sorghum Improvement Programme. In line with its mandate for research in Northern Ghana, the Savanna Agricultural Research Institute has focused attention on removing the constraints associated with sorghum production so as to step up sorghum production in the mandate area. The objective of the sorghum improvement programme is to develop high yielding varieties of sorghum with specific adaptation to different ecological conditions of the savanna. In fact, the programme is to identify and develop early and medium maturing varieties that have good grain quality (suitable for local dishes) and are resistant/tolerant to the major pests and diseases of sorghum.

Through SARI's sorghum improvement programme a number of improved varieties have been released to farmers after being tested on-farm. Notable among such varieties are Naga White, Framida, Kapaala, Kadaga and Dorado (Terbobri et al, 1998). The superiority of these varieties over the local varieties, in terms of yield, maturity period and *striga* tolerance, has been proven by researchers in on-farm trials. However, the picture on the ground, in terms of adoption, is unknown and yet to be examined. The extent to which farmers have adopted these varieties is not known. The factors affecting adoption or non-adoption are also not known, neither are the constraints to adoption.

In addition, the ever-increasing scarcity of resources has prompted donors (and governments) to be much more results oriented. Priorities must be set as choices have to be made. Investments in agricultural research must therefore be justified in terms of returns to these investments. Thus it is common to have donors asking for evidence of people-level impacts of their investments in agricultural research. However, the benefits of agricultural research may be delayed, gradual and widely dispersed and hence may not be easy to capture. Economic impact studies provide the tools for measuring these people-level impacts, but no such studies have been conducted to assess returns to sorghum research. Thus the basic question that arises is whether or not past investments in sorghum research at SARI have generated sufficient returns to justify continued investment.

## 1.4 Objectives

The general objective is to evaluate the adoption and impact of improved sorghum varieties introduced by the Savannah Agricultural Research Institute (SARI) and provide the needed information for researchers and extension organisations to guide their work. The specific objectives are to:

(i) describe the pattern or spread of adoption;

(ii) determine the factors that influence the adoption of improved sorghum varieties;

(iii) estimate the rate and intensity of adoption;

(iv) compare quality of new and traditional varieties with those preferred by farmers;

(v) estimate the rate of return to research into improved sorghum.

## 1.5 Relevance of study

Though research efforts have made available improved varieties of sorghum to farmers, the adoption of these technologies is yet on a small scale and largely unknown. Currently information relating specifically to the adoption of improved varieties of sorghum in Ghana is not available. No attempt has been made to document the adoption diffusion pattern and use intensity of these improved technologies, and hence their impact. The provision of micro level data or information of this sort is critical for the direction and prioritization of future sorghum research. It will help research and extension to be more effective in responding to farmers' needs. Moreover such information is necessary for financial support for future sorghum research as donors get more and more results oriented. In addition, this study may provide lessons for other crop improvement programmes, both here in Ghana and elsewhere. Hence the study is very germane.

## 1.6 The Study Area/Location

The Upper West Region, in the northwestern area of the country with its capital at Wa, was carved out of the former Upper Region in 1983. It consists of five administrative districts made up of Wa, Nadawli, Lawra, Jirapa-Lambussie and Tumu. The Region is bounded to the east by the Upper East Region, Northern Region to the south, Burkina Faso to the north and Cote d'Ivoire to the west. The region covers a total land area of 18,476 square kilometres and had an estimated population of 439,161 persons in 1984. Its population density ranges between 20 and 60 persons per square kilometre. The economic base of the area hinges on agriculture with over 80% of the population depending on farming for their livelihood (Ghana Statistical Service,1984). It is the most backward region in terms of income per capita and access to basic needs. In fact the overall picture is one of both absolute and relative poverty (Songsore and Denkabe, 1995).

This region lies within the Guinea Savanna belt often described as the Savanna high plains with an average altitude of between 180 and 300 metres above sea level. The area has a generally gently undulating landscape where topography is no barrier to agriculture (Dickson and Benneh, 1970). The area is generally well drained with the main rivers being the Black Volta and its many tributaries to the west and, the Kulpawn and its tributaries to the east. The two main soil types are the ground water lateritic soils and the savanna orchrosols along the Black Volta.

The most critical factor affecting agricultural activity, rainfall, is characterised by seasonality, variability and unreliability. The rainy season extends from April to October with an annual total of about 115cm (Dickson and Benneh, 1970). This situation limits peasants to only one harvest a year towards the end of the rainy season.

The main farming systems are bush fallow and compound farming. Bush fallowing is a system of rotation of crops or fields and bush. After a plot of land has been cultivated for a number of farming seasons, it is abandoned and allowed to revert to secondary vegetation. The length of this resting period depends on how pressing the need is for land for cultivation. In sparsely settled areas it may be as long as fifteen or more years while in densely settled areas it may be as short as three years (Dickson and Benneh, 1970). Compound farming is a permanent system in which the land around the individual compound household is manured and cultivated intensively by the members of the household for their staple crops. This system is most common in the densely settled areas of Lawra and Jirapa-Lambussie districts.

Land is controlled through family ownership, a system that guarantees every member of a household access to a plot of land from what the household already enjoys use rights. This situation varies, but there is no sharecropping neither is there buying and selling of land except in the towns, for housing purposes. It should be noted that women do not own land.

The seasonality in rainfall often leads to soil drought during critical periods in plant growth thereby reducing yields drastically from year to year. Thus the region faces a perennial long "season of hunger" with low food stores and shortages from March to about July (Hunter, 1967; Songsore, 1985). During this period, those peasants who undertook distress sales at harvest for their cash mediated subsistence consumption often have to repurchase food at higher prices.

In order to turn this situation around and ensure food security, Songsore and Denkabe (1995) suggest a people oriented development strategy, one which is self-reliant and sustainable, and taps strength from within, relying on resources locally available and technologies adapted to the area. They argue that the problem with the region's agriculture is the use of primitive tools and the lack of improved varieties and breeds to enhance productivity, adding that the available technologies are often technocratic, top-down style alien ones beyond the reach of the majority of small farmers. The current study seeks to evaluate the case of improved sorghum varieties from the adaptive research efforts of the Savanna Agricultural Research Institute.

The Upper West Region was chosen for this study mainly because it is the only region within the mandate area of the Savanna Agricultural Research Institute where these improved sorghum varieties were vigorously promoted by the defunct Global 2000 Sorghum Programme.

### 1.7 Organisation of Study

The study is organised into five chapters. Chapter 2 covers an exploration of literature on adoption and impact of innovations. It discusses, among other things, the determinants of adoption and impact of agricultural technologies. Chapter 3 provides coverage of the theoretical framework for the study, methods of estimation, the data requirements and data collection procedures used. The results of the analysis are presented and discussed in the fourth chapter, while chapter 5 presents the summary, conclusions and policy implications of the study.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Introduction

In this section literature on adoption and the impact of innovations in agriculture is reviewed. The chapter seeks to identify some of the factors most likely to influence farmer adoption behaviour as well as those affecting the impact of new technologies. It explores the methodologies employed by similar past studies and discusses some of their findings. The review of literature is also expected to give direction as to the choice of explanatory variables to include in the models and the most appropriate methods of analysis to use.

## 2.2 History of Adoption Studies

Griliches conducted one of the earliest adoption studies on hybrid corn in the United States of America (Griliches, 1957). His pioneering role reflects clearly in part of his conclusion:

> "this study does indicate that at least the process of innovation, the process of adapting and distributing a particular invention to different markets and its acceptance by entrepreneurs, is amenable to economic analysis. It is possible to account for a large share of spatial and chronological differences in the use of hybrid corn with the help of *economic* variables"[1] (Griliches, 1957, Econometrica 25 p522).

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[1] Griliches, Zvi (1957) "Hybrid Corn: An Exploration in the Economics of Technological Change" Econometrica 25:501-522

Since the pioneering work of Griliches, considerable attention has continued to be devoted to the adoption of new agricultural technologies. To mention a few, Mansfield (1961) examined the diffusion of new manufacturing techniques among major industrial firms; Shaka and Flinn (1985) studied the adoption of modern varieties and fertilizer use on rice in Nepal; Akinola (1987) studied the adoption of tractor hiring scheme in Nigeria; Hailu (1990) studied adoption of improved seed varieties, bullock traction technology and agrochemicals in northern Ghana; Zinnah et al (1993) studied the adoption of improved mangrove swamp rice technology in West Africa; Hounkpe (1999) studied the adoption of narrow maize crib in Southern Benin.

Although the importance of technical innovations is well understood, the factors affecting the adoption of innovations are less obvious. But one would expect comparative advantage considerations (dynamic as well as static) to be crucial in determining patterns of adoption of innovations. This was observed by Griliches (1957), Manfield (1961) and Nelson (1968). However, most studies of the adoption behaviour of individual farmers use static analysis that relates the degree of adoption to factors affecting it.

The tendency has been to take agriculture as a static receptacle into which we pour new production technology as a social input. The technology is usually regarded as appropriate, and farmers are viewed as static units to which technology is to be transferred, with the result that they will all be better off (Schuh, 1989). However, things do not work this way. New technology has implications for resource productivity and hence relative resource allocation. Also, the farmer is a social being with well-defined tastes and preferences. Besides, in subsistence agriculture, profit maximization may not be the primary objective. This realisation has led to an evolving new trend in which several factors, including the institutional, environmental and the technical characteristics of the technology itself, are being examined in adoption studies.

**2.3 Types of adoption Studies**

The form and focus of an adoption study depends on the purpose of the study. Whatever the purpose, however, the results often require careful analysis and presentation. Generally, adoption studies may seek to document the degree of adoption, especially where the researcher is interested in the rate of progress of technology generation effort. On the other hand, adoption studies may want to analyse adoption patterns and try to identify/explain the determinants of adoption.

There are two basic types of adoption studies. The first explains adoption by seeking out the opinions and observations of farmers. This type of adoption study tries to explain farmer decision-making with regard to innovation adoption through farmer decisions. It relies on the fact that farmers usually know what they like and what they do not like about a new technology and are able to express their opinions. These opinions reflect their own experience (CIMMYT, 1993). One of the most commonly used tools (in this qualitative kind of analysis) is "decision trees" (CIMMYT, 1993). Decision trees are a method of representing a farmer's choice about a new technology as series of decisions, arranged in a hierarchy (Gladwin, 1989).

The second makes use of statistical comparison of the farmers' adoption behaviour with various characteristics of the farmers' environment. Farmers may be asked to describe these characteristics and the researcher then tries to trace the causal links, using various statistical tests. These tests aid the researcher to provide a consistent, coherent, and logical explanation for the adoption patterns observed.

The simplest method in use here is the contingency tables (especially where the variable/ characteristic is nominal or categorical), using the chi-square test. Where the variable is continuous, one option is to compare means for adopters and non-adopters. The relevant test here is the t-test. Correlation and regression analyses are employed where adoption itself is represented as a continuous variable. In dealing with multivariate relationships, researchers often call upon multiple regression techniques. Two related multifactorial analytical techniques that are particularly useful for adoption studies are logit and probit analysis. Another useful technique is the Tobit model.

**2.4 Determinants of Adoption**

Through various national and international efforts, several new agricultural technologies including improved varieties of some major cereals "suitable for many of sub-Sahara Africa's agro-ecological zones"[2] are made available. For instance, Hailu (1990) reported the existence of thirteen different improved varieties of four crop species among which were two sorghum varieties. However, the general view in the literature is that the use of improved seed varieties is low and often highly limited to major export crops. For

[2] FAO (1986). African Agriculture: Input Supply and Incentive Policies. Annex III; Rome.

instance, FAO (1986) reported that the use of improved seed in sub-Saharan Africa accounts for only 10 percent of cereal production whereas major export crops are entirely grown from improved seeds. Also Nweke (1988) stated that farmers are more willing to adopt new technologies for producing cash crops than for producing crops that provide for family food security. As Hailu put it,

> "the mere fact that a new technology is introduced in smallholder farming by itself does not guarantee a widespread adoption and efficient use"[3].

He argued that success in this respect depends on the fulfilment of specific socio-economic, technical and institutional conditions. Several studies support this view.

### 2.4.1 Socio-economic Characteristics

In general, household decision-making with respect to farming operations is influenced not only by the economic merits of actions but also by social factors pertinent to the household and those operating at the community level. For example Akinola (1987) observed that in a traditional African setting, the strength of family ties often compels farm workers to tolerate very poor working conditions and wages as a result of their family loyalty. The farm operator thus assumes a financially advantageous position to spend more money on adoption of new technologies. In addition, such factors as income/wealth, farm size, relative advantage, innovation cost, and profit have been found to influence farmers' adoption behaviour (Kislev and Shchori-Bachrach, 1973; Rogers, 1983;

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[3] Hailu Z. (1990). The Adoption of Modern Farm Practices in African Agriculture:Empirical Evidence about the Impacts of Household Characteristics and Input Supply Systems in the Northern Region of Ghana. Nyankpala Agricultural Research Report No.7.

CIMMYT, 1993; Hounkpe, 1999). The innovation cost may restrict the use of certain technologies to only farmers with a certain level of income. Farm size may tend to be associated with income in most cases, and relative advantage and profit serve as motivation for potential adopters, which may explain their influence.

Also, with education and experience come new knowledge and skills, and an associated increase in confidence, as uncertainty is reduced. It has been argued that education enhances one's ability to receive, decode and understand information (Schultz, 1964). Experience has effects similar to education as it builds confidence and dispels doubt (Kebede, 1992). Also, age, leadership status and gender may determine whether or not an individual takes decisions regarding the choice of technology used on the farm. For example, Pannin (1988) noted that elders in traditional African societies are widely accepted as superior because experiences and decisions relating to the adoption of innovations are positively influenced by the age factor. However, some researchers have argued that younger farmers, being more adventurous and with a longer planning horizon, are more inclined to accept innovations than older ones (Polson and Spencer, 1992).

It is therefore not surprising that age, education, experience, leadership status and gender have been found to influence farmers' adoption behaviour (Schultz, 1964; Petzel, 1976; Mueller and Jansen, 1988; Lin 1992; CMMYT, 1993).

One factor that has not featured frequently in adoption studies is the technological level of the farmer. It should be noted that there exist positive interactions between certain technologies. Such technologies therefore complement each other in the realisation of their potentials. For example, the optimal effect of chemical fertilizers is reached with simultaneous use of modern crop varieties, as these mainly show a significantly greater response to fertilizer application than traditional ones (Ruthenberg, 1985). Similarly, Byerlee (1986) noted that adoption of certain technologies by small holders follows a sequential pattern and the adoption of one is expected to hasten the adoption of related components.

### 2.4.2 Institutional Factors

These are self-evident, as it does not require much to realise that the availability of inputs, credit and subsidies create an enabling environment and broadens the scope for a larger number of potential adopters. Previous adoption studies have found access to credit to be an important determinant of innovation adoption (Shakya and Flinn, 1985; Akinola, 1987). However, it is worth noting that Hailu (1990) noted that access to institutional credit for the majority of small farmers in northern Ghana is hardly possible. He also observed that increased use of modern agricultural inputs in northern Ghana is constrained by deficiencies in supply and distribution systems. He stressed that input availability at the right time and place is a major bottleneck to adoption.

Through education, extension service conscientizes farmers, clears some doubts and may appeal to some farmers to give an innovation a try. Also, markets for products assure producers of an outlet for their produce and serve as a motivation.

This may explain why it is widely documented that availability of inputs, credit, subsidies, extension service and markets for products are some of the institutional factors affecting the adoption behaviour of small farmers. Evidence in support of this abounds (Akibonde, 1969; Rogers, 1983; FAO, 1986b; CIMMYT, 1993).

**2.4.3 Technical Characteristics**

Technology refers to a way or method of carrying out an operation/activity while innovation means a new approach or method. These (particularly the later) have implications for the available resources and the end product. Given that culture (a way of life of a people) and tastes and preferences do not change overnight, the innovation itself or its technical characteristics are bound to influence adoption. Some important innovation characteristics found to be influencing adoption are compatibility with the existing farming system, suitability for popular uses and opportunities for new uses (Edwin, 1996; Hounkpe, 1999).

