ABSTRACT

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New agricultural technologies are promoted in developing countries to bring about some combination of economic, environmental, and or health benefit. All of these benefits are considered to improve the livelihoods of the households that adopt them. However, the adoption of these new innovations by farm households is never uniform but is based on each household's evaluation of the utility of the new technology with relation to that household's attributes. This study looks at the adoption of a new agricultural crop—soybeans—that has been promoted for its nutritional effects in the Tamberma region of Benin and Togo. Variables affecting adoption and disadoption are based on five broad categories of adoption determinants found in the literature: household preferences, resource endowments, economic incentives, risk and uncertainty, and biophysical characteristics. A sixth category of farmer's perceptions is added to this model to determine current perceptions of soybean utility in the study area. A Probit model is employed to determine factors affecting adoption and disadoption rates in the study area. Variables statistically correlated with the adoption decision include: education, extension, membership, health, cash cropping, and soil quality. Variables statistically correlated with the disadoption decision include: education, experience, expected price, and type of soil.

Technology Adoption in West Africa:
adoption and disadoption of soybeans on the Togo-Benin border

by

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BIOGRAPHY

The writer of this thesis graduated with a Bachelor of Science in Biology and a concentration in Environmental Sciences from Meredith College in Raleigh, NC. She then continued in her studies at North Carolina State University in the Department of Forestry, where she pursued a Master of Science in Natural Resource Management with a concentration in International Resources. Kelly was a participant in the Masters International program and spent two years serving as a Peace Corps Volunteer in Togo, West Africa as a part of her graduate studies. It was during this period that she conducted her master's research, which is presented in this thesis.

ACKNOWLEDGMENTS

The author of this thesis would like to thank her committee members for their support and professional comments and suggestions. She would especially like to acknowledge the advice, input, and direction of her advisor, Erin Sills. The author, however, is solely responsible for all information contained in this thesis.

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CHAPTER 1: INTRODUCTION

1.1 Problem Statement

In the crop farming zones of the Sahel, soil degradation maps show that 70% of dryland areas suffer form moderate to severe land degradation (UNEP 1993). As land degradation increases and population pressures rise, food outputs are negatively affected (Sanders *et al.* 1995; Oldeman *et al.* 1991). Consequently, many crop farmers in this region are not able to satisfy household consumption demands (Baidu-Forson 1999). This is further compounded by the poor nutritional content of the food that is produced in the area; nearly 50% of the African diet comes from cereal crops. Women and children are most affected by this poor nutritional content as their access to proteins rarely is met. Protein-energy malnutrition is common among infants and children in West Africa and often goes unnoticed because the child may appear healthy while being severely malnourished (Galiba 2003).

Protein malnutrition is considered by nutritionists to be one of the major problems in developing countries (Meller and Johnston 1984). The prevalence of malnutrition is a relevant and valid measure of endemic poverty; nutritionists argue that it is a better indicator than estimates of per capita income. A direct impact of protein deficiency in Sub-Saharan Africa is inadequate growth and stunting (Onofiok and Nnanyelugo 1998). Stunting has a negative impact on the intellectual and physical development of children, compromising the development of human resources in poor countries. Persistent high prevalence of stunting among children indicates chronic failure in poverty alleviation. The reduction of chronic malnutrition can boost economic growth and help alleviate poverty in these countries (Poverty Mapping 2004).

Inadequate food security and poor nutritional diet lead to disease, sickness, and famine that are directly contributing to a reduction in productive labor in Africa. The fact that economic growth in the Sahel is dependent primarily on agricultural growth, and thus a productive labor force, makes this predicament even more severe. The introduction of technologies that improve food security and nutrition in the area are seen as critical to the future development of the Sahelian regions. However, the adoption of these new technologies by farm households has only been met with partial success. Understanding the factors that influence this adoption has thus attracted the attention of development workers. For example, there have been numerous studies on the adoption of agroforestry technologies. Key questions in these studies focus on determining the role information, training, wealth resources, risk aversion, and uncertainty have on the adoption process.

In West Africa, soybean cultivation is one 'technology' promoted to decrease malnutrition in children and women. Soybeans have one of the highest protein contents of any food crop at 40% and are second only to groundnuts in their oil content. Compared to other sources of protein in these countries, such as meats, fish and eggs, the cost of soybeans is significantly cheaper. For these reasons soybeans are considered to be a high quality, but inexpensive, protein source for women and children affected by malnutrition (IITA 2004). The introduction of weaning foods that combine soybeans with other cereal crops is commonly promoted at health centers, among non-governmental organizations and through health extension agents.

As well as nutritional benefits, soybeans improve soil fertility by adding nitrogen to the soil. The majority of West Africa depends on agriculture for subsistence. This has led to the depletion of nitrogen from the soils and a significant decrease in soil fertility for the area. Inorganic fertilizers are not heavily used in the area due to lack of availability and expense. Thus, organic ways of providing the soil with required nutrients are needed to sustain the growing human population. Nitrogen-fixing plants, such as soybeans, are seen as one solution to enhancing soil fertility in West Africa at little monetary cost (Sanginga 2003). In a study in South Africa, Bloem (2001) estimates that soybeans contribute 22 kg/ha of residual soil nitrate and found that after rotation with soybeans, maize yields increased 51%. However, quantification of nitrogen fixed by soybeans in the agro-ecological zones of West Africa has not been developed (Sanginga 2003).

The International Institute of Tropical Agriculture (IITA) located in Nigeria, West Africa, has been promoting soybeans as a crop with the potential of providing nutritional, environmental and economic benefits to the people of West Africa since the 1980s. Many of these possibilities have been realized in Nigeria. In other parts of West Africa, governmental organizations, nongovernmental organizations (NGO), and local extension agents are promoting soybeans and have begun education and extension programs in their own countries. In rural Togo and Benin, soybean promotion has largely been carried out on a small scale by local volunteer organizations and missionaries starting in the 1980s. Most of these programs are promoting soybeans exclusively for their nutritional benefits. Targeting community health centers, malnutrition is being fought by educating women on the value of adding soy products to their children's diets.

1.2 Purpose of Study

Soybean technologies have been promoted in Togo and Benin for nearly two decades. However, these efforts have not been evaluated rigorously, and in particular, there have been no studies of the diffusion of soybean technologies. Not all households have adopted the new technologies and many "disadopt" when the technologies are no longer actively promoted. This is typical of efforts to promote technologies based on their environmental and health benefits but has not been adequately studied (Feder and Umali 1993). This thesis explores the reasons for both adoption and disadoption through a case study of the Tamberma region of Northeastern Togo and Northwestern Benin. This region is typical of the rural Sahel in climate, geography, livelihoods, and resource conditions. The author served as a Peace Corps Volunteer in Togo from 2002 to 2004. While adoption of soybean technology was occurring, disadoption of the technology was also quite high in the region. This provided an opportunity to address the gap in the literature on disadoption rates and the factors that lead to abandonment of a new technology.

I define adoption for this study as the choice to cultivate the soybean technology as of the survey year, even if the household was no longer cultivating it. Defining adoption as the choice to cultivate the technology is also a good indicator for soybean consumption, since the primary use of this crop was for home consumption. Disadoption refers to the abandonment of the technology and is defined in this study as no longer planting the soybean crop as of the survey year. The rate or percent of people who had adopted or disadopted the technology is identified as well as the factors that influence these decision processes.

Data were collected through a cross-sectional survey of 135 farm households. The five categories of determinants of adoption as identified in Pattanayak *et al.* (2003) were used as the explanatory variables to evaluate the adoption process. These categories include: household preferences, resource endowments, economic incentives, biophysical factors, and risk and uncertainty. A sixth section in the survey instrument was used to determine local knowledge and perceptions of soybean farming and soybean attributes (nutritional value, soil-improving capabilities, ease of use, etc.). Independent variables from these six categories were modeled to determine their effect on the dependent variable, the decision whether to plant soybeans or not and for those who chose to adopt, the decision whether to abandon the technology or not. Variables collected in the research were analyzed using a utility-based maximization model and results were compared with results from similar technology adoption studies. Participant and direct observation were used to gather qualitative information on the study areas, specifically on soybean cultivation and utilization. This information was used to interpret and understand quantitative results.

This thesis proceeds as follows: the rest of Chapter 1 will explore the research questions and the theoretical model used to answer these questions, as well as limitations to this study; Chapter 2 describes the study area, focusing on the socioeconomic, biophysical, and extension characteristics of the two villages, as well as the history of soybean promotion and cultivation in West Africa; Chapter 3 reviews the literature on the adoption process, including the history of adoption studies, the five categories of adoption determinants and their corresponding variables, and the disadoption process; Chapter 4 is a preliminary look at the data for this study, including data collection methods, study variables, and similarities and differences between the two study sites; Chapter 5 turns to the empirical analysis and includes descriptive statistics and empirical models used for adoption and disadoption of the technology, as well as results from these models; Chapter 6 answers the original research questions posed in Chapter 1 and discusses the implications of these findings.

1.3 Research Questions

Data was collected from farm households specifically to answer two key research questions:

1. **What is the adoption rate of soybeans by households in the villages of Warengo, Togo and Koudogou, Benin and what factors are significantly correlated with the adoption decision?** Understanding the rate of adoption and the factors affecting that adoption are the first steps to understanding why farmers adopt or do not adopt a new technology. This allows for better targeting of extension programs. For this thesis, the collected data were used to determine the adoption rate for soybeans in the two villages and also to determine which of the five categories of adoption determinants and the associated factors were significantly correlated with the adoption decision.

2. **What is the disadoption rate of soybeans by households in the villages of Warengo, Togo and Koudogou, Benin and what factors are significantly correlated with the disadoption decision?** Understanding the rate of disadoption and the factors affecting the abandonment of a technology are important to understand the long-term constraints and practicality of the technology. For this thesis, data from households that had adopted soybeans were used to determine disadoption rates for soybeans and also to determine which factors were significantly correlated with the disadoption decision.

In addition to the two primary research questions, data collected will offer insight into the following subsidiary research questions:

3. **What are the perceptions of farmers towards soybean utility and farming in the region?** Soybeans are promoted as providing environmental and health benefits to the farming community. This research sought to determine whether farmers were aware of these health and environmental benefits and whether these benefits were being realized. The research collected also addressed farmer perceptions towards the marketability, ease of preparation, and use of fertilizers in cultivating soybeans.

4. **How do the adoption rates and the factors that affect those adoption rates compare between two villages of similar ethnicity, livelihoods, and extension history but different geopolitical characteristics?** Being posted on the border of Togo and Benin, I had a unique opportunity to look across countries and study whether factors that influence technology adoption remain the same or are different. Villages on either side of the border

represented the same ethnicity, livelihoods, and resource base. The main difference between the two villages is the country they lie in. The hypothesis is that adoption and disadoption rates and factors affecting these decisions are similar for these two villages. If they are not similar, then this thesis will seek to explain what factors account for these differences.

5. **Do the categories used to assess the adoption of new agricultural technologies fit when the given technology has been promoted almost exclusively for its nutritional benefits or are different variables affecting adoption?** The meta-analysis (Pattanayak *et al.* 2003) on adoption of agricultural technologies identified five broad categories of adoption factors. The agricultural technology being evaluated in this research had only been promoted for its nutritional benefits and not its environmental or economic benefits like most agricultural technologies. In light of this, this thesis sought to determine if the factors that influence adoption of technologies promoted almost exclusively for nutritional benefits fall in the same categories identified by the meta-analysis.

1.4 Theoretical Model of Adoption Choice

Adoption decisions can be modeled based on the rate of adoption (the percent of farmers that adopt a given technology) and the extent of adoption (the level of use of the new technology). Data collected in this study does not allow the extent of adoption to be measured, and therefore only the rate of adoption and disadoption and the factors that determine these decisions is examined.

The adoption decision can be modeled as a dichotomous choice of whether to adopt a new technology or not to adopt. Since this variable can take on only two values: 1 and 0 (adopt or not adopt), a binary choice model is used to analyze this adoption decision. Assumptions underlying binary choice models are that: (1) the economic agent is faced with a choice between two alternatives (Ayuk 1997; Pindyck and Rubinfield 1981), e.g. to adopt or not adopt; and (2) the choice the agent makes will depend on his/her attributes or characteristics. The conceptual framework is then to build a model that will predict the adoption decision of an economic agent with given attributes (Ayuk 1997; Pindyck and Rubinfield 1981).

The utility maximization framework can be used to motivate this binary choice model. A household's adoption choice is based on whether the expected net utility derived from adopting the new technology is greater than from not adopting. For a new crop species, a household chooses between whether or not to plant the new crop in order to maximize their utilization of the land. Adoption is treated as an investment choice, where the farm household is seeking to maximize agricultural profit in relation to a chosen set of inputs and outputs. The decision whether to adopt or not is based on whether the new technology will bring more utility to the farm household than the current technology (Mercer and Pattanayak 2003; Caviglia-Harris 2003).

A household maximizes utility by comparing its expected net utility with and without the new technology. First, the expected net utility from adopting or not adopting the technology given the explanatory factors that define that household will be determined:

$E\mu_{iA}$(adopt) = f (explanatory factors) + ε_i

$E\mu_{iN}$ (status quo) = f (explanatory factors) + ε_i

Where,

$E\mu_{iA}$ = expected net utility of the i^{th} household from adopting

$E\mu_{iN}$ = expected net utility of the i^{th} household from not adopting

ε_i = error

Second, the expected net utility from each of these decisions will be compared such that:

$E\mu_{iA} - E\mu_{iN} > 0$, or

$E\mu_{iA} - E\mu_{iN} < 0$

Third, using Y_i as an indicator of whether the i^{th} household adopts the new technology (Y_i=1) or not (Y_i=0), then:

$$Y_i=1 \text{ if } E\mu_{iA} - E\mu_{iN} > 0 \text{ and } Y_i=0 \text{ if } E\mu_{iA} - E\mu_{iN} < 0$$

Therefore, the probability that the i^{th} household adopts the new technology is the probability that the expected net utility gained from the adoption of the new technology is greater than the expected net utility derived from not adopting (Caviglia-Harris 2003).