From the foregoing, one can say that farm level decisions about the adoption of improved technologies are often governed by socio-economic and institutional factors as much as they are by technical factors. The current study seeks to explore the relationship between all these categories of factors, and farmers' behaviour with respect to the adoption of improved sorghum varieties and the associated technologies.

## 2.5 Methodologies of Adoption Studies

Several different methods of analysis have been used in assessing the adoption of innovations. Most often, adoption studies have focussed on the individual (decision-maker, particularly the household head) as the unit of observation. Again, most studies define adoption as being dichotomous, that is, an innovation is either adopted or not. The methods of analysis can generally be categorised as qualitative or quantitative, but the quantitative techniques dominate the literature. However, as will be seen in the discussion that follows, researcher perception, the purpose and the scope of the study influence the choice of analytical techniques.

Francis (1976) seemed more interested in identifying early adopters in his study on population characteristics and development activities. He thus calculated adoption scores on the basis of the date that each of several new agricultural ideas and practices were first used by each individual. Alao (1973) assessed the level of adoption by measuring the percentage of farmers, out of the total number of sampled farmers, that are using the innovation in question. This is exactly what the logistic or cumulative normal curve, used to describe cumulative adoption over time, does but on a yearly basis, with the Y axis defined as the proportion of farmers using innovation (Edwin, 1996). However, when Y is defined as the proportion of area under the new practice, it gives an estimate of use intensity. The method then becomes similar to the acceptability index proposed by Waugh (1982, *cited in Engmann* 1993). This index is computed as a percentage of representative farmers using the innovation multiplied by the percentage of land area being used for the new practice. Engmann (1993) modified this index to determine the intensity of adoption of soyabean in Ghana. She calculated it as:

$$\text{Modified Acceptability Index} = (N_s/N_t)^* (L_s/L_t) * 100 \qquad (2.1)$$

where $N_s$ is the number of farmers in the sample using the new practice, $N_t$ is the total number of farmers in sample, $L_s$ is land area used for new practice by sample and $L_t$ is the total land area cultivated by farmer.

In all the above cases, one thing stands out. The determinants of adoption do not seem of interest to the researcher. In contrast, Roe (1983) included risk preferences along with other factors in his adoption models. Several other adoption studies have explored the determinants of adoption. Generally, in many such studies models used are exponential functions, both univariate and multivariate. In fact, probit and logit models and their modified forms have been used extensively (Shakya and Flinn, 1985; Hailu, 1990; Kebede and Coffin, 1990; Edwin, 1996; Hounkpe, 1999).

Several studies have used the analytical techniques just described to explore the relationships between the adoption of improved agricultural technologies and a range of interdisciplinary factors. Some recent experiences include Edwin (1996) who used the logistic curve to examine the adoption pattern and the tobit model to analyse the adoption of improved rice varieties in Sierra Leone; Hounkpe (1999) used the Probit model to analyse the adoption of Maize narrow crib in Benin; Akinola and Young (1985) applied Tobit model to analyse the adoption and use of cocoa spraying chemicals in Nigeria; Shakya and Flinn (1985) used Probit and Tobit models to examine the adoption of modern varieties and fertilizer use on rice in Nepal; Akinola (1987) used probit model to analyse the adoption of tractor hiring service scheme in Nigeria; Hailu 1990 used the logistic curve, and the Probit and Tobit models to study adoption of improved seed varieties, bullock traction technology and agrochemicals in northern Ghana.

## 2.6 Economic Impact Assessment

In view of the scarcity of resources and the unlimited needs of man, all governments and donors need to justify their investments. However, the economic value of many a public investment may not be obvious. It is particularly difficult to observe the impact of agricultural research, mainly because the benefits are diffused over several years and among a host of dispersed producers and consumers. Economic impact studies provide the tools for measuring those benefits and comparing them with the costs of the research. Approaches to impact assessment fall into three main categories: econometric approaches, programming methods and economic surplus methods. Although all these methods are used widely, the economic surplus method is the most popular because its basic techniques are easy to grasp, it has the least data requirements and can be applied to the broadest range of situations (Masters et al., 1996).

## 2.7 Factors Affecting the Impact of Agricultural Research

An important aspect of impact assessment is an analysis of factors that influence the impact of technology development and transfer i.e. factors that affect the benefit and cost streams of investments in agricultural research. These qualitative analyses seek to explain why an investment had high, low or negative returns, unlike quantitative analyses such as rate of return calculations, which simply estimate the financial and/or economic returns to investments. Qualitative analysis may also help explain how returns are distributed. With these insights, the policy choice set is expanded to include policies that alter the potential returns of investments.

A search through the literature reveals that factors such as research system performance, extension and research linkage, linkages beyond the national/local system, government policies, markets and climate have important influences on the impact of investments in agricultural research.

### 2.7.1 Research System Performance

In order to achieve optimum impact, the research system must be effective in generating improved technology. This requires the setting of appropriate priorities, effective scientific leadership, the availability of favourable incentives and adequate human and financial resources. Oehmke and Crawford (1993) noted that a combination of well funded National Agricultural Research System (NARS), International Agricultural Research Centres (IARCs) and donor efforts in countries such as Zambia, Kenya and Cameroon have resulted in the release of improved technologies that were adopted by farmers.

### 2.7.2 Extension and Research Linkage

Effective interaction between research and extension is necessary if the much-desired farm-level impact of agricultural research is to be achieved. A system that links together all the pieces of the development puzzle (Mazzucato and Ly, 1994) is what is required. There must be a well co-ordinated research and extension system. Such a system should provide for regular meetings and offer opportunities for interdisciplinary interaction among researchers and extension staff. Participation at such meetings should include staff of the agriculture ministry, researchers, NGOs and farmers.

For example, it was noted that in Cameroon such interaction shifted the research agenda from a primary focus on producing high grain yields to addressing post-harvest storage constraints. This system provides a feedback from the farm to researchers, and the fact that researchers are aware of the existence of a network that will diffuse the product of their work is good motivation.

### 2.7.3 Linkages beyond the Local System

International Agricultural Research Centres (IARC) and other international networks can be very important partners in developing and sustaining an effective agricultural research system. By collecting, maintaining and distributing germplasm, they act as important catalysts for agricultural development (Sterns and Bernsten, 1994). Linkages, via donor projects, between the NARS and IARCs therefore enhance the technology development and transfer process. For example, IARCs serve as a source of alternative cultivars or varieties as in the case of *kapaala*, an ICRISAT introduced material in Ghana (NAES Annual Report, 1994). Besides, they provide an expanded resource base and also provide for human resource development through seminars and workshops.

### 2.7.4 Government Policies

The line of action pursued by government can be a source of failure of an otherwise successful agricultural innovation. Policies affecting the supply and price of agricultural inputs, and the market for and price of agricultural outputs clearly have effects on the impacts of improved technology. Ahmed et al (1992) showed that the adoption of improved sorghum in Sudan was frustrated when government pricing policy changed adversely. Also, in Mali, Boughton and de Frahan (1994) observed that a well co-ordinated sub-sector and mechanised farming system resulted in high rates of technology adoption. However, with the withdrawal of marketing services and guaranteed prices, maize farmers changed their choice of technology and virtually resorted to their traditional practices.

### 2.7.5 Markets

Even in subsistence agriculture peasant farmers often have to sell farm produce to meet their cash-mediated subsistence requirements. It is therefore not surprising that output markets and input supplies (including credit) should play key roles in supporting or restraining adoption of productivity-increasing technology. Oehmke and Crawford (1994) found that lack of effective, improved seed multiplication and distribution was a critical constraint in Niger and Uganda, as was lack of fertilizer in Mali. It was similarly found that limited output markets were constraints in Mali and Uganda.

### 2.7.6 Climate

Harsh climatic conditions introduce considerable risk in farming. Variability in rainfall is an important risk factor in rain-fed agriculture. The more variation in the quality and distribution of rainfall, the more the production of rain-fed crops becomes unstable. The risk that climate imposes on agricultural cultivation has direct consequences on the level of adoption of new technologies. Farmers are less inclined to invest in agricultural inputs, which raise the potential economic losses in case of a crop failure. Mazzucato and Ly (1994) noted that certain of the new varieties outproduce local varieties only when rainfall is adequate. Also Lowenberg-deBoer et al (1992) showed that in years of bad rainfall, the cultivation practices carrying the least risk were use of local varieties with traditional agronomic practices. Thus climatic fluctuations increase the risk of adopting an improved variety.

## 2.8 Methodologies of Impact Studies

Studies evaluating the returns to agricultural research can be classified into two broad categories: *ex-post* and *ex-ante*. The ex-post studies evaluate the returns on past investments while ex-ante studies try to estimate future returns. Ex-post studies include a range of methodologies with varying objectives and evaluation criteria. Schuh and Tollini (1979) summarised ex-post studies as those which measure benefits of research in terms of resources saved, economic surplus, production functions, impact on national income and changes in the nutritional status of the population.

The production function approach as used by Thirtle (1999), assumes that the difference between productivity growth in a given crop and the rest of the agricultural sector is attributable to crop-specific research and extension expenditures. These expenditures are used to explain the difference between total factor productivity (TFP) growth in the crop and the rest of the agricultural sector. The TFP indices are calculated and their growth rates obtained. The elasticity of TFP for the crop is then employed to compute the rate of return. That is, the rate of return calculation is normally based on the estimated coefficients of research and development in explaining TFP (Lu et al, 1979; Davis, 1981; Thirtle and Bottomley, 1989; Alston et al, 1995) or on the research and development coefficient in the estimation of the dual profit function (Jayne et al, 1994).

Evenson et al (1987) have shown that there are equivalent measures of technological change based on dual relationships among production, cost and profit functions and that these measures are equivalent to economic accounting measures, which are based on index number theory.

Traditional indicators of research output include the productivity of the research system and discovery of new agricultural techniques such as the number of new varieties released. In some cases, the percentage adoption is used to measure impact. An example is the case of *Xanthomonas Campestris* resistant cassava varieties in Congo where a reported 90 percent adoption by farmers was adjudged good impact. These are not always good indicators of impact. However they are important measures of progress in meeting the conditions necessary for impact.

In a pioneering study on measuring the returns to investment in agricultural research, Schuh (1953) used the resources saved approach. He calculated how much it would cost to obtain the agricultural output of 1950 with the agricultural technology of 1910. He then compared that value with the actual cost incurred in 1950 to produce that output. Adesina and Zinnah (1992) estimated that rice yields increased with the introduction of improved rice varieties developed by the West Africa Rice Development Association (WARDA). They noted that these varieties resulted in aggregate increases in 1990 farm household incomes of US$0.4million and US$14million in Guinea and Sierra Leone, respectively.

Also, Nyaribo-Roberts and Ospina (1992) estimated that the development of a dual-purpose goat (milk and meat) increased the incomes of adopting Kenyan farmers by as much as 60 percent. In Ethiopia, the complementarities between livestock and crops were used to develop new ploughing and crop and water management techniques. These new techniques increased gross returns to farming and farm labour by over 300 percent each.

Griliches (1958) used the economic surplus model to measure returns to agricultural research. He worked on corn in the United States of America. Then, Akino and Hayami (1975) refined the economic surplus approach by separating the benefits accruing to producers and consumers from rice breeding research in Japan.

In all these cases, the distributional effects are not addressed; neither is there a standard against which we could compare the measure. The rate of return measure eliminates this problem of lack of a yardstick. This rate is often compared with the opportunity cost of capital. This may be the rate at which money could be borrowed from a financial institution or the rate it could earn in the next best alternative investment.

Some recent examples of the application of rate of return measurement include the following. Lopez-Pereira et al (1991) used the Akino-Hayami approach of disaggregated benefits to evaluate the impact of sorghum research in Honduras. In the said study, they used economic prices to compute the rate of return to sorghum research. However, Sterns and Bernsten (1994) used nominal estimates of costs and benefits to compute a simple rate of return to sorghum and cowpea research in Cameroon. They also used the economic surplus model but without disaggregating the benefits. This is because in Cameroon (like in Ghana) the crop is in the hands of subsistence farmers so producers are the same as the consumers. This is the approach adopted by the present study.

However, the rate of return measure (like other quantitative indicators) fails to capture certain benefits of investments in agricultural research, mainly because of difficulties in quantifying them. These include improvements in the environment and sustainability of agricultural production; improvements in the status of women in the household; improvements in the human and institutional capacity for research; and improvements in equity (income distribution).

**2.9 Findings of Rate of Return Studies**

Several rate of return assessments find positive rates of return of an economically important magnitude. For instance in Ghana, returns on maize research over the period 1962-1992 was estimated at 74 percent (World Bank, 1999). The same source estimated a rate of return of 34-37 percent for cotton in Senegal, whilst Abidogun estimated 42 percent for cocoa in Nigeria. With an already established extension system in Mali, Boughton and de Frahan (1992) estimated a rate return of 135 percent for maize research. Again in Senegal, Schwartz et al (1992) estimated a rate of return of 31 percent for an investment in cowpea research dubbed "Operation Cowpea". This figure rose to 92 percent when premium was placed on cowpea harvested during the hungry season.

The above rate of return calculations seem to support a hypothesis that rate of return studies focus primarily on success stories, and thus bias the available evidence in favour of technology development and transfer. This may not be so as for instance negative rates of return were registered for dates in Niger and Uganda. In Niger, Mazzucato and Ly (1994) estimated a positive rate only by extending the analysis to 2010 at an assumed constant adoption rate. Also in Cameroon, a rate of 3 percent was estimated for cowpea while another as low as 1 percent was estimated for sorghum research and extension in Niger. However, Uganda's negative rate of return was said to be a direct consequence of political problems of the 1970s and early 1980s. The present study seeks to examine the case of sorghum research at SARI.

It is worth noting that these rates of return studies were undertaken from the perspective of national agricultural research systems, hence only costs associated with the national agricultural research organisations are included. However, most of the activities being evaluated may have benefited from discussions with IARCs and other regional networks, access to international germplasm, and/or direct importation of improved varieties. Therefore, the rates are best interpreted as indicators of return to investments in national agricultural research programmes if the IARCs continue to function at their current level of effectiveness.

**2.10: Conclusion**

The literature on adoption studies indicates that there are two types of adoption studies, one that tries to explain adoption through farmer decisions and the other that uses statistical comparison of the farmers' adoption behaviour with characteristics of the farmers' environment. In either case however, researcher perception, the purpose and the scope of the study influence the choice of analytical techniques. To explore the determinants of adoption, Probit and Tobit models have been used extensively and in impact studies the preferred technique is the economic surplus model.

It has been shown that most adoption studies regard the technology as appropriate, and farmers are viewed as static units to which technology is to be transferred. However, this approach is no longer justifiable as it has been noted that the success of a new technology depends on the fulfillment of specific socio-economic, technical and institutional conditions. This study explores factors in all these categories in order to identify specific determinants of adoption and the intensity of use of improved Sorghum varieties. This will contribute to efforts at guiding policy to promote widespread adoption.

The literature also indicates that the impact of new technology depends on various factors, mainly external to the technology itself. The literature reports rates of return ranging from negative values for dates in Niger to an estimated 135 percent for maize in Mali. The estimated rate of return for improved Sorghum varieties is compared with some of those reported.

So far there is no literature on the adoption and impact of improved technology in the Upper West region. This study will contribute to filling this information gap by identifying the factors that influence adoption and the intensity of adoption, and also estimating a rate of return to Sorghum research.

# CHAPTER 3

# METHODOLOGY

## 3.1 Introduction

This chapter presents a formal definition of adoption, the theoretical frameworks and analytical tools employed to address the study objectives. Also discussed in this chapter are the data requirements, data collection techniques and how estimates of certain basic parameters were derived for use in the estimation procedure.

## 3.2 The Concept of Adoption

According to Feder et al. (1985), adoption refers to the use of a new technology or an innovation in long-run equilibrium when a farmer (user) has full information about the new technology and its potential. However, the issue may not be as simple, since most new technologies are often recommended in packages. For instance, the technology under study has three components: the (use) planting of the improved sorghum variety, the use of chemical fertilizer and row planting. In such a situation adoption becomes difficult to define. Does adoption mean the use of all components? What combinations or levels of use qualify as adoption? Is any planting of improved sorghum adoption? These are a few of some of the pertinent questions at stake. For the purposes of this study however, adoption simply refers to the realisation of the decision of a farmer to plant any of the improved sorghum varieties.