For those households that adopt the technology, annually they choose either to continue with the new technology or to abandon the technology. If the utility from having adopted the new technology is greater than without the technology, they will continue with the technology. If the utility derived from the new technology is smaller, they will disadopt the technology. This decision is also a dichotomous choice and can be analyzed using a similar binary choice model where the Y_i variable takes on the value of 1 if the household chooses to disadopt and 0 if the household chooses not to disadopt (or to continue adopting). In addition to measuring disadoption as a binary choice, this thesis will also model the duration of technology adoption. This model will determine the factors that influence how many years a given household will implement the soybean technology.

1.5 Significance of the Study

New technologies are promoted to improve the economic, environmental, and health conditions in developing countries. However, the adoption rates of these new technologies are often low and are not uniform (Feder *et al.* 1985). Many extension projects are created without understanding the preferences, priorities and constraints of the farming community (Scherr and Hazell 1994). Successful extension programs must be based on an understanding of the variables that affect a farm household's adoption decision. An abundance of adoption studies have proliferated in recent years to address this need (Pattanayak *et al.* 2003). Preferences, priorities, and constraints have been identified but are not consistent across studies. Continued research on adoption determinants helps to improve the knowledge base on local, national and international levels.

Specifically, technologies that decrease malnutrition in developing countries, and thus improve labor productivity and quality of life, are critical to sustainable development. The importance of health is increasingly being acknowledged as an essential component to the development process. Soybean cultivation is one such technology and understanding the adoption characteristics is important on many levels. Factors identified to affect soybean adoption can be used to better target health-related extension programs in West Africa.

Disadoption is a part of the adoption cycle that has historically been overlooked. Technologies that are abandoned are just as ineffective as technologies that are not adopted. Understanding disadoption is needed in order to improve the longevity and efficacy of new technologies. By identifying constraints that will lead to the eventual abandonment of a technology, extension programs can be better designed.

1.6 Limitations of the study

Data collected for this thesis was not able to measure for the extent of adoption of the soybean technology, a notable omission to the adoption information. Surveys were conducted during the dry season, when farmers have more free time and are more likely to be found at home. Consequentially, there are no crops in the fields during this time and therefore the intensity of adoption (i.e., hectares) could not be visually verified. The area cultivated with soybeans was asked in the survey instrument, but responses cannot be assumed to be accurate as it had been several years in some cases since the farmer had planted soybeans. For these reasons, the extent of adoption is not explored in this thesis.

This study is also limited in that the integrity of the data may have varied due to the translation of the survey instrument from English to French to the local language, Ditammari. The researcher cannot be certain that the meaning of all questions was preserved during these translations. The use of local translators may have also created measurement bias, as the researcher could not be positive of how the question was being phrased in the interviews.

CHAPTER 2: BACKGROUND

2.1 Introduction to the Study Areas

This study was conducted in two West African countries (see Figure 2.1): Benin and Togo (see Figures 2.2 and 2.3). The countries of Benin and Togo are similar socioeconomically and face similar resource constraints. Both countries are former French colonies, having gained their independence in 1960. Economic activities in the two countries are similar, with the majority of people earning their livelihood from agricultural production (38% in Benin and 42% in Togo) or service industries (49% in Benin and 37% in Togo). Important exports for both countries include agricultural products: cotton, cocoa, and coffee. Benin also exports crude oil and Togo is the fourth largest exporter of phosphates in the world (World Facts and Figures 2004). Social and economic indicators for the two countries are listed in Table 2.1.

Table 2.1: Social and economic indicators[1]

Indicators	Benin	Togo
Population (millions)	6.5	4.8
GNI/ per capita (US$)	380	270
Life expectancy at birth (years)	51	50
Literacy rate (percent)	37	57
Infant mortality (per 1000 live births)	93	79

[1] UNICEF 2002 Country Statistics

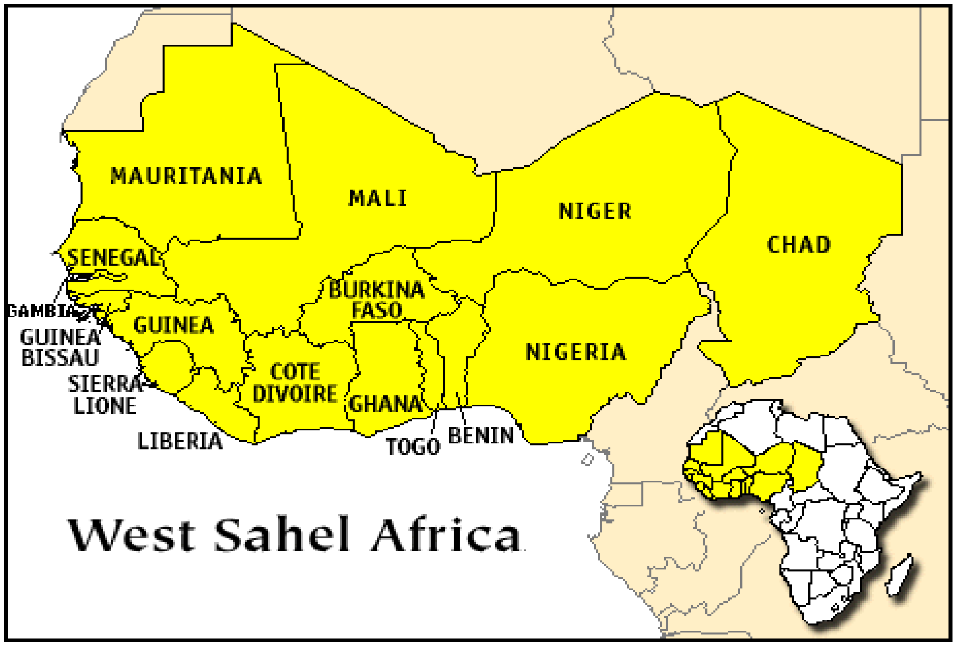

Figure 2.1: Map of West Africa[2]

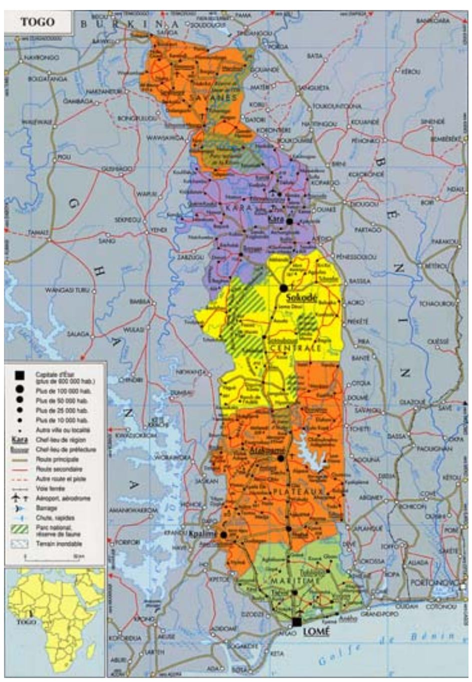

Figure 2.2: Map of Togo[2]

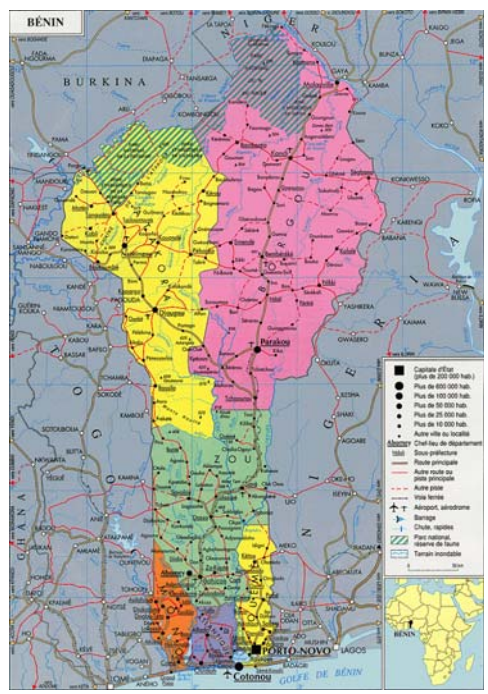

Figure 2.3: Map of Benin[2]

[2] IZF

Benin has a land area of 112,620 sq km, in which 13% is arable land and 31% remains in forests and woodland. Benin consists of flat plains, with a maximum elevation reaching 658 meters. Togo is smaller, occupying an area of 56,785 sq km, in which 38% is arable and 17% is forested. The geography of Togo is mostly flat plains, with some central hills, reaching a maximum elevation of about 986 meters. Soils for both countries are considered degraded and natural resource problems include desertification and deforestation (World Facts and Figures 2004).

Beyond the demographic and resource characteristics of the two countries, the comparability stops. Benin, although recently a socialist country, is currently a democratic nation, having adopted democratic reforms in 1990. Free elections are held, and the most current president was elected in 1996. Togo, while calling itself a democratic nation, is in reality ruled by a military dictatorship. Togo is plagued by political unrest and has come under fire by international organizations for its human rights abuses. The current president has been in power since 1967 (World Facts and Figures 2004).

In Benin the population is content with their governmental regime, government agencies implement their public responsibilities, a number of non-government organizations are present, and outside funding and research is high. In contrast, the population of Togo is not happy with their government, few to no government agencies implement their public responsibilities, few non-governmental organizations work in the country, and outside funding and research is low. Most bilateral and multilateral aid to Togo has been frozen since the early 1990's. In 2001, Benin received $270 million dollars in external aid money; during the same time period, Togo’s total external aid money totaled only $47 million dollars (UNICEF 2002).

2.2 Biophysical Characteristics of the Study Areas

This study was conducted in the villages of Koudogou, Benin and Warengo, Togo (see Figure 2.4); both of these villages are located in the Tamberma region. The Tamberma region encompasses an area of approximately 1300 square kilometers (AFVP 1998, PNUD 1993). This region is located on an undulating plateau of innumerable small hills, not exceeding 200 meters. The Atakora Mountain range, with altitudes between 400 and 600 meters, borders the region to the southeast (Tanti 1997; AFVP 1998).

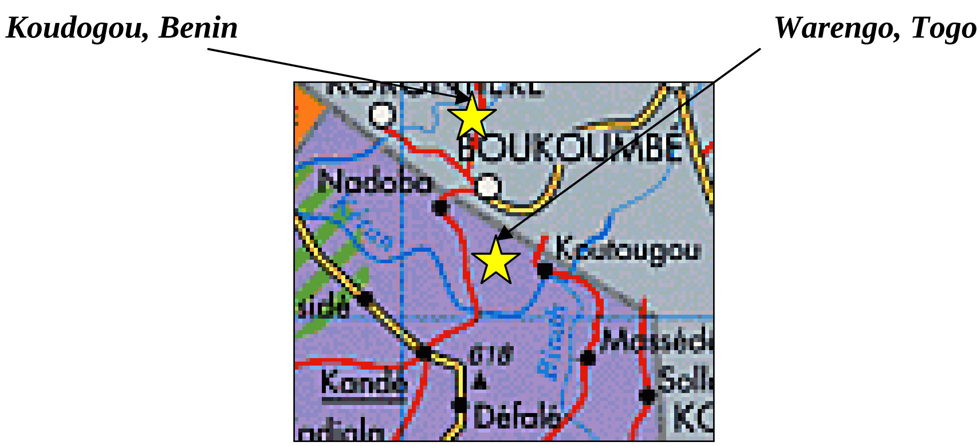

Figure 2.4: Study sites

The Tamberma region is semi-arid and falls between the Guinean and Soudanian climatic zones. There is only one rainy season, with a mean annual rainfall of 1000-1200 mm. The mean monthly temperature ranges between 29-32 degrees Celsius. Three distinct seasons are observed here: a rainy season (May to October), a dry season (November to April), and a Harmattan season (December to February). The Harmattan, a phenomenon unique to West Africa, is a period of extreme dry winds blown southwards from the Sahara (Tanti 1997).

The soils in this region are classified as Alfisols under the US Soil Taxonomy System. In a 1996 Human-Induced Land Degradation status report by Brabant *et al.* (1996), the soils of the Tamberma region were assigned the worst ranking of "severe land degradation." This low soil fertility is compounded by the harsh climate and erratic rainfall of the area. FAO human-induced soil degradation maps also show the soils in the Tamberma region of both Benin and Togo to be severely degraded (see Figures 2.5 and 2.6).

The vegetation is characterized as tree and shrub savanna. The landscape consists of mostly *Andropogon* grasses and *Hyparrhenia* shrubs, with scattered trees, dominated by *Adansonia digitata* (Baobab), *Parkia biglobosa* (Nere), *Butyrospermum parkii* (Shea butter) and *Azadirachta indica* (Neem) (Polidoro 2002). Large areas of contiguous forest are increasingly rare. Mosaics of original and secondary forest can be found along the mountains and river ways. The community has protected other small pockets of "sacred" forests.