The rate of adoption is defined as the percentage of sampled farmers who planted any of the improved sorghum varieties in the survey year. Also, the intensity of adoption is defined as the level of use of a given technology. In this case, the proportion of a farmer's sorghum farm planted with improved varieties.

Generally, researchers and extension workers want to know the factors that affect both the rate and intensity of adoption of new technologies. To the researcher, this is important in designing technologies that will achieve high levels of adoption. To the extension worker such knowledge helps in designing extension messages that respond to the identified factors, in order to achieve the desired results.

### 3.3 Conceptual Framework and Analytical Tools for the Pattern of Adoption

The first objective of this research is to describe the pattern or spread of adoption. The purpose here is to describe how the adoption of improved sorghum has changed over time in the Upper West Region. Diffusion is the process by which an innovation is spread through certain channels over time among the members of a social system. Tarde (1969) describes it as a process characterised by a slow advance, followed by a rapid and uniformly accelerated progress, followed again by progress that continues to slacken until it finally stops. In fact, the process seems to describe the behaviour of agents observing a divine commandment that says:

> "Be not the first by whom the new idea is tried, Nor the last to put the old aside."[1]

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[1] Alexander Pope, An essay on criticism, Part II *quoted by* Rogers, E.M. (1983). Diffusion of Innovations. Macmillan, Landon; New York.

This is based on the concept of learning and it is due to the cumulatively increasing influences upon an individual to adopt or reject an innovation, resulting from the activation of peer networks about the innovation in the system. This phenomenon is explained in terms the innovativeness of the individual and if the cumulative number of adopters is plotted, the result is an S-shaped diffusion curve (Ryan and Gross, 1943). The cumulative normal and logistic distributions are two of several simple S-shaped curves, most widely used in handling growth phenomena, diffusion and technology transfer (Griliches, 1957). However, the logistic curve was chosen because it is simpler to fit and easier to interpret.

### 3.3.1: The Logistic Curve

This curve documents adoption history by looking at time of initial adoptions of the new technology and the cumulative effect over time. Logistic curves help to determine whether extension needs to be strengthened and by quantifying the change in the number of technology users over time, they can be used to assess impact (CIMMYT, 1993). The logistic curve determines pattern of adoption or diffusion by assuming that the cumulative proportion of adopters follows an S-shaped (sigmoid) curve. This curve depicts a slow initial growth in the use of the new technology, followed by a more rapid increase and then a slowing down as the cumulative proportion of adoption reaches its maximum (which may be well below 100% of the farmers) (CIMMYT, 1993).

The most common function used to portray the curve is the logistic function. For technology adoption the Y-axis represents the proportion of farmers adopting or area applied to a technology and the X-axis represents time. The logistic curve follows a general form:

$$DY_t/dt = bY_t/k(k-Y_t) \quad (3.1)$$

where:

$Yt$ = number of individuals who have adopted the innovation at time t (cumulative percentage of adopters or area under improved technology at time t).

k = the fixed population of potential adopters (upper bound on percentage adoption)

b = parameter reflecting the rate of adoption (probability of adopting upon learning about the innovation).

Solving for $Y_t$ from the logistic differential equation generates the result:

$$Y_t = k/(1+e^{-a-bt}) \quad (3.2)$$

where 'a' is the constant of integration (time when adoption begins) and 'b' is a constant related to the rate of adoption. The equation is however transformed to be estimated by ordinary least square regression as:

$$\text{In } (Y_t /k- Y_t) = a + bt \quad (3.3)$$

and k is estimated as the level that appears to be the upper bound of adoption on the cumulative adoption curve.

The logistic curve just described is fitted to data showing the percentage of farmers using improved sorghum in the study area beginning from 1988. The data required for this analysis was collected through a survey described in section 3.7 below.

### 3.4 Theoretical Framework for Identifying Determinants of Adoption

This framework applies to the achievement of second and third objectives of this study. The constraints imposed on agricultural development by inelastic supply of natural resources can be offset by the adoption of new technologies and technical change. In order to accelerate adoption of new technologies and reap maximum benefit, it is necessary to first identify factors that influence the adoption behaviour of small farmers. The adoption behavioural model is frequently used as a framework to examine variables associated with technology adoption. It is generally assumed that farmers' response to innovation adoption is individualistic. Some respond partially, others quickly, while others do not respond at all to new innovations.

This framework has its roots in the threshold theory of decision making in which a reaction occurs only after the strength of the stimuli increases beyond the farmers' reaction threshold (Hill and Kau, 1973). This presupposes that every individual, when faced with a choice has a reaction threshold determined by several influential factors. The decision to adopt an innovation is dichotomous between two mutually exclusive alternatives. The individual chooses either to adopt or not to adopt. This implies that there exists a 'breaking point' or threshold in the dimension of the explanatory variable(s) below which a stimulus elicits no observable response. Only when the strength of the stimulus reaches the threshold level does a reaction occur. Additional increases in the strength of the stimulus results in no effect on the observed response.

Phenomena of this sort are handled using a general model of the form:

$Y_i = \beta_i X_i + u_i$

such that

$Y_i = 1$ if $X_i > X^*$ and 0 if $X_i < X^*$ (3.4)

Models such as the above, which express the dichotomous dependent variable Y as a linear function of the explanatory variable(s) X are called linear probability models (LPM). This is because E $(Y_i/X_i)$, the conditional expectation of $Y_i$ given $X_i$, can be interpreted as the conditional probability that the event will occur given $X_i$; i. e., Prob $(Yi = 1/X_i)$ (Goldberger, 1964; Aldrich and Nelson, 1984; Judge et al., 1985).

The framework for this study focuses on the threshold decision theory as it applies to adoption diffusion paradigm.

### 3.4.1 Methodological Considerations

The fact that many methodological problems are encountered in estimating relationships in which the dependent variable is dichotomous is well documented in the literature. As already indicated the adoption of improved crop varieties by a farmer is a decision involving two mutually excluding alternatives, either to adopt or not to adopt. The decision depends on a vector of X explanatory variables and a vector of unknown parameters β. A positive decision takes place only when the combined effect of the explanatory variables ($X'\beta$) reaches a certain unobservable critical value $X_i^*$

This means that a given farmer will adopt improved sorghum varieties only when the combined effect of the socio-economic and technical characteristics, and institutional factors is able to offset the inherent tendency of the farmer to resist change. In fact, a farmer adopts only when he assesses the consequences of adoption to be favourable when weighed against the economic, social, and technical feasibility. This critical value reflects the individual decision threshold and plays the role of the error term (Goldberger, 1964). By denoting the dependent variable as Yi that takes the value of 1 if a positive decision occurs and 0 otherwise, the dichotomous adoption decision model for the $i^{th}$ farmer is specified as follows:

$$Y_i = 1 \text{ if } X_i'\beta > X_i^* \text{ and}$$

$$= 0 \text{ if } X_i'\beta < X_i^* \qquad (3.5)$$

$$i=1,2, \ldots N \text{ observations.}$$

For this study $Y_i$ takes a value of 1 if farmer uses improved sorghum, and 0 if farmer does not use improved sorghum varieties. The main objective in the estimation of such qualitative response models is not the reconstruction of the decision variable $Y_i$, but the estimation of the conditional probability that $Y_i$ assumes one of the specified values (Jung 1983). Thus the probability that a given farmer is an adopter of improved sorghum

$X_i'\beta > X_i^*$, $(Y_i = 1)$ is given as:

$$P_i = \text{Prob}(Y_i = 1) = F(X_i'\beta) \qquad (3.6)$$

Also, the probability that a given farmer is a non-adopter $X_i'\beta < X_i^*$, $(Y_i = 0)$ is given as:

$$1-P_i = \text{Prob}(Y_i = 0) = 1-F(X_i'\beta), \qquad (3.7)$$

where $F(X_i'\beta)$ represents a cumulative distribution function evaluated at the value of the argument. It is well documented in the literature that the specification of $F(X_i'\beta)$ as a linear probability functional form and estimating the unknown parameters with the use of least square regression models have been found to be inefficient for the following reasons:

(i) the disturbance term exhibits heteroscedasticity

(ii) the expected value of $Y_i$ may sometimes be greater than one or less than zero

(iii) classical tests of significance for the estimated coefficients are not applicable since the estimated standard errors are not consistent (Goldberger, 1964; Dagenais, 1969; Judge et al., 1985).

Although Aitkin's generalized least squares can be used to correct for heteroscedasticity, further problems may be encountered in determining the weighting factor. Above all, the fundamental problem with the linear probability model is that it assumes that $\text{Prob}(Y_i = 1) = E(Y = 1/X)$ increases linearly with X, that is, the marginal or incremental effect of X remains constant throughout and that makes it logically not attractive.

Several other techniques have been suggested including the logit (Berkon, 1944), gompit (Brennan, 1949), Zellner and Lee's (1965) mixed estimation techniques, and simultaneous equation systems (Hill and Kau, 1973). Also the method of discriminant analysis can answer some questions relating to models having dichotomous dependent variables.

However, farmers' behaviour in the adoption of improved sorghum varieties will be modeled using primary data and the Probit (normit) model, given the dichotomous nature of adoption and the several desirable properties of the probit model. These properties include: (i) it constrains the expected value of Y to lie between zero and one; (ii) it resolves the problem of heteroscedasticity and (iii) it gives consistent estimates of the standard errors (Hill and Kau, 1973). Though this model assumes normal distribution of the sample, its use with large samples is justified even when the underlying distribution of the sample is not normal (Pindyck and Rubinfeld, 1991).

It is important to note however, that the parameter estimates of the probit model need to be interpreted with some care. In the first instance, the magnitudes of these estimates depend on the unit of measurement. They are also expressed as indices and are therefore not comparable with one another (Hailu, 1990; Shakya and Flinn, 1985). Furthermore, they do not alone, provide direct information about the effects of changes in the explanatory variables on the probability of adoption. Such effects are predicted from the derivative of the probability with respect to a particular explanatory variable, given by Maddala (1983) as

$$\partial(P_i)/\partial X_{ik} = \partial F(X_i'\beta)/\partial Xik = f(X_i'\beta)\beta_k \qquad (3.8)$$

where $f(X_i'\beta)$ is the value of the normal density function at $X_i'\beta$ and $\beta_k$ is the estimated coefficient of the $k^{th}$ explanatory variable. The above derivative can be calculated at different levels of the explanatory variables. However, the weighted aggregate elasticity, i.e the sum of the individual elasticities weighted by their probabilities (the preferred choice) is used in the current study (see Hailu, 1990; Maddala, 1983). This is because the elasticities at the mean values of the explanatory variables tend to overestimate the actual response, owing to the nature of the normal density function.

As already noted, qualitative choice problems frequently concern dependent variables that are discrete, usually taking on only two values. There are occasions, however, in which the dependent variable has been constructed on the basis of an underlying continuous variable, for which there are a number of observations about which we do not have information (Pindyck and Rubinfeld, 1991).

In the current study, farmers' level of use of improved sorghum varieties, is a case in point. For the users we can obtain the proportion of an individual's sorghum land which is under improved varieties. However, for those who do not use improved sorghum varieties, we have no measure of the proportion of sorghum land that a given individual would have been willing to put under improved varieties at the time of the survey. Thus the values of the dependent variable are unobservable though the corresponding values of the independent variables are, hence the name *censored* dependent variable. The general model is of the form

$$Y_i = X_i\beta + \mu_I$$
$$0 \text{ otherwise} \qquad (3.9)$$

The Tobit is a combination of Probit and linear regression techniques (Maddala, 1983) designed to handle these special cases of qualitative choice problems.

It is therefore clear that the Tobit and Probit models share common framework, similar methodological concerns and estimation procedures and problems.

### 3.4.2 Empirical Multi-nomial Probit Model

This model enables us to estimate the probability that a farmer, having learnt about an innovation, will adopt the innovation given his characteristics. It thus provides a tool for guessing the chances that a farmer with given characteristics will adopt a technology such as improved sorghum, after having learned about it. In this way it helps to identify some of the variables that influence farmer adoption behaviour.

The Probit model as systematized by Finney (1952) and extended by Tobin (1955) determines the decision variable $Y_i$, by $Y_i = 0$ if $X < X^*$ and $Y_i = 1$ if $X \geq X^*$. It is clear that $X^*$ plays the role of a "breaking point" and thus explicitly incorporates the threshold concept in the model. In a multivariate case, such as the current study an aggregate variable A is assumed such that A is a linear combination of the explanatory variables with $A^*$ as threshold playing the role of the disturbance forces. The disturbance term is thus homoscedastic (Hill and Kau, 1973).

For the purpose of this study, the model to be estimated is given as:

$$E(Y_i / A_i) = Prob(Y_i = 1/ A_i) = F_i(A_i) = F_i(\beta_1 X_1 + \beta_2 X_2 + \ldots\ldots\ldots\ldots + \beta_n X_n) \qquad (3.10)$$

where F is a cumulative normal distribution. This distribution is given by

$$F(X'_i \beta) = \int_{-\infty}^{X'_i \beta} \frac{1}{\sqrt{2\Pi}} e^{-t^2/2} dt \qquad (3.11)$$

where t is a random variable distributed as a standard normal deviate, that is, t is N(0,1). Thus, the probability of a positive decision ($Y_i = 1$) is the area under the standard normal curve between $-\infty$ and $X_i'\beta$. The larger the value of $X_i'\beta$ the more likely adoption is to take place (Pindyck and Rubinfeld, 1991).

Since F is a normal cumulative function, whatever value $A_i$ takes will necessarily be transformed to the interval of zero and unity, and the difficulty of the expected value of $Y_i$ being greater than one or less than zero (i.e. $E(Y_i) > 1$ or $E(Y_i) < 0$) is overcome. Moreover, the derived functional form between A and Y is a normal sigmoid curve (Hill and Kau, 1973). Therefore, any linear or nonlinear relationship between X and Y through A can be accommodated. In addition, the magnitude of the effect of a relevant economic stimulus depends upon the status of the economic unit as well as upon the magnitude of the estimated coefficient βi, i.e.,$\Delta E(Y_i) = f(A_i, \Delta A_i)$ where $\Delta Ai = \beta_j \Delta(X_{ij})$. Thus the probability does not depend on only the explanatory variables, $X_i$.

The parameters in the probit model are estimated by maximum likelihood methods. The likelihood function L is specified as the product of the probabilities of both alternatives and its log is maximized with respect to unknown parameters.

$$L = \prod_{n} [P(y_i = 1)]^{y_i} [p(y_i = 0)]^{1-y_i}$$

$$= \prod_{i=0} [F(X_i \beta)]^{y_i} [1-F(X_i \beta)]^{1-y_i} \qquad (3.12)$$

where n represents the number of observations in the sample. Section 3.5 below presents a discussion of the choice of explanatory variables used in the models.

### 3.5.1. Theoretical Framework and Methodological Issues for Identifying Determinants of Intensity of Adoption

The Probit model provides information only with respect to the household's decision to adopt or not to adopt but not on the intensity of use after adoption. To measure the intensity of use, a model that incorporates both forms of the dependent variable (dichotomous and continuous) and provides information on all aspects of the decision making process is required. That is, one that measures the probability of adoption and the intensity of use thereafter on the basis of information on the entire sample. For such purposes an approach developed out of Probit and linear regression models by Tobin, known as the Tobit model, is found to be appropriate (Amemiya, 1984).