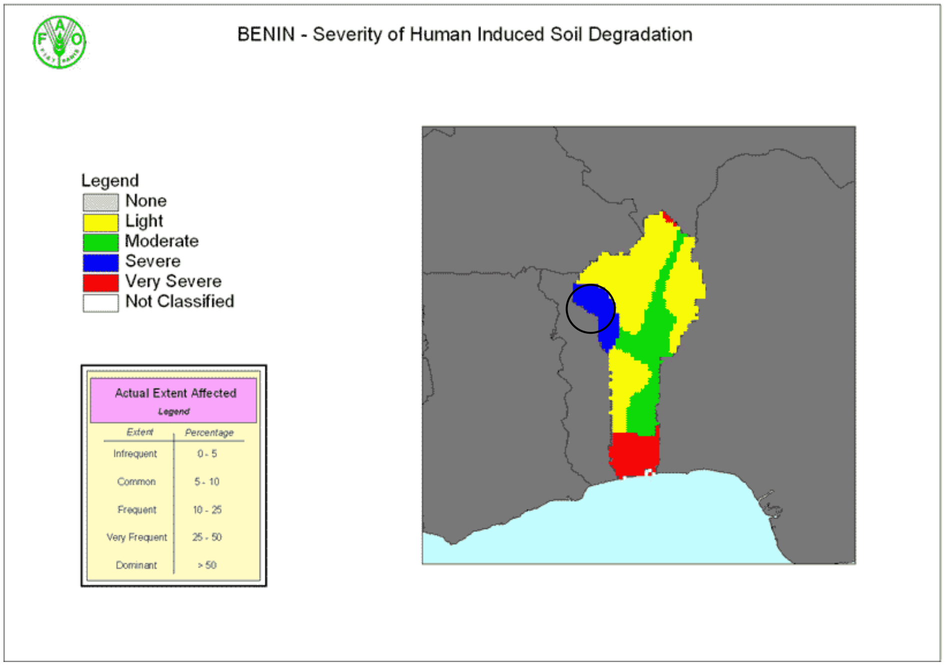

Figure 2.5: Benin soil degradation[3]

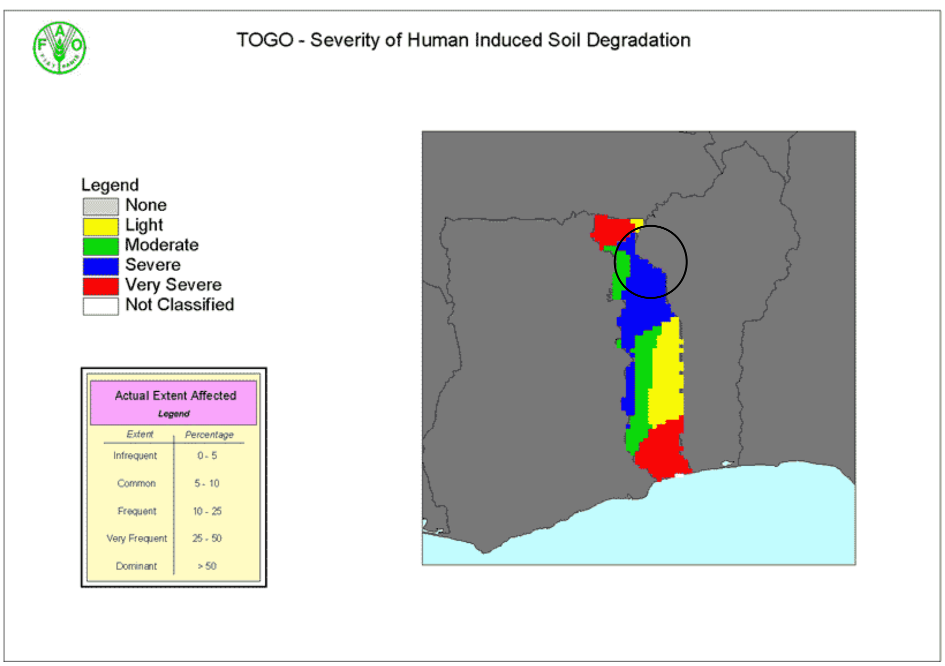

Figure 2.6: Togo soil degradation[3]

[3] FAO National Soil Degradation Maps

2.3 Socioeconomic Characteristics of the Study Areas

The population of the Tamberma region is around 70,000 (AFVP 1998, PNUD 1993). With an average of 5.5 persons per household (PNUD 1993), the number of households in the region can be estimated at 12,727. Average population density is between 65 and 75 persons per square kilometer, with some areas exceeding a density of 100 persons per square kilometer (Tanti and Julien 1998). In Togo, the Tamberma region consists of 22 villages divided into three cantons (districts): Nadoba, Warengo, and Koutougou. The Warengo canton, where this study took place, is believed to have a population of 4500 (AFVP 1998). The village of Warengo has approximately 2000 inhabitants (Tanti 2003). In Benin, the Tamberma region consists of three zones: zone west, zone central, and zone east. This study took place in the central zone in the canton of Natta. Natta consists of 10 villages, with a total population of about 8,000. This study took place in the village of Koudogou, where the population is believed to be approximately 800 persons (PNUD 1993).

The economic center of the Tamberma region in Togo is Nadoba. It is the location of the only middle school in the region, a health center and the region's weekly market. The weekly market consists of agricultural goods, manufactured products, clothing, and millet beer. Infrastructure in Nadoba is limited, with no electricity (however, this was in the process of being installed) or running water and only one permanent store. The closest paved road is 25 km away. Daily commerce is limited to the buying and selling of millet beer and food items. Warengo is located 9 km from Nadoba and has its own elementary school and health dispensary. After Nadoba, the closest market towns to Warengo are Boukoumbe, Benin (13 km) and Kande, Togo (25 km).

The economic center of the Tamberma region in Benin is Boukoumbe. The infrastructure in Boukoumbe is greater than that of Nadoba, even though the two are only 4 km apart. The market in Boukoumbe is on a 4-day rotation. Prices are slightly higher at this market compared to the Nadoba market. Boukoumbe has a hospital, two primary schools and one secondary school, electricity, running water, standpipes and wells, several permanent stores, and several non-governmental and governmental offices. The closest paved road is 45 km away, but unpaved roads in the area are much better maintained than those in Togo. Koudogou is located 4 km from Boukoumbe and has its own elementary school and health dispensary. After Boukoumbe, the closest market towns to Koudogou are Nadoba, Togo (9 km) and Matta, Benin (22 km).

Ninety percent of the population in the Tamberma region is of Tamberma ethnicity (also referred to as Somba or Otammari). They speak their own dialect of Voltaic origin, referred to as Ditammari and spoken nowhere else in the world. Other minor ethnic groups are found within the region, including the nomadic group known as the Peulh, the Lamba, and the Kabeye. These other ethnic groups tend to live in the towns of Boukoumbe and Nadoba, as these are the main economic centers of the region (AFVP 1998). Isolated ethnically and geographically from the rest of their countries, the Tamberma people are noted for having strongly maintained many of their traditional customs and beliefs.

The major land use in the Tamberma region is subsistence agriculture. Ninety-eight percent of the population is engaged in agricultural production. Principal food crops include sorghum *(Sorghum bicolor),* millet *(Pennisetum cereale)*, maize *(Zea mays*), groundnuts (*Arachis hypogaea*), cowpea (*Vigna unguiculata*) and fonio (*Digitaria exelis*). The majority of fields are planted under a mixed cereal-legume cropping system, usually sorghum or millet and cowpea. In wetter areas, crops also include rice (*Oryza sativa* L.), yams (*Dioscorea* spp.) and sweet potatoes (*Ipomoea batatas* (L.) Poir). An increasing part of the livelihoods in this region is cash cropping, especially of cotton (*Gossypium spp.*). Heavy subsidies on cotton farming are resulting in a decline in subsistence agriculture and creating competition with more sustainable land uses, such as soybean farming. The majority of agricultural production is still done by hand. Farmers burn crop residues at the beginning of the dry season (AFVP 1998; PNUD 1993).

The livestock component is also of major importance in the Tamberma region, with an estimated 80% of the people owning animals (AFVP 1998). Cattle, sheep, goats, pigs, chickens, and guinea fowl are all raised. Animals are considered a form of economic reserve in many developing societies, as there are few stable formal banking institutions to store money. Livestock are a form of equity and can be cashed in quickly if money is needed. In addition to this incentive, livestock are also important culturally in the Tamberma region. The majority of people are animists and livestock are used in all of their traditional and religious ceremonies. Animals are, in principle, restrained or attended to by children during the rainy season but roam freely during the dry season.

As agriculturalists, the average Tamberma's schedule varies throughout the calendar year, with the bulk of their activities occurring during the rainy season, between the months of April and December (see Figure 2.7, where black indicates activity). During these months, men, women and children are occupied preparing their fields, planting, weeding, harvesting and processing their crops.

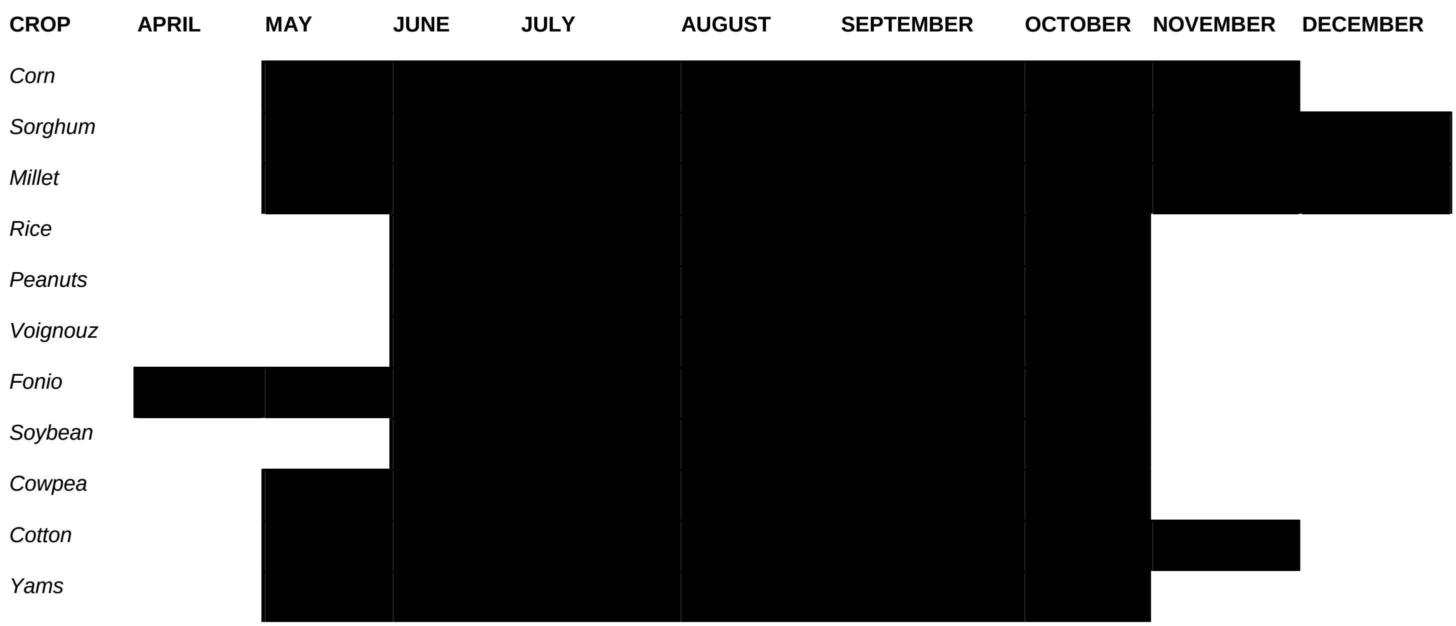

Figure 2.7: Seasonal farming calender[4]

The notion of a village is really only relevant in the Tamberma region in an official administrative sense. The important social structures for the region are clan and neighborhood. A person's clan includes all of the descendents from a common ancestor. It is within this clan that inheritance rights, including those for land, are derived. Each "village" is regrouped into a number of neighborhoods, consisting of persons of different clans and ethnicities. It is within these neighborhoods that daily life takes place. The

[4] Jones 2004 (Fieldwork)

neighborhood is seen as the unit of economic development in the Tamberma region (AFVP 1998).

Historically, land was not considered individual property but community property in the region. Clans divided land up and ownership was determined by male lineage. To farm a piece of land, one should ask permission from the "true" owner of the land and give some form of payment to that owner, usually in the form of millet beer. Any naturally occurring Nere or Shea butter trees found on the land were considered the property of the "true" owner. Traditionally land could never be sold but was always the property of the original clan. While this system of land tenure is still observed today, changes have started to occur as a result of demographic pressure, the growing importance of money, and the introduction of the notion of private property. Today, individuals have started to sell property for money or rent their land for a set monetary fee (AFVP 1998).

Women have never been allowed to own land and must ask permission from their husband or some other male in the community for land to cultivate. This still holds true today. Most women cultivate their own fields; women typically farm the non-cereal crops, such as rice, peanuts, cowpeas and soybeans. Males are responsible for the cereal and cash crops and women are expected to help males with these crops while also attending to their own, less valued crops (AFVP 1998).

2.4 History of Soybeans in West Africa

The domestic soybean (*Glycine max* (L.) Merrill) originated in China over 3000 years ago. Colonials and missionaries first introduced soybeans into West Africa in the early 1900s. However, it wasn't until 1987 that the International Institute of Tropical Agriculture (IITA), supported with funds from the International Development Centre (IDRC), aggressively introduced soybeans into West Africa, focusing on Nigeria. In 1985, Nigeria produced only 28 metric tons of soybeans; this production had increased to 200,000 metric tons by 1995 (Dashiell 1998).

Soybean production in West Africa is low compared to the rest of the world, accounting for only 1% of the over 160 million tones that were harvested in the year 2000. Production rates of soybeans are also low in Africa, at 990kg per hectare in 2000, compared to the global average yield of 2210kg per hectare. The reason for this is that small-scale farmers, using little or no inputs other than labor, farm the majority of soybeans in Africa. Seed quality has also been a constraint to production (Dashiell 1998). The IITA has been actively developing improved varieties of soybean seed, including varieties that fix more nitrogen, have higher yields, store well, and are resistant to pod shattering. However, seed sold in many local markets tends to be of an unimproved variety.