This model enables us to identify, in addition to estimating the probability of adopting, the factors which determine the extent to which a farmer having adopted improved sorghum, will use it. The Tobit model to be used in this study similarly estimates the probability of adoption and simultaneously the expected value of the continuous dependent variable $Y_i$ as a function of the set of explanatory variables $X_i$ weighted by the probability that $Y_i > 0$. This expected value of $Y_i$ equals zero if the estimated value of $X_i\ \beta$ falls below the critical threshold level $X^*$ (Kinsey, 1984). It is clear from the theoretical model discussed above that the functions for the dichotomous choice (adoption) and the intensity of use should have the same set of explanatory variables. Thus the Tobit model to be estimated is given as:

$$Prob(Y_i = 1/A_i) = F_i(A_i) = F_i(\beta_1 X_1 + \beta_2 X_2 + \dots\dots\dots\dots + \beta_n X_n) \quad (3.13)$$

The adoption variable in the Tobit model $Y_i$ is defined to assume a continuous character. An iterative maximum likelihood algorithm (White 1978) is used to estimate the models in order to obtain asymptotically efficient parameter estimates.

Over the entire sample the expected value of $Y_i$ is calculated as:

$$E(Y_i / X_i'\beta) = (X_i'\beta) \bullet F(X_i'\beta)/\sigma + \sigma \bullet f(X_i'\beta)/\sigma \qquad (3.14)$$

And for the sub-sample already above the limit (Yi>0) the expected value is given by

$$E(Y_i^*) = E(Y_i/Y_i>0) = (X_i'\beta) + \sigma \bullet f(X_i''\beta/\sigma) \bullet F(X_i'\beta/\sigma) \qquad (3.15)$$

where F $(X_i'\beta/\sigma)$ is the probability that $Y_i > 0$ calculated from the cumulative normal distribution, $f(X_i'\beta/\sigma)$ is the normal density function and $\sigma$ is the standard error of estimate (Goldberger,1964; Judge et al., 1985). Equation (3.14) gives an estimate of the average area a sorghum farmer, selected at random from the sample is likely to have under improved sorghum. Also, (3.15) gives an estimate of the average area an adopter of improved sorghum, selected at random is likely to have under improved sorghum.

The parameters in the Tobit model, like in the probit are estimated by iterative maximum likelihood procedure (White, 1978). Since the maximum likelihood estimates of the coefficients in a large sample are approximately normally distributed, the significance of the individual coefficients can be tested in both models, (Probit and Tobit) by the ratio of the estimated coefficient and its standard error (asymptotic t-value). However, tests concerning the significance of all or a subset of the coefficients in the models is done by the log likelihood ratio test (LRT). This test is the Chi-square distributed with k degrees of freedom, where k is the number of parameters in the model less the constant.

## 3.6 Choice of Variables and Working Hypotheses for the Determinants of Adoption and Intensity of Adoption

In accordance with the study objectives and with direction from existing literature, explanatory variables have been chosen from among factors related to all the areas of concern. These include various socio-economic characteristics of the farmer and technology specific factors that influence the demand for, and the use of improved sorghum varieties. They also include institutional factors that impact on the availability of, and market access to improved sorghum seed in the study area. The definitions and measures of the explanatory variables used in the models are summarised in Table 3.1 and discussed below.

### 3.6.1 Socio-economic factors

The socio-economic factors included in the models are age of respondent, farm size, family labour force, non-farm income, education, the use of complementary inputs, fallow period and distance to sorghum farm. As already discussed in the literature review (pp.16-17) these determinants of adoption have been proved in similar studies in the past to be influential in the adoption of agricultural innovations.

Whereas it is often presumed that younger farmers, being more adventurous and with a longer planning horizon, are more inclined to accept innovations than older ones, some researchers have observed otherwise. In this study youthfulness (younger age) is expected to have a positive effect on adoption for the same reasons expressed above.

The changes in the production process involved in the adoption of a new technology may bring risks resulting from imperfect information and the possibility of committing errors. As observed in the literature review (pp. 17), education enhances one's ability to receive, decode and understand information and experience has effects similar to education as it

**Table 3.1: Definitions of Variables used in the Models**

| | |
|---|---|
| Age[2] | Age of household head measured by a dummy 1 if farmer between 31-50years, 0 if farmer is above 50years. |
| Educational Status | Measured by a dummy 1=literate 0=illiterate |
| Extension Contact | Number of extension visits to farmer |
| Off-farm income | Measured by a dummy 1= has off-farm income 0 = has no off-farm income |
| Farm Size | Number of acres under sorghum |
| Fallow Period | Number of years land is left to fallow |
| Farm type | Measured by a dummy 1 if sorghum farm is around homestead (less than 1km), 0 otherwise. |
| Farm Credit | Measured by a dummy 1 = Additional cash 0 = Own cash |
| Fertilizer | Use of complementary inputs by farmer measured by a dummy variable 1 if the farmer used chemical fertilizer in the survey year, 0 otherwise. |
| Family Labour | Available Family labour for farm work on household farm measured in persons. |
| Market access to improved seed | Distance to nearest sales point as a proxy for market access to agricultural inputs measured as number of kilometres. |
| ADOPTION (Probit) | Measured by a dummy 1if farmer adopts and 0 otherwise. |
| ADOPTION (Tobit) | Proportion of total sorghum area under improved sorghum |

[8] So defined for fear that farmers may not be able to tell their exact age

builds confidence and dispels doubt. In view of the foregoing the experience and educational status of respondent, are expected to have a positive influence on adoption.

The available family labour and farm size, are two important factors often found to be key determinants of innovation adoption at the household level. As observed earlier on (pp.16), in a traditional African setting, the strength of family ties often compels farm workers to tolerate very poor working conditions and wages as a result of their family loyalty. The farm operator thus assumes a financially advantageous position to spend more money on adoption of new technologies. This situation may be enforced in the study area where there is very limited labour market for off-farm employment and hence the opportunity cost of labour is very low. The two factors are therefore expected to have a positive effect on adoption.

Farm size, a good proxy for wealth, may have a positive influence on the adoption of new technologies, especially those involving the use of purchased inputs (e.g. improved seed, chemical fertilizers etc.). Similarly, people with off-farm income have the means to procure purchased inputs, which the adoption of a new technology may require. These variables are therefore hypothesised to favour innovation adoption.

The use of chemical fertilizers in the survey year has been entered as an explanatory variable to determine the effect of the use of complementary inputs by a farm-household on the adoption of improved sorghum varieties. This proxy, for the technological level of the farmer, is expected to have a positive effect on adoption.

There are two types of sorghum farms in the study area, bush farms and compound farms. The compound farms cultivated around the homesteads are often reserved for short duration crops, which are harvested during the lean season, with the bush farms being planted to late maturing full-season varieties. Farmers were asked to indicate the distance to their Sorghum farms. It was noted that where farmers had more than one Sorghum plot, the tendency was to plant the one near the home to improved varieties. Distance to sorghum farm is used as a proxy for farm type, which is given a value of 1 if the sorghum farm is around the homestead (less than 1km), 0 otherwise. It is therefore expected that the farms located near homestead and adoption of improved sorghum will be associated positively, given the short maturity period of most of the available improved varieties.

As discussed earlier, one farming system in the study area is the bush fallow system in which a piece of land is left to regain its fertility after having been cultivated for a number of farming seasons. As a particular plot is being abandoned to fallow, the farmer works on another, and hence, how quickly the farmer returns to the plot in time gives an indication of the level of pressure on land for cultivation. However, according to the induced innovation model of agricultural development, pressure on agricultural land provides an incentive for land-constrained farmers to adopt high yielding varieties. Longer fallow periods are therefore expected to have a negative effect on the improved Sorghum varieties.

### 3.6.2 Technical Characteristics

Here the farmer's perception of the characteristics of the improved varieties is to be explored. A perception index included in the models was computed from among several technology specific factors. These include: disease tolerance, drought tolerance, pest tolerance, maturity period, fertilizer requirement, varietal yield, storage or shelf life, taste quality, suitability for local dishes, weed suppression and marketability. Farmers were asked to compare (i.e. rank improved variety as 1 if better, 0 otherwise) the best known improved variety with their best traditional variety in terms of these varietal characteristics. The index is specified as a dummy and takes on a value of 1 if the cumulative score for a given characteristic is greater than 6, and 0 otherwise.

This index is expected to capture a farmer's perception of the risks associated with the adoption of improved sorghum as well as the compatibility of the improved varieties with the socio-cultural setting of the people in the study area. Hence the index is expected to have a positive relationship with adoption of improved sorghum.

### 3.6.3 Institutional factors

The institutional factors included in the models are, access to extension information, distance to the nearest purchase point for agricultural inputs as a proxy for market access, and farmer's access to credit in the survey year. Although the role of output markets is acknowledged no variable was included in this study to capture its effect.

Extension organisations are expected to educate farmers on new techniques of farming including the available new varieties and their use. Contact with extension activities has therefore been included in the analysis in order to assess its role in farmer's adoption decision. This is of particular interest as it may throw some light on how research and extension relate in the area. It has been suggested that SARI has for a long time not had a very strong link with the national agriculture extension system, neither has it had a strong extension component besides the on-farm research teams.

In fact, financial constraints are a common feature in smallholder agriculture. The availability of farm credit to enable small farmers to procure the necessary inputs on a timely basis is therefore vital. However, as observed earlier (pp. 18) access to institutional credit for the majority of small farmers in northern Ghana is hardly possible and increased use of modern agricultural inputs in northern Ghana is constrained by deficiencies in supply and distribution systems. This may be particularly serious in the study area, as the physical infrastructure is not yet well developed. In addition, the distance between a farm household and the nearest purchase point affects input purchasing costs (*ceteris paribus*) and hence influences the adoption decision of the farm household. For this reason the distance between a farmer's village and the nearest purchase point for agricultural inputs (e.g. improved seed, chemical fertilizers, etc.), unlike access to credit, is hypothesised to have a negative effect on adoption.

### 3.7 Data Requirements and Data Collection for the Probit and Tobit Analyses

From the preceding section, it is clear that such analyses require primary data on the various determinants of adoption. The variables on which data was collected span all three categories discussed above.

The data was collected through a structured sample survey conducted in all the five districts of the Upper West Region. A purposive sample of two villages from each district was first selected based on importance in terms of sorghum production. A random sub-sample of 20 farmers was then selected from the selected villages in each of these districts, which benefited from the dissemination of the improved varieties, giving a total of 100 respondents. Trained enumerators interviewed the respondents using structured questionnaire which, covered the following areas:

- Socio-economic characteristics of farmers: age of the farmer, education, farm size, family labour force, the use of complementary inputs, fallow period and off-farm income.

-Technical characteristics of varieties: disease tolerance, pests tolerance, drought tolerance, maturity period, fertilizer requirement, varietal yield, storage, taste quality, weed suppression, marketability and suitability for local dishes.

-Institutional factors: extension contact, distance to sorghum farm, distance to nearest purchase point for improved seed and access to farm credit. The questionnaire is found in Appendix 2.

### 3.8 Method of Analysis for Farmers Varietal Preferences

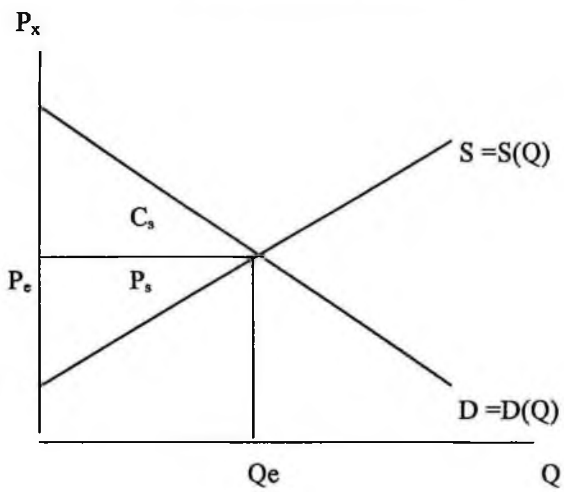
It is important to answer the question of what influences farmers' choice of improved seed so that sorghum researchers can determine what type of sorghum will be appropriate to the biophysical and socioeconomic circumstances of farmers in the region. Farmers were asked to rank the important characteristics that they consider in their choice of sorghum variety to plant. This information, was collected during the survey described in section 3.6 above, and is analysed using frequency distributions and cross-tabulations to identify the traits desired most by sorghum farmers and capture their varietal preferences.

### 3.9 Theoretical Framework and Methodological Issues for Estimating the Rate of Return on Sorghum Research

The main thrust of an impact assessment analysis is to compare a situation *without* research against an alternative situation *with* research. In fact, this analysis should not be confused with a *before* and *after* comparison since this can be misleading as conditions are constantly changing. The present study employs the economic surplus method of impact assessment.

The concept of Economic Surplus provides the theoretical framework for the economic surplus method. In order to turn agronomic data (the value of research) into economic values, the surplus approach uses the concepts of 'supply', 'demand', and 'equilibrium'. Rooted in the Marshallian concepts of social welfare and cost, it measures the social returns to research in terms of changes in consumers' and producers' surpluses resulting from the shift in the supply curve corresponding to a shift in the production function. This 'economic surplus' is some measure of economic welfare. In this application 'supply' represents producers' production costs, while 'demand' represents consumers' consumption values. The interaction of these two forces results in some 'temporary equilibrium' quantity and price. The economic surplus measured as the sum of producer surplus and consumer surplus is as shown in figure 3.1 below.

**Figure 3.1: Producer and Consumer Surplus**




where D is an inverse demand curve D = D(Q) and S is an inverse supply curve, S = S(Q); $C_s$ = Consumers' Surplus; $P_s$ = Producers' Surplus.

The demand and supply curves can be written as:

$$P_d = f_d(Q_d), \tag{3.16}$$

$$P_s = f_s(Q_s), \tag{3.17}$$

where $P_d$ is the demand price of the product, $Q_d$ is the quantity demanded, $P_s$ is the supply price of the product, and $Q_s$ is the quantity supplied.

It is assumed that the demand and supply functions obey their respective laws, *ceteris paribus*. Although demand and supply curves can take various shapes, it is often appropriate to consider them to be linear and assume parallel shifts (Masters et al., 1996). This simplifies the analysis without changing the end result, which is the area below the demand curve, between the two supply curves. Thus we have

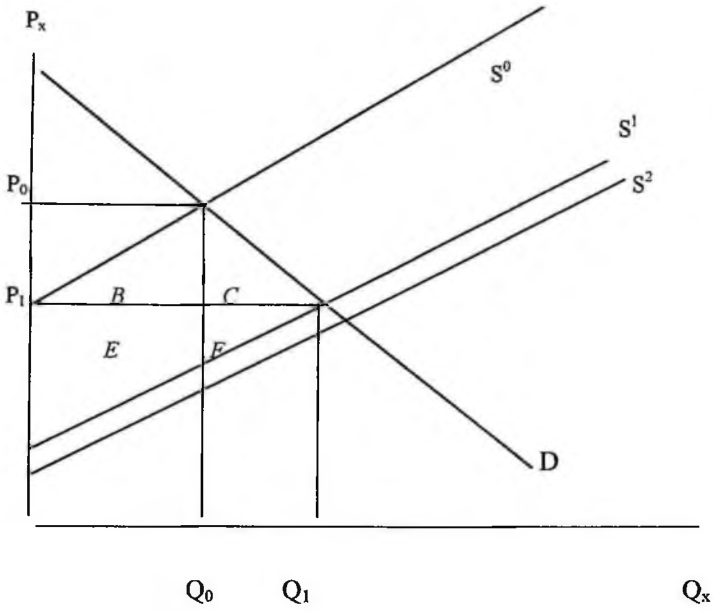
$P_s = a + bQ_s$, $b > 0$ for supply and

$P_d = c + dQ_d$, $d < 0$ for demand (3.18)

Finally, the levels of quantities produced must be some equilibrium (temporary though) between supply and demand. At each point in time, for some particular region, there is a single quantity that is both supplied and demanded ($Q_e$) as well as a single price that is both paid by demanders and received by suppliers ($P_e$).

As already indicated, the effect of research is captured as a change in economic surplus as innovations from research shift the supply curve to the right. This enables producers to supply a larger quantity at the same price or the same quantity at a lower price. Note that increases in the cost of production due to new technology create a further shift in the supply curve upward from $S^2$ to $S^1$. The scenario is depicted in figure 3.2 below.

**Fig 3.2: Supply shift with improved varieties**




Source: Adapted from Teal and Dinwiddy, 1996,p9.