Soybeans have been promoted in West Africa as a "miracle crop." Nutritionally, soybeans are a relatively cheap source of protein compared to other sources in West Africa. Large areas of West Africa (Figure 2.8) are suitable for soybean cultivation, and the incidence of pests and disease is low (FAO 1997). Finally, the ability of soybeans to fix nitrogen is considered a sustainable solution to soil fertility problems in the area.

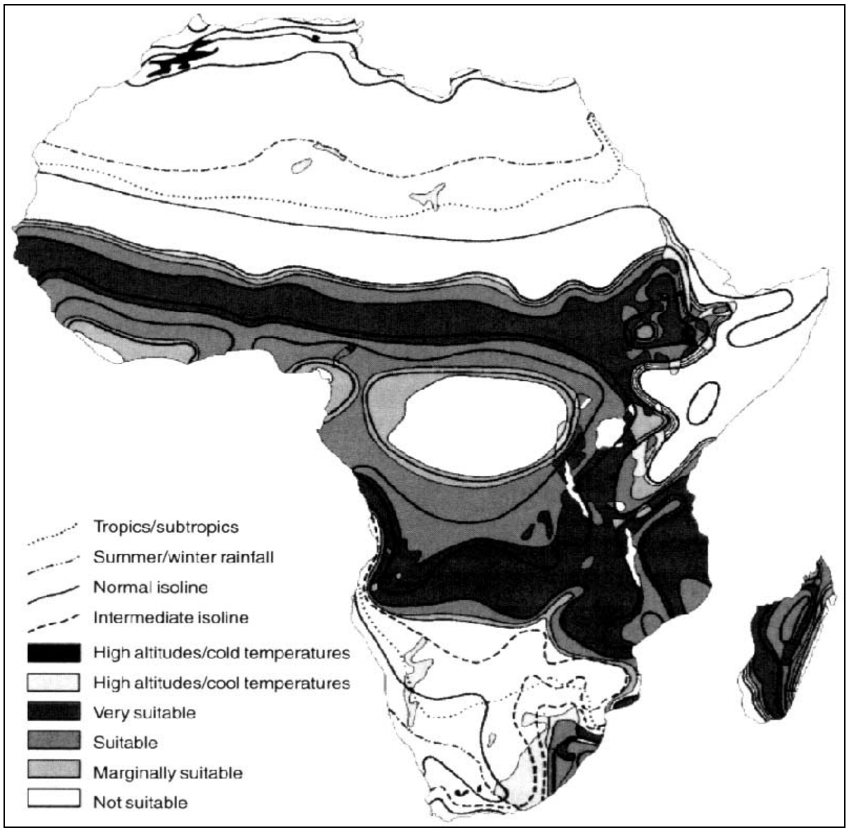

Figure 2.8: Suitability of soybean cultivation in Africa[5]

Despite these attributes, interest in soybean farming by farmers in West Africa has been low. This is due to a lack of access to markets and a lack of knowledge of how to prepare the product for home consumption. Extension agents have been addressing the latter problem by training people how to use soybeans in traditional and new food products. Another constraint on soybean cultivation is its sensitivity to low soil fertility, inadequate

[5] FAO 1997

water supply and ineffective weed control (IITA 2004). While soybeans are promoted because of their N-fixing ability, other nutrients, such as phosphorus, may be limiting the production level of soybeans in many parts of West Africa. Another concern is that appropriate rhizobium inoculators are missing since soybeans are not native to the area. IITA is addressing these agronomic issues through the development of varieties that are tolerant to phosphorous-deficient soils, varieties that can nodulate with fast and slow-growing rhizobia representing several different genera, and improved varieties that are high-yielding and fix more nitrogen (IITA 2004).

The IITA recently evaluated the social impact of soybeans in the Benue Region of Nigeria. A social impact assessment (SIA) framework was used to collect data on 203 households to examine the level of adoption and impact of soybeans in an area where the IITA had been working. Various soybean varieties were evaluated, and data were analyzed using a Tobit model. Results showed that the adoption of soybeans had a positive and significant impact on household income generation, material welfare, gender relations, and social equity in the region. Adoption of soybeans had risen significantly, from 9% in 1989 to 75% in 1997. The nutritional status of children in soybean producing areas was also significantly better than in non-soybean producing areas. The study concluded that soybeans had become an acceptable substitute for traditional foods. The most commonly adopted food, at a 90% adoption rate, was *dawadawa*. Only 25% of the people had adopted more western-style soy foods, such as soymilk or tofu (Sanginga *et al.* 1999).

Dawadawa is a traditional fermented condiment that was previously produced using the local tree species *Parkia biglobosa* (Nere). As this tree has become scarcer, women are finding that soybeans make an acceptable substitute. Producing *dawadawa* from soybeans is similar to the process of using *P. biglobosa* with one exception—seeds from *P. biglobosa* have to be boiled for fourteen hours before preparation, while soybean seeds only have to be boiled for one hour before preparation. Most people still prefer the traditional form of *dawadawa*; despite this, Konlani *et al.* (1999) found that soybean *dawadawa* is now the prevalent form in Togo either because it was a cheaper substitute or because the traditional *dawadawa* cannot be found. The fermented condiment made from these two products is used to season sauces and stews throughout West Africa. The traditional *dawadawa* is a source of protein, fat, and Vitamin B for nutrient-poor communities. Soybean *dawadawa* is just as nutritious as the traditional form, rich in proteins, fats, and amino acids. Consumption levels of *dawadawa* are high throughout West Africa, with one study finding that *dawadawa* constituted 5% of the protein intake of people in northern Nigeria (Odunfa 1985).

2.5 Soybean Promotion and Other Extension Services in the Study Areas

2.5.1 Warengo, Togo

The earliest recollection of soybean extension in Warengo came from the local nurse. Missionaries from Kande, Togo came to the village in 1996 to talk about soybeans at the local health center. It was noted that before 1996, a Kabeye family moved into the area from the Kara region. The wife in this family farmed soybeans and taught women how to produce *dawadawa*. This woman no longer lives in the area (Jones 2004).

More recent outreach has come from two sources: a local NGO formed by a French expatriate and the United States Peace Corps. A former French volunteer in the area created a NGO in 2000 between her home village in France and Warengo, Togo. The NGO is involved in various community activities, including the promotion of soybeans to fight malnutrition. The NGO is collaborating with the local health center and other female leaders to educate women about soy and to train them how to make soy products. A small amount of soybean seeds were initially given to interested women with the condition that they had to return a portion of seeds from their harvest to be passed along to another farmer. The effectiveness of these activities has varied, as some of the female leaders are not carrying out their roles. Education at the local health center occurs weekly and is targeting new mothers. The local nurse visited each neighborhood in 2001 to talk with people about the benefits of planting soy and to give out soy samples. However, no demonstrations on farming or preparing soybeans took place (Jones 2004).