With the improved sorghum varieties, the supply curve was expected to have shifted to the right and price declined. Society benefits with $B + C + E + F$. It should be noted, however, that this framework assumes a static demand function. This is a limitation since the assumption is not realistic, at least in the face of increasing population.

### 3.10.1 Method of Estimation

In order to be able to make an informed opinion of the profitability of the investment, it is often necessary to compare discounted costs and benefits over the period under consideration. This is because most research benefits do not start until after much cost has been incurred. Besides, during the early years following the development of a new technology, adoption levels may be low, and research benefits are therefore quite low. As adoption proceeds, the economic surplus grows exponentially, as the area between the supply and demand curves increases. Thus it is only after adoption is more widespread that significant benefits may be obtained.

Masters et al. (1996) recommend the use of the internal rate of return IRR, as the most important indicator for assessing the benefits of research over time. The IRR is the rate that results in

$$\sum_{t=0}^{T}(B_t - C_t)/(1+r_i)^t = 0 \qquad (3.20)$$

where $B_t$ is the social benefit in year t

$C_t$ is the research cost in year t

$r_i$ is the discount rate

$t$ is time, t = 1,2,…T

$T$ is the year in which research ceases to produce returns.

This measure gives the earning power of the investment (Gittinger, 1982). The IRR can then be compared to any interest rate, such as the cost of borrowing funds from a bank, or the returns earned in other investments. If the IRR from the research investment exceeds these rates, then the investment was worthwhile.

The financial rate of return calculated for Sorghum research covered the period 1966-1998. This period was chosen for two main reasons. The first was difficulties with obtaining the relevant data. It should be noted that it was generally difficult to obtain the data necessary for a good impact assessment. Data on quantity of improved seed distributed to farmers could only be obtained from the Global 2000 co-ordinator, with very little from the Seed Growers Association and none from the national agricultural extension service. Secondly, the Sorghum programme released its first improved variety in 1971 and this according to sorghum breeders was worked on for at least five years prior to the release.

Also, due to resource constraints and estimation problems, only the cost of sorghum improvement research was considered, but not the cost of technology transfer. It was assumed that 60 percent of the costs of the Sorghum section of SARI (which also caters for millet) is attributable to sorghum, based on discussions with the programme co-ordinator. The study follows the approach adopted by ICRISAT and the International Potato Center (CIP) in separate cases to analyse the returns to agricultural research. Both cases included only their own research costs, excluding costs associated with technology transfer. The costs also do not include past, sunk costs (in this case costs incurred before 1966). Thus the resulting rate should be viewed as the rate of return to sorghum improvement research. According to Kelly (1995) such a rate is best interpreted as an estimate of the economic benefit or the value of research at the margin.

### 3.11 Data Requirements for Impact Assessment (Rate of Return Computation)

The basic components besides observed prices and quantities, required for calculating the impacts of technological change on society and the distribution of the gains between producers and consumers are the elasticities of demand ($e_d$) and supply ($e_s$) and the shift parameter ($k$). Mathematically, the computations of the parameters needed for this exercise, following Mazzucato and Ly (1994), are as follows:

The change in production due to the improved varieties, as a proportion of total production is given as:

$$j = (\Delta Y \bullet a_t)/Y \qquad (3.21)$$

where $\Delta Y$ is the yield (kg/ha) difference between the improved varieties and the traditional ones; $Y$ is average yield i.e., total production divided by total acreage (ha); and '$a_t$' is the proportion of total sorghum area under improved sorghum.

The adoption costs of the improved varieties, as a proportion of the product price, is given as:

$$c = (\Delta C\ a_t)/(Y \bullet P) \qquad (3.22)$$

where $\Delta C$ is the difference per hectare between input cost on improved varieties and the traditional (¢/ha) and $P$ is the annual average product price paid to producers in real terms (¢/kg).

The net change in production costs, as a proportion of the product price, $k$ is given as:

$$k = (j/e_s) - c \qquad (3.23)$$

where $e_s$ is the elasticity of supply.

In the face of lack of per-unit cost reduction estimates this study uses the $j$ parameter to approximate $k$, and since technologies take time before benefits accrue the relevant per-unit cost reduction is given by

$$k_t = k \bullet a_t \quad or \quad j \bullet a_t \qquad (3.24)$$

In the absence the required elasticity estimates this is a realistic assumption. Mazzucato and Ly (1994) have shown that $j$ is exactly equal to $k$ when the long-run elasticity of supply is equal to one.

The social gains or economic benefits from the adoption of improved sorghum varieties measured as the total change in economic surplus ($\Delta TS_t$) and captured as $B + C + E + F$ in figure 3.2 is given as:

$$B_t = P_t Q_t k_t \quad (3.25)$$

Finally, the net benefit is obtained by subtracting the costs of research and this is given as:

$$B_{net} = B_t - C_t \quad (3.26)$$

where $C_t$ is the total cost of research that produced the improved varieties.

Estimating the adoption of improved technologies is an essential component of an evaluation of the benefits of research. In the face of an acute lack of a comprehensive set of adoption statistics on sorghum varieties being evaluated, synthetic estimates were derived of adoption rates using a variety of information sources.

Seed distribution figures were obtained from MOFA seed stores, the regional Sasakawa Global 2000 offices and Ghana Seed Company. The statistics however, grossly underestimate use of improved seed. This is in view of the fact that farmers themselves select and retain seed of improved varieties for use in subsequent years. An estimate of the percentage of improved seed in use derived from farmer-retained seed was made and added to the quantity of seed distributed to get a more realistic estimate of total amount of improved seed being used in a given year. Discussions with extension personnel indicate that in normal years farmers could retain over 100 per cent of the distributed seed sold, for the following year. This implies that the retention rate is over 100 per cent since other farmers also obtain improved seed as gift. For example, in Niger, Mazzucato and Ly (1994) estimated a retention rate of 120 per cent for millet. However, a retention rate of 100 per cent is assumed in this study to account for genetic degradation that takes place over time in an open-pollinated variety like sorghum. Estimates of annual area cultivated with sorghum over the relevant period were obtained from the PPMED of MOFA. A recommended 5kg/ha seed application rate for sorghum was obtained from the researchers.

Once the seed utilisation figure is obtained, it is then divided by the total area cultivated with sorghum and by the seed application rate to obtain the percentage adoption for improved sorghum. The relevant formula is

$$IS_t = (ISD_{t-1} \bullet F_t) + ISD_t \tag{3.27}$$

where

$IS_t$ = total improved seed used (kg) in year t

$ISD_{t-1}$ = improved seed distributed (kg) in preceding year

$ISD_t$ = improved seed distributed (kg) in current year

$F_t$ = proportion of improved seed carried over from a given year to the next (own seed)

The proportion of cultivated area sown to improved sorghum is calculated as

$$a_t = (IS_t \bullet R^{-1}) \bullet A_T^{-1} \quad (3.28)$$

where $R$ = seed application rate (kg/ha); $A_T$ = total area cultivated with sorghum (ha).

It is also realised that estimates of the social benefits arising from investments in research depend on the nature and size of the research-induced shift in the supply curve. Yield relativities are used to estimate the supply shift as defined earlier. Ideally, on-farm yield differentials between traditional varieties and new, improved varieties should be used for each location (district) where the improved varieties were grown to include site-specific differences in the yield differentials of improved varieties. However, all trials were only located at Wa, hence the available average yield figure of 1.35ton/Ha was used.

Output prices used in the calculation of the supply shift are the average annual market prices, converted to real values using price index. The price data was obtained from PPMED of MOFA. The cost of research was estimated as the sum of the annual salaries and allowances of all the staff on the sorghum improvement programme at SARI and the annual running cost of the sorghum section.

# CHAPTER 4

# RESULTS AND DISCUSSION

## 4.0: Introduction

This chapter opens with a brief discussion of the characteristics of the sampled farm-households based on the preliminary survey results. The study objectives are then addressed in turn, using the logistic function and Probit and Tobit analysis to examine adoption. Finally, farmers' varietal preferences are assessed and the rate of return used to measure the impact of research.

## 4.1: Characteristics of Sampled Farm-Households

The sample of 100 respondents, turned out to be predominantly illiterate males with only 7% being females and 17% of respondents having had either formal or non-formal education. The age distribution of the sample was as follows: below 31 years (5%); 31-40 years (38%); 41-50 years (28%) while 6% were above 60 years. The remaining 23% were aged between 51 and 60 years. The major reasons advanced for growing sorghum were (i) mainly for food 40%; (ii) for food and cash 54% and (iii) mainly for cash 5%. Approximately 60% of respondents intercropped their sorghum, mainly with cowpea 45%, maize 7% and maize/cowpea in combination 4%. The major source of labour for farm operations as reported by the respondents was family or reciprocal labour. It was only in land clearing and weeding that some 11% indicated having used hired labour.

It is worth noting that 86% of the respondents did not use inorganic fertilizer, the major reason being that it is expensive and they could not afford it. Credit was reported to be particularly difficult to obtain especially at the beginning of the farming season (60%) and during weeding (21%). Only 8% of all sampled farm-households indicated they had used farm credit from banks, moneylenders and trader pre-financing. Thirty-eight percent (38%) of the respondents had sources of non-farm income, the main sources were (i) trading 16%; (ii) charcoal burning 6%; (iii) wage employment 5%. Some of the main household characteristics of the respondents are compared in Table 4.1 below.

**Table 4.1: Main Characteristics of Sampled Households, UWR, Ghana, 1988 - 1999.**

| Variable/Units | | Mean | | p-value |
|---|---|---|---|---|
| | | Adopters | Non-adopters | |
| Family labour | (persons) | 9.00 | 7.00 | 0.0028*** |
| Farm size | (hectares) | 2.20 | 1.76 | 0.0852* |
| Market access | (km) | 10.50 | 17.90 | 0.0000*** |
| Fallow period | (yrs) | 3.00 | 3.79 | 0.0527** |
| Extension visits | (no./yr) | 4.88 | 10.62 | 0.0261** |

Source: Computed from survey data.

* Significance levels *** = 1%; ** = 5%; * = 10%

The statistics in Table 4.1 clearly show that the adopters' sub-sample tend to be in better positions than their no-adopting counterparts. They have on the average more family labour, larger farms and shorter fallow periods. They were also closer to sources of farm inputs (purchase points). However, they had fewer visits from extension agents.

The most important traditional varieties grown are *Chare/Nyoso* 55%, *Dawele* 18% and *Latuor/Gon* 11%. The major reasons why some farm-households never planted improved sorghum varieties as reported in the survey were that they (i) were not aware (15%), (ii) had no seed (13%) and (iii) preferred traditional varieties (11%).

### 4.2.1: The Pattern of the Adoption of Improved Sorghum Varieties in the Upper West Region of Ghana.

The results of the estimated logistic function in Table 4.2 are used to fit the diffusion curve.

**Table 4.2: Estimates of Logistic Function, UWR, Ghana, 1988 - 1999.**

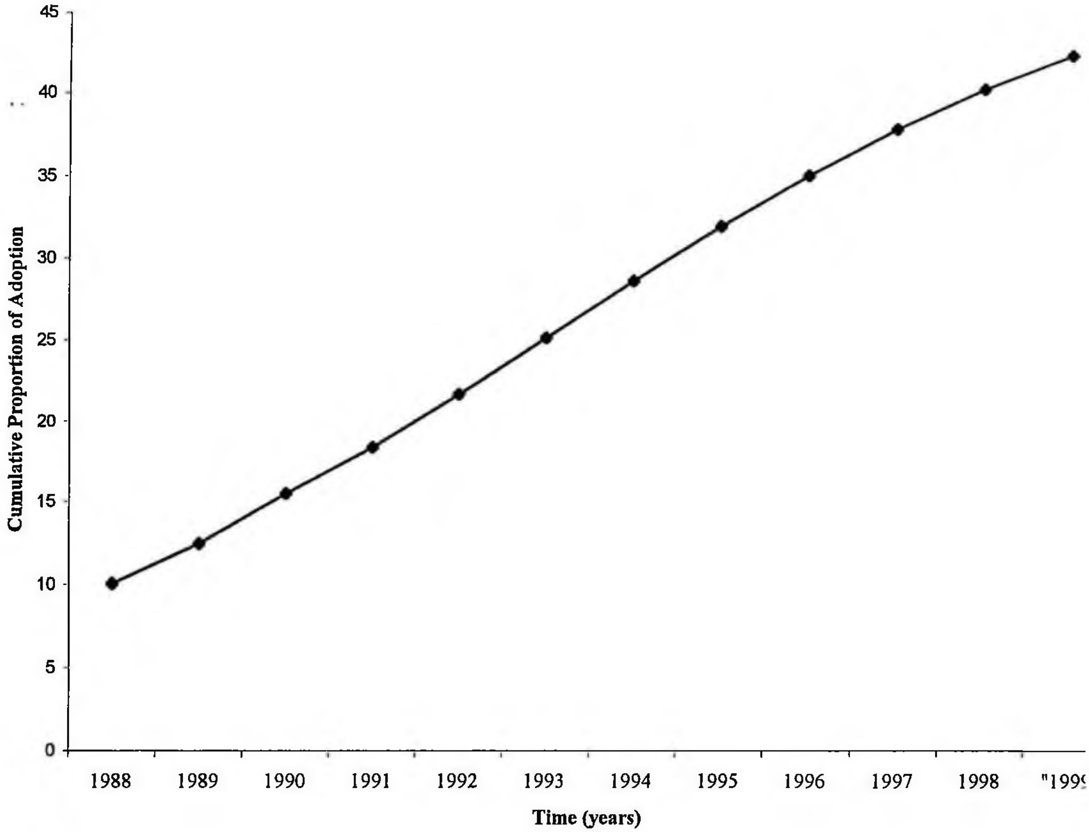
| Variable | Coefficient | Standard error | t-value | p-value |
|---|---|---|---|---|
| Intercept | -1.6816 | 0.1708 | -9.8464 | 0.0000*** |
| Time | 0.29995 | 0.0232 | 12.9263 | 0.0000*** |
| Degrees of freedom | 10 | | | |

Source: Computed from survey data.

* Significance levels *** = 1%

The fitted diffusion curve below describes the adoption pattern for improved sorghum varieties over the period 1988-1999. The curve, which approximates the expected S-shaped curve typical of successful diffusion, shows a gradually increasing trend in the rate of adoption of improved sorghum varieties. The rather painfully slow initial stages of the process have not featured prominently because some of the improved varieties were in use well before 1988. The maximum value on the curve as it tapers off is about 43%, but this does not give the actual proportion who planted improved varieties in 1999 since the curve assumes continual use after adoption. The curve in figure 4.1 depicts a normal diffusion process with an estimated diffusion rate of about 0.3 percent.

**Fig. 4.1: Diffusion Curve for Improved Sorghum Varieties, UWR, 1988 - 1999**




Source: Data compiled from Field Survey

### 4.2.2: Empirical Results of the Determinants of Adoption of Improved Sorghum Varieties

In this section the determinants are identified for the decision to adopt or not, using the Probit model and the intensity of adoption using the Tobit model. The results of the specified probit model are presented (Table 4.3).

**Table 4.3: Estimates of the Determinants of the Adoption of Improved Sorghum Varieties: Probit Model (1999/2000, UWR, Ghana)**

| Variable | Estimated coefficient | Standard error | Asymptotic T-ratio | Elasticity of predicted probability |
|---|---|---|---|---|
| Age | 1.45610 | 0.54427 | 2.67530*** | 0.48764 |
| Education | 0.22157 | 0.41231 | 0.53738 | 0.02895 |
| Extension visits | -0.02487 | 0.01465 | -1.69740* | -0.08473 |
| Credit | 0.62022 | 0.65814 | 0.94239 | 0.02533 |
| Non-farm income | 0.67108 | 0.40451 | 1.65900* | 0.10725 |
| Fallow | -0.31391 | 0.12340 | -2.54390** | -0.47781 |
| ChemicalFertilizer | -0.45282 | 0.41076 | -1.10240 | -0.10160 |
| Family Labour | 0.26043 | 0.07219 | 3.60780*** | 0.84712 |
| Distance to nearest salespoint | -0.09015 | 0.02671 | -3.37510*** | -0.58011 |
| Perception Index | 1.24290 | 0.55290 | 2.24790** | 0.15464 |
| Farm Type | 0.69223 | 0.40315 | 1.71700* | 0.16177 |
| Farm Size | 0.38752 | 0.15964 | 2.42750** | 0.32727 |
| Constant | -2.20780 | 0.86753 | -2.54500 | -0.94036 |

| | |
|---|---|
| Likelihood-ratio statistic | 65.1467*** |
| Sample size | 100 |
| Estimated rate of adoption | 0.47 |
| Observed rate of adoption | 0.48 |
| Mean predicted probability of adoption | |
| Among adopters | 0.8813 |
| Among non-adopters | 0.1364 |

Significance levels: *** = 1%; ** = 5%; * = 10%

On the basis of the likelihood ratio test (LRT), the probit model specified to examine the factors affecting the adoption of improved sorghum varieties is significant at the 1% significance level. This implies that the explanatory variables included in the model jointly influence a farmer's decision with respect to the adoption of improved sorghum varieties. In addition, the model predicted 83% of the cases (adopters and non-adopters) rightly and could therefore be used to test the validity of the hypotheses laid down earlier.

According to the asymptotic t values of the coefficients, some of the explanatory variables in the model were found not to be in conformity with *a priori* expectations. In the first instance, the extension contact variable did not show the expected sign though it was statistically significant at the 10% significance level. This observation contrasts sharply with general trends in adoption literature (see Hounkpe, 1999; Njoku, 1993; Shakya and Flinn, 1985). However, it is not the first of its kind as Denning (1991, *cited in CIMMYT, 1993*) observed no significant statistical association between extension visits and the adoption of dry-seeded rice in the Philippines. In the case of improved sorghum varieties in Northern Ghana, the main vehicle for the dissemination of information between SARI and sorghum farmers was the contact-farmers with whom on-farm trials were conducted until the establishment of a Research-Extension Liaison Committee in 1993/94. This unit presents research findings to the staff of the national agricultural extension network. The observed negative relationship raises questions about the appropriateness of the whole extension method. Specifically, no attention is given to sorghum extension activities in the study area.

Educational status and the use of farm credit, though with the expected signs, were not statistically significant at the 10% significance level. This is similar to the observation by Hailu (1990) that, though positively related, education did not prove to be significantly associated with the adoption of bullock traction technology in the Northern region of Ghana. However, he argued that this resulted probably because the educated saw tractor use as a better alternative. It is interesting to note that the sampled respondents in the current study turned out to be predominantly illiterate, with only 7% having had any formal education at all. This and problems of measurement of the variable are likely responsible for the observed result.

The observation on farmers' use of farm credit may be similarly explained. The general impression is that the use of credit for farming is very limited in the study area. Apart from cotton farmers who obtained farm credit in the form of inputs, only 5% of all sampled farm households indicated having used credit for farming in the survey year. The fact that it showed the expected sign could suggest validation of the hypothesis concerning the variable.

The chemical fertilizer variable, which captures the effect of the use of complementary inputs, neither showed the expected sign nor was it statistically significant. The non-significance may be due to the limited use of the input, while the negative sign may be explained by the fact that chemical fertilizers are not normally applied to sorghum in the study area. This is not an isolated case as Garcia et al (1997) noted that inspite of their knowledge and use of recommended technology farmers used less amounts of expensive inputs. In addition Coulibaly (1995) noted with concern, that in sub-Saharan Africa, inorganic fertilizers are mainly used on cotton and maize, and not on sorghum and millet.

He concluded that this presents a formidable challenge to researchers, extension workers and policy makers.

The rest of the factors proved to be significant determinants of the adoption of improved sorghum varieties. Among the socio-economic factors, the age variable was found to be positive and significant. Hence the hypothesis that young farmers are less risk averse and more adventurous could be considered confirmed. This observation is similar to the findings of Polson and Spencer (1992) and Manyong et al., (1998). However, this is contrary to the earlier observation by Pannin (1988) that decisions regarding the adoption of innovations are positively influenced by the age factor.

Farm size, the available family labour and non-farm income tend to exert positive influence on farmers' adoption decisions. Such findings appear to be the rule rather than the exception. For instance, Nkonya et al (1998) found that farm size was an important determinant of maize varietal adoption in Northern Tanzania. Similarly, Feder et al. (1985) showed that the share of area allocated to modern crop varieties increases with farm size. Also, Polson and Spencer (1992) found farmers' income to be an influential variable in adoption decisions. Besides, Akinola (1985) Pannin (1988), and Hailu (1990) found the available family labour to be an important determinant of adoption of chemical fertilizers and bullock traction technologies in the Northern region of Ghana. These results should be expected since the production of sorghum in the study area is in the hands of small-scale farmers who use little or no external inputs (including credit), with the farm household as the main source of farm labour.

Farm type and the number of years that farmers fallow their farmland were found to significantly influence the adoption behaviour of sorghum farmers. As expected, fallow (indicating intensity of land use) showed a negative effect as opposed to farm type. This is similar to the observation by Yaron et al. (1992) that small land area, which forced continuous and intensive cultivation (an indication of pressure on farmland) provided an incentive to adopt high pay-off, input intensive innovations in the Nazareth region of Israel. These findings are in line with the induced innovations hypothesis of Hayami and Ruttan (1984) to the effect that land-constrained farmers tend to adopt high yielding input intensive varieties. It should be noted that compound farming in the study area is practiced in areas where pressure on farmland has made it almost impossible for farmers to practice the bush fallow system.

The distance to the nearest purchase point for improved sorghum seed, a proxy for market access to improved sorghum seed was significant at 1%. Coulibaly (1995) emphasized the importance of access to input (and output) markets as an incentive for sustained adoption of new technologies. Specifically, Hailu (1990) observed that the distance to supply centres significantly influenced farmers' adoption of chemical fertilizers in the Northern region of Ghana. Hence the hypothesis that longer distances to the nearest purchase point exerts a negative effect on adoption of improved sorghum varieties is confirmed.

Last but not the least is the variable examining the effect of the characteristics of the technology itself, the perception index. This variable was found to be significant at the 5% and to exert a positive influence on adoption. Similar observations have been made in adoption studies in the past. Sperling and Loevinsohn (1993) noted that the salient factor in the adoption and spread of new varieties is the grower's appreciation of the variety. In an earlier study, Haugerud (1988) observed that the acceptability of new potato varieties depended, among other things, on taste preference, the starch content, cooking time, blight resistance, market acceptance and compatibility with the existing farming system. In addition, Yapi et al. (1998) reported that the most important reasons that were advanced for adopting S-35, an improved sorghum variety was its early maturity, high yield and good taste. These are some of the characteristics factored into the perception index and such findings should be of utmost interest to researchers. The discussion of the results of farmers' preferred characteristics is undertaken in section 4.2.4 below.

The mean predicted probability of adoption among adopters was found to be higher (0.88) than it was among non-adopters (0.14). Regardless of those that did not show the expected signs, most of the explanatory variables as measured by the corresponding weighted elasticities tend to be potential areas of future policy influences. This follows from the interpretation of these elasticities, which is simple and direct. For example, a change (policy) that brings about a 10% increase in non-farm income would lead to a 1% increase in the probability of adoption. Similarly, any change (policy) that brings about a 10 % increase in the available family labour, farm size or a 10% improvement in farmers' perception would lead to 8%, 3% and 2% increase in the probability of adoption, respectively. Also, a 10% improvement in farmers' market access to improved seed would lead to a 6% increase in the probability of adoption.

It should be noted that the probabilities in themselves are not important, but the elasticities which measure the direction and magnitude of the effects of changes in the explanatory variables on the probability of adoption.

### 4.2.3: Determinants of Intensity of Adoption: Tobit Model

The results of the Tobit model specified to examine the rate and intensity of adoption of improved sorghum varieties are summarised in Table 4.4 and discussed below.

**Table 4.4: Estimates of the Determinants of Intensity of Adoption: Tobit Model (1999/2000, UWR, Ghana)**

| Variable | Estimated coefficient | Standard error | Asymptotic T-ratio |
|---|---|---|---|
| Age | 0.92167 | 0.35312 | 3.2009*** |
| Credit | 0.37059 | 0.46218 | 0.9834 |
| Extension visits | -0.01326 | 0.01130 | -1.4393 |
| Non-farm income | 0.02931 | 0.25221 | 0.1425 |
| Fallow | -0.17074 | 0.07661 | -2.7331*** |
| Family Labour | 0.06220 | 0.04554 | 1.6750* |
| Distance to nearest salespoint | -0.02882 | 0.01656 | -2.1346** |
| Perception Index | 0.53019 | 0.34861 | 1.8652* |
| Farm Type | 0.09143 | 0.26221 | 0.4276 |
| Farm Size | 0.20073 | 0.09543 | 2.5796** |
| Constant | -1.00250 | 0.61314 | -2.0051 |

| | |
|---|---|
| Sample size | 100 |
| Estimated rate of adoption | 0.40 |
| Observed rate of adoption | 0.48 |
| Expected share of area under improved varieties | |
| entire sample E(Y) | 0.2101 |
| among adopters E(Y*) | 0.5633 |
| Mean predicted probability of adoption | |
| among adopters | 0.5567 |
| among non-adopters | 0.2737 |

Significance levels: *** = 1%; ** = 5%; * = 10%

Based on the asymptotic t-values of the parameter estimates six of the ten independent variables included in the model proved to be significantly associated with the intensity of adoption of improved sorghum varieties, and thereby confirm the hypotheses laid down.

Specifically, the results confirm that the probability of a sorghum farmer planting improved varieties and the share of sorghum area planted with improved varieties would be higher with improvement in his access to markets, perception about improved varieties, with increasing available family labour and farm size. The results confirm that younger farmers are more inclined to adopt and plant a higher proportion of their sorghum area to improved varieties than older ones. Hailu (1990) reported findings that are very similar to the findings on the above variables.

The results on the fallow variable do indicate that farmers with shorter fallow periods are more likely to adopt and plant more of their sorghum land to improved varieties. As explained earlier, this confirms the hypothesis that land-constrained farmers more often resort to high yielding input intensive varieties.

However, for completeness it is important to mention that non-farm income and farm type, though with the expected signs were not significant at the 10% level. Here again the extension contact variable neither showed the expected sign nor was it significantly associated with adoption. Also, as in the probit model the use of farm credit in the survey year was not a significant determinant of adoption.

As was noted about the probit model, the parameter estimates of the tobit model provide no direct information about the effect of changes in the explanatory variables on the probability of adoption and the intensity of use. To predict such effects, the parameter estimates must be weighted by the predicted probability of adoption. The change in the expected share of sorghum area under improved varieties, E(Y) in the entire sample as a result of a change in the $k^{th}$ explanatory variable is given by

$$\partial E(Y)/\partial X_{ik} = F(X_i' \beta)\beta_k \qquad (4.1)$$

where $\beta_k$ represents the coefficient of the $k^{th}$ explanatory variable (Maddala, 1983). McDonald and Moffit, (1980) developed a useful decomposition of this change which helps derive the required elasticities given by

$$\partial E(Y)/\partial X_{ik} = F(X_i' \beta)/\sigma \bullet \partial E(Y_i^*)/\partial X_{ik} + \partial E(Y^*) \bullet F(X_i' \beta)/\partial X_{ik} \qquad (4.2)$$

It has been shown that by multiplying both sides of the above equation by $X_i/E(Y_i)$ each term can be converted to an elasticity measure (Kinsey, 1984). With the help of this procedure the elasticity of the expected value of the dependent variable, E(Y) with respect to the kth explanatory variable has been decomposed to obtain the elasticity of the predicted probability of adoption and the elasticity of intensity of use. The results are presented in Table 4.5.

**Table 4.5: Elasticities of the Predicted Probability of Adoption and Expected Use Intensity of Improved Sorghum Varieties (1999/2000, UWR, Ghana)**

| Variable | [1]Elasticity of probability of adoption | expected sorghum area under improved varieties |
|---|---|---|
| Age | 2.5773 | 1.1615 |
| Fallow | -2.2932 | -1.0334 |
| Family Labour | 1.8864 | 0.8501 |
| Distance to nearest purchase point | -1.5878 | -0.7155 |
| Perception Index | 0.8144 | 0.3670 |
| Farm Size | 1.5583 | 0.7023 |

The estimated rate of adoption was 0.4 (40% of sampled farm households). The expected proportion of sorghum area planted with improved varieties was 0.21 (21.01%) for the entire sample whereas it was 0.5633 (56.33%) following a decision to adopt (i.e. among adopters). Judging from the reported elasticities it is clear that the explanatory variables have more influence on the probability of adoption than the intensity of use after adoption. The interpretation of these elasticities is simple and straightforward. For example, a 10% improvement in farmers' market access to improved sorghum seed would lead to about 16% increase in the probability of adoption and a 7% increase in the intensity of use.

### 4.2.4: Farmers preferred Varietal Characteristics

The section presents the results of farmers own ranking of the varietal traits or characteristics that they consider in their choice of sorghum variety to plant. The traits included for each farmer's consideration were the same ones that were used to compute the perception index used earlier. Those traits that placed first-to-third in each

elasticities are calculated at the means of the variables respondent's consideration were compiled and the results are as shown in Table 4.6. From the table it is clear that most farmers consider yield potential, maturity and market value in the choice of potential sorghum varieties. Farmers' consideration of yield potential and market value in cash-mediated subsistence farming such as practiced in the study area is quite understandable. This reflects each farmer's desire to meet household consumption needs from their own farms, and possibly have surplus to sell to meet their subsistence cash needs. The second trait, maturity period, deserves its place because of the short and erratic nature of the rainfall pattern in the region.

**Table 4.6: Farmers Preferred varietal characteristics according to percentage of respondents (1999/2000, UWR, Ghana).**

| Varietal Characteristic | Percentage |
|---|---|
| Yield | 87 |
| Short maturity period | 62 |
| Market value | 49 |
| Taste | 48 |
| Suitability for local dishes | 41 |

Source: compiled from survey data.

Finally, the place given to taste and suitability for local dishes may be explained by the fact that the bulk of the sorghum crop is often consumed by the farm-household.

As a follow up, farmers were also asked to compare their best traditional variety with the best of the improved varieties that they know in terms of varietal traits listed in Table 4.6

above. The results in Table 4.7 below show that a good number of the sampled farmers assess the improved varieties to be worse than, or at best the same as the traditional ones, especially in terms of their suitability for local dishes, taste and market value. The high non-response rate could also mean that there is very little awareness about the qualities of the improved varieties.

**Table 4.7: Comparison of Improved and Traditional Varieties by Farmers (1999/2000, UWR, Ghana)**

| Varietal Characteristic | Improved Variety is | | | |
|---|---|---|---|---|
| | No Response /Cannot tell | Better | Same | Worse |
| Yield | 41 | 51 | 7 | 1 |
| Short maturity period | 42 | 49 | 6 | 3 |
| Market value | 45 | 27 | 9 | 19 |
| Taste | 44 | 24 | 17 | 15 |
| Suitability for local dishes | 51 | 12 | 14 | 23 |

Source: compiled from survey data.

So the low rates of adoption can be attributed to the farmers' assessment of the improved varieties as not being superior to their traditional ones and/ or their lack of knowledge about the qualities or capabilities of the improved varieties. Farmer education on the capabilities of the improved varieties needs to be intensified. Above all, it is necessary to give these farmers' preferences due consideration in order to come out with improved material with a wide acceptance.

### 4.2.5: The Impact of Sorghum Research: Results of Rate of Return Analysis

A summary of the results of the rate of return analysis is presented in appendix 1a. The estimated rate was 8 percent at 1985 prices (US Dollars). Comparing this rate with results from similar studies makes interesting discourse. As already discussed under literature review, Sterns and Bernsten (1992) reported a rate of return of 3 percent for sorghum and cowpea research in Cameroon, while another as low as 1 percent was reported for sorghum research in Niger. Also, in Niger, Mazzucato and Ly (1992) estimated a negative rate of return for sorghum and cowpea research, and Laker-Ojok (1992) estimated a negative rate for sunflower, cowpea and soybean in Uganda. While the situation in Uganda was blamed on the turbulent political climate of the late 1970s and early 1980s, the researchers' in Cameroon explained that sorghum has presented a formidable problem to researchers throughout West and Central Africa for over 30 years. They concluded that low returns to sorghum research, though undesirable, may simply reflect long run historical trends of the performance of Sorghum research. Viewed form this standpoint, an 8 percent rate of return represents an enviable achievement.

However, Lopez-Pereira et al., (1991) estimated a rate of return of 32 percent for sorghum in the Honduras. In the said study the real cost of capital, a proxy for the next best alternative investment project, was estimated to be between 15 and 20 percent. More importantly, according to Kelly (1995) ICRSAT ranked 110 different research areas, and the average rate of return for the top 20 was 39 percent. Also, Kristjanson et al., (1999) reported that a rate of return estimate of 13-15 percent was obtained when CIP analysed returns to 15 research themes. Several other impact studies have reported even higher estimates for the rate of return to research. A survey of the literature indicates that such rates vary widely from 21 percent for maize in Zambia (Howard et al., 1992) to 135 percent for maize in Mali (Boughton, 1992).

From the foregoing therefore the estimated rate of return of 8 percent, baring all data deficiencies, though not the worst is one of the lowest and cannot be considered attractive. To test the robustness of this estimate, sensitivity analysis was conducted using three scenarios.

(i) Discussions with some of the sorghum researchers indicate that it is the aim of the programme to get as much as 50 percent of sorghum land under improved sorghum varieties. Therefore the effect of changes in the adoption rate (the proportion of sorghum area under improved varieties) was the first scenario. An increase in the adoption rate from 0.1 percent to 1 percent of sorghum area gave a rate of return of 109 percent (see appendix 1b). This shows that the current estimated low rate of 8 percent may be due mainly to the ridiculously low rate of adoption.

(ii) Atokple (1993) observed that sorghum yields can be increased to double current levels (to between 2 and 3t/ha) with the adoption of improved varieties, chemical fertilizers and improved farming practices. The second scenario looked at a 10 percent increase in the yield over and above the current 1.35t/ha. The result was an estimated rate of return of 10 percent (see appendix 1c).

(iii) The current practice by sorghum farmers is that chemical fertilizers are not applied to the crop. However, as noted by Sanders and Vitale (1998) there is little yield potential from improved sorghum cultivars unless they are combined with at least moderate levels of fertilization. Hence a 10 percent decline in the yield of the improved materials (from the current on-farm average of 1.35t/ha) provided the third scenario. This yielded an estimate of 6 percent (see appendix 1d). The results from the above analysis suggest that the focus should be on improving upon the adoption rate.

# CHAPTER 5

# SUMMARY, CONCLUSION AND POLICY IMPLICATIONS

## 5.1 Summary

The production of sorghum, one of the most important food crops with multiple uses in the savanna zone of Ghana, has been bedevilled with several problems. The most important problems are low yields, lack of improved varieties and *striga* infestation. These problems elicited research efforts at the Savanna Agricultural Research Institute to produce improved high yielding sorghum varieties that are adapted to the socio-economic and agroecological conditions of northern Ghana. This study examines the adoption and impact of improved sorghum varieties that were promoted in the Upper West region.

It was established in the review of literature that farm level decisions about the adoption of improved technologies are often governed by socio-economic and institutional factors as much as they are by technology specific factors. The Probit and Tobit models, specified to include factors from all three categories, are used to examine the adoption and, the rate and intensity of use of improved sorghum varieties. The logistic curve is used to describe adoption pattern while the economic surplus model provides the theoretical framework used to estimate the rate of return to sorghum research.

A normal adoption pattern is observed with a diffusion rate of about 0.3 percent. It is found that age, the available family labour, non-farm income, fallow period, farmers perception about the varieties, farm size, farm type and the distance to the nearest purchase point for improved seed are significant determinants of adoption. Education and farm credit though with the expected signs, were found not to be significant. The use of chemical fertilizers and the extension contact variable both showed the wrong signs though the extension variable is statistically significant. The mean predicted probability of adoption was 0.88 among adopters whereas it is only 0.13 among non-adopters.

The factors that influence both the rate and intensity of adoption are: age, available family labour, fallow period, farmers perception about the varieties, farm size and the distance to the nearest purchase point for improved seed. Education and farm type are found not to be significant while the extension contact variable neither showed the expected sign nor is it significantly associated with the dependent variable. The estimated rate of adoption is 0.40 (40% of sampled farmers) while the intensity of use, measured as the proportion of sorghum area under improved varieties, is 56.33% following a decision to adopt.

It is found that farmers' choice of variety to plant depends on yield, maturity period, market value, taste and suitability for local dishes, among others.

Finally, the economic surplus model framework is employed to estimate a rate of return of 8% for sorghum research. A sensitivity analysis is conducted using three different scenarios, an increase in the adoption rate to 1% of sorghum area, a 10% decline in yield and a 10% increase in yield. The results reveal that the first scenario has the highest rate of return of 109%.

### 5.2 Conclusions

An important aspect of agricultural development is the adoption of innovations by farmers. In order to overcome some of the constraints to sorghum production, the Savanna Agricultural Research Institute (SARI) has for over 30years embarked on a sorghum improvement programme, through which a number of improved varieties have been released to farmers. However, the fact that a technology has been released or recommended does not guarantee its widespread adoption. It is therefore important to identify the factors that influence farmers' adoption decision with respect to the technology.

The influence of each of the explanatory variables was found to be more on the probability of adoption than the intensity of use. This means that the chances of getting a farmer to plant improved sorghum are better than getting a user to plant more. The intensity of use estimated at 0.56 for adopters implies that the question of acceptability of the improved varieties is yet to be addressed. This explains why the estimated area under improved sorghum varieties is less than 1 percent whereas the percentage of farmers planting improved sorghum varieties is as high as 40 percent of the sample. Farmers are simply not convinced about the superiority of the improved varieties.

There is the need to redirect more attention to farmers' preferences and socio-economic conditions. This is against the background that such a re-orientation would enhance acceptability and hence adoption. This will ultimately improve the impact of Sorghum research and hence justify further investments.

### 5.3 Policy Implications

Policy implications of the findings of this study are outlined in this section. The estimated Probit and Tobit models have identified factors that are needed to boost adoption. Improving farmers' perception about the improved varieties is essential in influencing adoption and the intensity of use. There is the need to effectively educate farmers to understand the capabilities of the varieties and the production procedures for optimum results. This can best be achieved by forging strong research-extension-farmer linkages to ensure that while farmers are being educated, there is an effective feedback mechanism to convey their opinions and preferences to researchers. Incorporating farmers' concerns in Sorghum research will help to develop varieties that meet widespread acceptance. There is room for further varietal improvement with qualities of traditional varieties that farmers' desire most. In this regard efforts should be directed at improving the yield potential of such traditional varieties as *Chare/Nyoso, Dawelle* and *Latuor/Gon* as these already enjoy widespread acceptance among sorghum farmers.

It is recommended that extension efforts should focus more on the younger farmers while research is made more sensitive to farmer resource levels. This is against the background that younger farmers are predisposed to adopt the improved varieties, and access to family labour and non-farm income also enhance adoption. Also, in the face of limited access to credit, empowering farmers to engage in non-farm income generating activities could be an effective strategy of increasing farm level investment in general, and adoption of farm technologies in particular.

Farmers' market access to improved seed is essential in influencing the intensity of adoption. Therefore, it is necessary to intensify efforts at improving distribution networks, which could better be achieved through improved infrastructure and active involvement of farmers in acquisition of inputs. To ensure that improved seeds (and other inputs) are readily available to farmers there is the need for government to integrate the activities of extension agents, NGOs and the Seed Growers Association in the area. Also, as threats of land scarcity grow, there is the need for more strategic research to meet the technological needs for land use intensification. The Sorghum varieties are proving to meet that kind of need among farmers in the Upper West region.

Finally, the prospects for Sorghum research are good and there is the need for further investment. Though the rate of return of 8% may seem low, it is good. This is because of a possible underestimation of benefits since the estimated cost included more than just the development of varieties. The results of sensitivity analysis show that effective technology transfer is essential for reaping the benefits of new technologies. Hence more efforts in this direction will make prospects for Sorghum research even better.

### 5.4 Suggestions for Future Research

The database for conducting reliable impact assessment of agricultural research/projects is very weak. No systematic adoption rates are available on the various recommended technologies, neither are there consistent and reliable costs data on most of these technologies. Yet the results of impact assessments obey the "Garbage-In-Garbage-Out" principle. Hence, there is the need for research institutions in collaboration with extension organisations to pursue a systematic policy to build up and maintain a comprehensive database for the purpose.

Such a database should include time-series information on:

Quantities of inputs used, prices per unit of input used, quantities of output produced, prices per unit of output, adoption rates for the technology or quantities of improved seed planted by or distributed to farmers, research costs, and the costs of technology transfer. Also, the recommended input use rates, and the demand and supply elasticities of the product concerned should be available.

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**Appendix 1a: Rate of Return Calculation**

| YEAR | $C_t$ | $K_t$ | $P_t$ | Qt('000)kg | $B_t$ | $B_{net}$ |
|---|---|---|---|---|---|---|
| 1966 | 232309.4 | | | | | -232309 |
| 1967 | 328878 | | | | | -328878 |
| 1968 | 465594.8 | | | | | -465595 |
| 1969 | 564979.5 | | | | | -564979 |
| 1970 | 799840.3 | | | | | -799840 |
| 1971 | 512999.2 | 3.56E-05 | 7360.406 | 172.7 | 45306.38 | -467693 |
| 1972 | 914926.2 | 3.36E-05 | 11191.05 | 152.4 | 57251.42 | -857675 |
| 1973 | 1295261 | 3.43E-05 | 14228.62 | 166.6 | 81269.67 | -1213991 |
| 1974 | 1355768 | 3.81E-05 | 11820.33 | 176.8 | 79651.44 | -1276117 |
| 1975 | 1503499 | 4.68E-05 | 13888.89 | 135.1 | 87728.81 | -1415771 |
| 1976 | 1715510 | 3.4E-05 | 24253.73 | 188.5 | 155532.3 | -1559978 |
| 1977 | 1367390 | 3.52E-05 | 25210.08 | 140 | 124079.5 | -1243311 |
| 1978 | 446221.1 | 3.52E-05 | 5811.138 | 137.4 | 28066.03 | -418155 |
| 1979 | 444885.5 | 3.35E-05 | 5456.654 | 159.7 | 29158.4 | -415727 |
| 1980 | 424310 | 3.44E-05 | 29838.71 | 156.2 | 160482.2 | -263828 |
| 1981 | 383578.8 | 3.34E-05 | 26291.08 | 170.7 | 149956 | -233623 |
| 1982 | 445824 | 6.96E-05 | 25547.45 | 125.9 | 223890.9 | -221933 |
| 1983 | 28912.33 | 7.48E-05 | 25996.53 | 105.8 | 205748.3 | 176836 |
| 1984 | 17219.81 | 4.01E-05 | 18202.5 | 176 | 128509.1 | 111289.3 |
| 1985 | 15938.86 | 3.57E-05 | 17000 | 185 | 112391.6 | 96452.76 |
| 1986 | 9281.142 | 0.001709 | 13175.72 | 128.1 | 2884919 | 2875638 |
| 1987 | 3594.751 | 0.001216 | 11809.43 | 205.9 | 2956769 | 2953175 |
| 1988 | 2445.341 | 0.001740 | 17812.38 | 177.6 | 5505319 | 5502874 |
| 1989 | 1885.011 | 0.001662 | 15847.86 | 215 | 5663919 | 5662034 |
| 1990 | 1442.801 | 0.003440 | 11235.78 | 136 | 5256865 | 5255422 |
| 1991 | 1165.92 | 0.001195 | 14200.25 | 241.4 | 4095601 | 4094435 |
| 1992 | 1524.905 | 0.001379 | 17885.8 | 258.8 | 6381629 | 6380104 |
| 1993 | 795.033 | 0.000792 | 14372.39 | 328.3 | 3736024 | 3735229 |
| 1994 | 714.8427 | 0.000803 | 11983.91 | 323.9 | 3117237 | 3116522 |
| 1995 | 468.7497 | 0.000750 | 3654.116 | 360.1 | 986892.1 | 986423.4 |
| 1996 | 503.2884 | 0.000634 | 1264.741 | 353.4 | 283495.1 | 282991.8 |
| 1997 | 535.7087 | 0.001015 | 1205.946 | 332.6 | 407035.9 | 406500.2 |
| 1998 | 538.4116 | 0.000844 | 687.2138 | 355.4 | 206212 | 205673.5 |
| Rate of return (2d.p.) | | | | | | 0.08 |

Source: SARI Accounts, PPMED of MoFA and Author's computation.

**Appendix 1b: Sensitivity Analysis Assuming Adoption Rate Increases to 1% of Sorghum Area**

| YEAR | $C_t$ | $K_t$ | $P_t$ | Qt('000)kg | $B_t$ | $B_{net}$ |
|---|---|---|---|---|---|---|
| 1966 | 232309.4 | | | | | -232309 |
| 1967 | 328878 | | | | | -328878 |
| 1968 | 465594.8 | | | | | -465595 |
| 1969 | 564979.5 | | | | | -564979 |
| 1970 | 799840.3 | | | | | -799840 |
| 1971 | 512999.2 | 0.008221 | 7360.406 | 172.7 | 10450673 | 9937673 |
| 1972 | 914926.2 | 0.007743 | 11191.05 | 152.4 | 13205995 | 12291069 |
| 1973 | 1295261 | 0.007908 | 14228.62 | 166.6 | 18746203 | 17450942 |
| 1974 | 1355768 | 0.008792 | 11820.33 | 176.8 | 18372931 | 17017163 |
| 1975 | 1503499 | 0.010785 | 13888.89 | 135.1 | 20236111 | 18732612 |
| 1976 | 1715510 | 0.007847 | 24253.73 | 188.5 | 35876119 | 34160609 |
| 1977 | 1367390 | 0.008109 | 25210.08 | 140 | 28621008 | 27253618 |
| 1978 | 446221.1 | 0.008108 | 5811.138 | 137.4 | 6473898 | 6027677 |
| 1979 | 444885.5 | 0.007718 | 5456.654 | 159.7 | 6725871 | 6280986 |
| 1980 | 424310 | 0.007942 | 29838.71 | 156.2 | 37017903 | 36593593 |
| 1981 | 383578.8 | 0.007707 | 26291.08 | 170.7 | 34589859 | 34206280 |
| 1982 | 445824 | 0.016056 | 25547.45 | 125.9 | 51644161 | 51198337 |
| 1983 | 28912.33 | 0.017255 | 25996.53 | 105.8 | 47459272 | 47430360 |
| 1984 | 17219.81 | 0.009253 | 18202.5 | 176 | 29642776 | 29625556 |
| 1985 | 15938.86 | 0.008243 | 17000 | 185 | 25925000 | 25909061 |
| 1986 | 9281.142 | 0.00859 | 13175.72 | 128.1 | 14498566 | 14489285 |
| 1987 | 3594.751 | 0.007808 | 11809.43 | 205.9 | 18984835 | 18981241 |
| 1988 | 2445.341 | 0.008471 | 17812.38 | 177.6 | 26798728 | 26796282 |
| 1989 | 1885.011 | 0.008555 | 15847.86 | 215 | 29148173 | 29146288 |
| 1990 | 1442.801 | 0.011362 | 11235.78 | 136 | 17361532 | 17360089 |
| 1991 | 1165.92 | 0.004686 | 14200.25 | 241.4 | 16061901 | 16060735 |
| 1992 | 1524.905 | 0.00603 | 17885.8 | 258.8 | 27911678 | 27910153 |
| 1993 | 795.033 | 0.002731 | 14372.39 | 328.3 | 12886287 | 12885492 |
| 1994 | 714.8427 | 0.002471 | 11983.91 | 323.9 | 9589525 | 9588810 |
| 1995 | 468.7497 | 0.00254 | 3654.116 | 360.1 | 3342602 | 3342134 |
| 1996 | 503.2884 | 0.002006 | 1264.741 | 353.4 | 896764.3 | 896261.1 |
| 1997 | 535.7087 | 0.003135 | 1205.946 | 332.6 | 1257320 | 1256784 |
| 1998 | 538.4116 | 0.002626 | 687.2138 | 355.4 | 641445.4 | 640907 |
| Rate of return (2d.p.) | | | | | | 1.09 |

Source: SARI Accounts, PPMED of MoFA and Author's computation

**Appendix 1c: Sensitivity Analysis Assuming Yield Increases by 10% over the Current 1.35t/ha.**

| YEAR | $C_t$ | $K_t$ | $P_t$ | Qt('000)kg | $B_t$ | $B_{net}$ |
|---|---|---|---|---|---|---|
| 1966 | 232309.4 | | | | | -232309 |
| 1967 | 328878 | | | | | -328878 |
| 1968 | 465594.8 | | | | | -465595 |
| 1969 | 564979.5 | | | | | -564979 |
| 1970 | 799840.3 | | | | | -799840 |
| 1971 | 512999.2 | 4.57E+08 | 7360.406 | 172.7 | 55347.75 | -457651 |
| 1972 | 914926.2 | 6.47E+08 | 11191.05 | 152.4 | 70370.42 | -844556 |
| 1973 | 1295261 | 9.16E+08 | 14228.62 | 166.6 | 99673.31 | -1195588 |
| 1974 | 1355768 | 1.11E+09 | 11820.33 | 176.8 | 96676.56 | -1259092 |
| 1975 | 1503499 | 1.58E+09 | 13888.89 | 135.1 | 104636.3 | -1398863 |
| 1976 | 1715510 | 1.01E+09 | 24253.73 | 188.5 | 190905.6 | -1524604 |
| 1977 | 1367390 | 1.8E+09 | 25210.08 | 140 | 151788.4 | -1215602 |
| 1978 | 446221.1 | 2.56E+09 | 5811.138 | 137.4 | 34334.13 | -411887 |
| 1979 | 444885.5 | 2.68E+09 | 5456.654 | 159.7 | 35852.11 | -409033 |
| 1980 | 424310 | 2.97E+09 | 29838.71 | 156.2 | 196736.3 | -227574 |
| 1981 | 383578.8 | 3.39E+09 | 26291.08 | 170.7 | 284971.4 | -98607.4 |
| 1982 | 445824 | 2.7E+09 | 25547.45 | 125.9 | 741049.4 | 295225.4 |
| 1983 | 28912.33 | 8.83E+08 | 25996.53 | 105.8 | 849033.6 | 820121.3 |
| 1984 | 17219.81 | 8.8E+08 | 18202.5 | 176 | 727627.6 | 710407.8 |
| 1985 | 15938.86 | 8.4E+08 | 17000 | 185 | 1025865 | 1009926 |
| 1986 | 9281.142 | 7.6E+08 | 13175.72 | 128.1 | 3509250 | 3499969 |
| 1987 | 3594.751 | 8.84E+08 | 11809.43 | 205.9 | 3631147 | 3627552 |
| 1988 | 2445.341 | 57333154 | 17812.38 | 177.6 | 6705731 | 6703286 |
| 1989 | 1885.011 | 34164097 | 15847.86 | 215 | 6892398 | 6890513 |
| 1990 | 1442.801 | 31638633 | 11235.78 | 136 | 6245232 | 6243789 |
| 1991 | 1165.92 | 18432347 | 14200.25 | 241.4 | 5379247 | 5378081 |
| 1992 | 1524.905 | 7142770 | 17885.8 | 258.8 | 8078114 | 8076589 |
| 1993 | 795.033 | 4861338 | 14372.39 | 328.3 | 5477614 | 5476818 |
| 1994 | 714.8427 | 3749287 | 11983.91 | 323.9 | 4690736 | 4690021 |
| 1995 | 468.7497 | 2871174 | 3654.116 | 360.1 | 1474081 | 1473612 |
| 1996 | 503.2884 | 2321346 | 1264.741 | 353.4 | 453142.3 | 452639 |
| 1997 | 535.7087 | 3037612 | 1205.946 | 332.6 | 577588.1 | 577052.4 |
| 1998 | 538.4116 | 1584501 | 687.2138 | 355.4 | 206212 | 205673.5 |
| Rate of return (2d.p.) | | | | | | 0.10 |

Source: SARI Accounts, PPMED of MoFA and Author's computation

**Appendix 1d: Sensitivity Analysis Assuming Yield Decreases by 10% from the Current 1.35t/ha.**

| YEAR | $C_t$ | $K_t$ | $P_t$ | Qt('000)kg | $B_t$ | $B_{net}$ |
|---|---|---|---|---|---|---|
| 1966 | 232309.4 | | | | | -232309 |
| 1967 | 328878 | | | | | -328878 |
| 1968 | 465594.8 | | | | | -465595 |
| 1969 | 564979.5 | | | | | -564979 |
| 1970 | 799840.3 | | | | | -799840 |
| 1971 | 512999.2 | 4.57E+08 | 7360.406 | 172.7 | 35265.01 | -477734 |
| 1972 | 914926.2 | 6.47E+08 | 11191.05 | 152.4 | 44132.43 | -870794 |
| 1973 | 1295261 | 9.16E+08 | 14228.62 | 166.6 | 62866.02 | -1232395 |
| 1974 | 1355768 | 1.11E+09 | 11820.33 | 176.8 | 62626.32 | -1293142 |
| 1975 | 1503499 | 1.58E+09 | 13888.89 | 135.1 | 70821.29 | -1432678 |
| 1976 | 1715510 | 1.01E+09 | 24253.73 | 188.5 | 120159 | -1595351 |
| 1977 | 1367390 | 1.8E+09 | 25210.08 | 140 | 96370.65 | -1271020 |
| 1978 | 446221.1 | 2.56E+09 | 5811.138 | 137.4 | 21797.94 | -424423 |
| 1979 | 444885.5 | 2.68E+09 | 5456.654 | 159.7 | 22464.7 | -422421 |
| 1980 | 424310 | 2.97E+09 | 29838.71 | 156.2 | 124228.2 | -300082 |
| 1981 | 383578.8 | 3.39E+09 | 26291.08 | 170.7 | 178492.5 | -205086 |
| 1982 | 445824 | 2.7E+09 | 25547.45 | 125.9 | 534115.1 | 88291.08 |
| 1983 | 28912.33 | 8.83E+08 | 25996.53 | 105.8 | 617404.5 | 588492.2 |
| 1984 | 17219.81 | 8.8E+08 | 18202.5 | 176 | 476979.2 | 459759.4 |
| 1985 | 15938.86 | 8.4E+08 | 17000 | 185 | 654075 | 638136.1 |
| 1986 | 9281.142 | 7.6E+08 | 13175.72 | 128.1 | 2260587 | 2251306 |
| 1987 | 3594.751 | 8.84E+08 | 11809.43 | 205.9 | 2282392 | 2278797 |
| 1988 | 2445.341 | 57333154 | 17812.38 | 177.6 | 4304907 | 4302462 |
| 1989 | 1885.011 | 34164097 | 15847.86 | 215 | 4435441 | 4433556 |
| 1990 | 1442.801 | 31638633 | 11235.78 | 136 | 4268498 | 4267056 |
| 1991 | 1165.92 | 18432347 | 14200.25 | 241.4 | 2811956 | 2810790 |
| 1992 | 1524.905 | 7142770 | 17885.8 | 258.8 | 4685143 | 4683618 |
| 1993 | 795.033 | 4861338 | 14372.39 | 328.3 | 1994435 | 1993640 |
| 1994 | 714.8427 | 3749287 | 11983.91 | 323.9 | 1543737 | 1543022 |
| 1995 | 468.7497 | 2871174 | 3654.116 | 360.1 | 499703.5 | 499234.7 |
| 1996 | 503.2884 | 2321346 | 1264.741 | 353.4 | 113847.8 | 113344.5 |
| 1997 | 535.7087 | 3037612 | 1205.946 | 332.6 | 236483.7 | 235948 |
| 1998 | 538.4116 | 1584501 | 687.2138 | 355.4 | 107073.8 | 106535.4 |
| Rate of return (2d.p.) | | | | | | 0.06 |

Source: SARI Accounts, PPMED of MoFA and Author's computation

## APPENDIX 2

## THE DETERMINANTS OF ADOPTION, AND IMPACT OF IMPROVED SORGHUM VARIETIES IN THE UPPER WEST REGION, GHANA.

**Questionnaire for Farmer Survey**

Background: A Study of Socio-economic, Technological and Institutional Factors Affecting the Adoption of Improved Sorghum Varieties by Farmers in the Upper West Region, Ghana.

District code ..................... Interviewer's code..............................

Village code ..................... Date .....................

Name of household head ..............................................................................

Section A: Socioeconomic factors

1. Age of respondent in years.

 a) 21-30 b) 31-40 c) 41-50 d) 51-60 e) above 60

2. Sex of respondent. a) male b) female

3. What is your level of education?
 a) none b) non-formal c) basic d) secondary e) tertiary

4. Marital status of respondent a) single b) married c) separated d) divorced e) widow f)widower

5. What is the total number of members of your household? ......................

6. What is the total number of household members who really work on the household farm?
 No. of children ........... No. of women ......... No of men. .............

7.What is your major occupation? a) farming b) business c) other (specify)

8 Do you have any source of non-farm income? a) yes b) no

9 If yes, name them a) ........... b).............. c) ............. d) ........

10. Is any member of your household in paid employment? a) yes b) no

11. Do any of your wives brew pito a) yes b) no

12. Do you grow sorghum? a) yes b) no

13. If yes, how long have you been growing sorghum of your own as a farmer? ……..years

14. What is the estimated size of your farm?

| Plot Number | Crops grown | Size of plot (ha) | Size under improved sorghum | Average yield of sorghum(kg/ha) |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

Crop code 1. Sorghum 2. Millet 3. Cowpea 4. Maize 5. other

15. Do you use inorganic fertilizer? a) yes b) no

16. Do you use organic fertilizer?

17. If yes, indicate the source.

18. How much does it cost you to undertake each of the following activities on an acre of sorghum?

| Activity | Cost (¢/ha) or (¢/acre) | Source of labour |
|---|---|---|
| Ploughing<br>Harrowing<br>Sowing/Planting<br>Weeding<br>Harvesting<br>Threshing<br>Winnowing<br>Other (specify) | | |
| Total cost | | |

19. How much does it cost you to grow an acre/hectare of sorghum in terms of .......?

| Type/Input | Seed | Fertilizer | Land | Pesticide | Other |
|---|---|---|---|---|---|
| Traditional | | | | | |
| Framida | | | | | |
| Naga white | | | | | |
| Kadaga | | | | | |
| Kapaala | | | | | |
| Dorado | | | | | |
| Other | | | | | |

20. Would you say have enough land for farming? a) yes b) no

21. Is it easy to obtain/acquire farmland in this area? a ) yes b) no

22. Is it easy to get hired labour when needed? a) yes b) no

Section B: Technological factors

23. Which varieties of sorghum do you grow/plant?

| Variety | Year 1st planted | Varieties no longer grown |
|---|---|---|
| Traditional | | |
| Naga white | | |
| Framida | | |
| Kadaga | | |
| Kapaala | | |
| Dorado | | |
| Other | | |

24. Why do you no longer plant......?

25.Give reasons for the varieties you grow.

| Reasons | Traditional | Framada | Naga white | Kadaga | Kapaala | Other |
|---|---|---|---|---|---|---|
| Good yield | | | | | | |
| Does not lodge | | | | | | |
| Good for pito | | | | | | |
| Family food | | | | | | |
| Other | | | | | | |

26. Name the best local variety of sorghum you grow...................

27. Name the best improved variety of sorghum you grow..................

28. Area under sorghum crop has been ......... over the years.

| | Tick one | Possible reason |
|---|---|---|
| Decreasing | | |
| Same | | |
| Increasing | | |

29. The number of farmers growing improved sorghum has been ....... over the years.

| | Tick one | Possible reason |
|---|---|---|
| Decreasing | | |
| Same | | |
| Increasing | | |

30. In your opinion, has sorghum yields been .....?

| | Tick one | Possible reason |
|---|---|---|
| Decreasing | | |
| Same | | |
| Increasing | | |

31. In your opinion, what are the most important factors that could prevent you from growing improved sorghum?

32. Where do you obtain information on non-traditional sorghum varieties?

a) extension officer b) NGOs c) other farmers d) friends
e) farmers' group

33. What extra inputs are required for the growing of improved sorghum?

| Input/ha | Extra input required | | | | |
|---|---|---|---|---|---|
| | Framida | Kadaga | Naga White | Kapaala | Dorado |
| Labour | | | | | |
| Improved seed | | | | | |
| Fertilizer | | | | | |
| Pesticide | | | | | |
| Other (specify) | | | | | |

34. For the period starting from 1988, please indicate the varieties grown.

| Year | Variety | | | | |
|---|---|---|---|---|---|
| | Framida | Naga white | Kadaga | Kapaala | Dorado |
| 1988 | | | | | |
| 1989 | | | | | |
| 1990 | | | | | |
| 1991 | | | | | |
| 1992 | | | | | |
| 1993 | | | | | |
| 1994 | | | | | |
| 1995 | | | | | |
| 1996 | | | | | |
| 1997 | | | | | |
| 1998 | | | | | |
| 1999 | | | | | |
| Size of current acreage (ha) | | | | | |

35. How do you grow your sorghum? a) monocrop b) intercrop

36. What method of planting did you use for your sorghum in 1999?
a) row planting/lines b) random c) broadcasting.

37. Which will you plant in a normal year? a) Traditional b) improved

38. Which varieties give you better yield when rains are
a) average............b) below average.... c) above average.........

39. How do improved sorghum varieties compare with the traditional in terms of

| Characteristic | Improved variety is<br>Less/same or better/ more | | | | |
|---|---|---|---|---|---|
| | Framida | Naga white | Kadaga | Kapaala | Dorado |
| Disease tolerance | | | | | |
| Pest tolerance | | | | | |
| Drought tolerance | | | | | |
| Varietal yield | | | | | |
| Suitability for local dishes | | | | | |
| Maturity period | | | | | |
| Taste quality | | | | | |
| Marketability | | | | | |
| Fertilizer requirement | | | | | |
| Storage | | | | | |
| Weed suppression | | | | | |

Section C: Institutional factors

40. Where do you obtain your improved sorghum seed?
    a) extension officer b) NGOs c) other farmers d) market
    e) farmers' group f) select seed from own farm g) other (specify)

41. How often does the extension officer visit you as a farmer? a) once a week
b) once a month c) once a year d) never

42. Has the extension officer ever discussed your problems regarding sorghum production with you? a) yes b) no

43. Did he discuss with you the type of variety that would be suitable to you?
    a) yes b)no

44. Do you use inorganic fertilizer on your sorghum crop? a) yes b) no

45. If no, why? ............

46. Where do you obtain your fertilizer? a) extension officer b) market
    c) FASCOM d) NGOs e) Farmers' group/association

47. How much is the cost of a bag of fertilizer? (¢/50kg bag)

48. Are agricultural inputs (improved seed, fertilizer, etc) readily available when you need them? a) yes b) no

49. What is the distance of the nearest sale point for agricultural inputs in your area?.....km

50. Is there any credit facility available to you for growing improved sorghum? a)yes b) no

51. If yes, name the source. a) bank b) credit union c) NGOs d) other specify.......

52. What are the major uses to which you put your sorghum crop?

| Uses | % allocation |
|---|---|
| Sale | |
| Consumption | |
| Pito | |
| Other | |

53. Is there a ready market for improved sorghum? a) Yes b) no

54. Do you get a good price for your improved sorghum? a) yes b) no

*Secondary data/information was collected from the researchers at SARI, Seed Growers Association, Agricultural Extension Officers and PPMED of MOFA for impact aspect of the study.