The US Peace Corps has sent two volunteers to the village of Warengo. A volunteer was present from 1999 to 2001 and the author of this thesis was present from 2002 to 2004. Both Peace Corps Volunteers conducted village-wide soybean demonstrations, showing participants how to make soy products, including soy porridge, soy pate (a local food staple), soy flour, soymilk and tofu. A total of five demonstrations were conducted. The volunteers have also accompanied the local nurse to talks in the neighborhoods and have educated neighborhoods on their own. Both volunteers also prepared demonstration fields showing how to cultivate soybeans and worked with women who were cultivating soybeans in their own fields. Soybean seed was given out in 2000 and 2003 and was sold in 2004 at a reduced price by the volunteers (Jones 2004).

Warengo has had a series of French volunteers living and working in the village. In addition to soybean promotion, they have worked on projects related to health care, sanitation services, women's empowerment, small business development, tourism development, gardening and tree nursery promotion. The Peace Corps Volunteers in the village have also worked in the areas of small business development, agroforestry, improved cook stove building, gardening and tree nursery development (Jones 2004).

2.5.2 Koudogou, Benin

Soybean extension in the Boukoumbe area (the economic center of Benin's Tamberma region) started much earlier and has been more extensive than in Togo but has recently started to decline. Missionaries in Boukoumbe have been visiting villages in the region since 1981 to talk about the benefits of adding soy to diets and how to make soy porridge. They do not have a record of villages visited each year and have not visited any villages since 2002 due to transportation problems. During extension activities by the missionaries, no soybean seeds were given, bought or sold (Jones 2004).

In 1982, the government run Centre Sociale (Social Center), an extension of the local hospital in Boukoumbe, started introducing parents with malnourished children to soybeans. They showed parents how to make soy porridge and other soy products, such as *dawadawa*, soymilk and tofu. They did not sell soybeans, but they did buy soy to use in their demonstrations up until 2002. Today, a woman must provide her own soy in order to see a demonstration on how to make soy products (Jones 2004).

The only direct form of soybean extension in Koudogou was a visit by a local NGO named Alpha Omega. In 2000, an extension agent came and talked about the benefits of soy and how to make soy products. The agent offered to return to demonstrate how to make soy tofu, but interest was low and therefore Alpha Omega did not return (Jones 2004).

Koudogou has received extension from the NGO Alpha Omega on a series of other topics since 1995. These include constructing improved cook stoves, planting trees, erosion control methods, building wells, and improving rice cultivation. Alpha Omega has not visited the village very frequently in the last few years but the village still receives funding from the NGO to carry out many of these activities.

CHAPTER 3: LITERATURE REVIEW

3.1 Technology Adoption

Rogers (1962) describes the adoption process as "the mental process an individual passes from first hearing about an innovation to final adoption." When a new innovation is introduced, farmers go through periods of becoming knowledgeable about the new technology, to forming positive or negative attitudes toward the technology, and ultimately to deciding whether to adopt the technology or not. Numerous household, community, and institutional factors affecting the farmer influence this decision process.

Since Rogers' classic work on adoption, paradigms for explaining adoption decisions have revolved around three basic models: the innovation-diffusion model, the technology characteristics-user's context model, and the economic constraints model. The innovation-diffusion model is based directly off of the work of Rogers. This model holds that access to information about an innovation is the key factor in determining the adoption decision. The use of extension, media, and local opinion leaders thus play a key role in this model. The appropriateness of the technology is assumed, and the constraint to adoption is access to information (Adesina and Zinnah 1993).

The technology characteristics model assumes that the characteristics of a technology, such as the agro-ecological, socioeconomic, and institutional contexts, play the central role in the adoption and diffusion processes. The participation of farmers and stakeholders in the technology development process is essential (Negatu and Parikh 1999; Scoones and Thomson 1994; Biggs 1990).

In 1957, Griliches concluded that economic variables were the major determinants of technological change and adoption of innovations. In 1961, Mansfield also came to the conclusion that the adoption of innovations was determined by economics. The influence of economic thought on the adoption of innovations led Just and Zilberman (1983) to propose a theory of technology adoption under uncertainty using the expected utility framework. This model is an extension of the original Baron-Sandmo (1971) expected utility approach to producer behavior under uncertainty (Marra *et al.* 2003). This model contends that economic constraints, such as access to capital or land, significantly affect the adoption decision. Thus, the decisions of the farmer are derived from the maximization of expected utility (or profit) subject to his inputs (land availability, labor, credit, etc.). The expected utility model is the most commonly used model for adoption studies of agriculture and agroforestry technologies (for examples of studies using this model see Mercer and Pattanayak 2003; Negatu and Parikh 1999; Ayuk 1997; Baidu-Forson 1994 and 1999).

When a new technology is introduced, adoption is not uniform; it differs across socioeconomic groups and over time. Adoption is slow at first, but with time, information, knowledge, and experience with the new technology grows and the rate of adoption increases. This process is known as diffusion of a technology. Diffusion is defined as "the process of spread of a new technology within a region" (Feder *et al.* 1985). Diffusion occurs across persons while the adoption process is an individual decision process.

Research on the adoption process often seeks to determine the characteristics of producers that influence their adoption decisions. Why some producers adopt the technology while others do not is modeled as a dichotomous choice of whether to adopt the new technology or not. Regardless of the level of use, these studies record only the proportion of farmers that have adopted the new technology (Doss and Morris 2001; Feder *et al.* 1985). Other studies seek to measure the extent of adoption. The actual level of use of the technology is measured in these studies, for example the proportion of a farmer's land devoted to the new technology. Since data collection is more difficult for these types of studies, there are fewer of them (Feder *et al.* 1985). An even smaller number of adoption studies deal with the temporal adoption of innovations; they seek to identify why some producers are early adopters and others are "laggards" (Marra *et al.* 2003).

3.2 Adoption Determinants

Recent studies on agricultural and agroforestry technology adoption were reviewed for this thesis to identify adoption determinants. In the studies reviewed, data were primarily gathered through cross-sectional surveys of farm households (recent examples include Mercer and Pattanayak 2003; Moser and Barrett 2002; Neupane 2002; Negatu and Parikh 1999; and Ayuk 1997). In these studies, the farm household is defined as the set of people who farm and make farming decisions together. Random samples of the population are often stratified according to location (see Negatu and Parikh 1999), program intervention (see Baidu-Forson 1999), or adoption choice (see Moser and Barrett 2002). Sample sizes of the reviewed studies varied from as small as 96 households (Negatu and Parikh 1999) to 900 households (Feather 1994). Most studies had a sample size between 100 and 300 households (examples include Mercer and Pattanayak 2003; Ayuk 1997; and Strauss 1991). An expected utility maximization model was used by most studies to model adoption as a dichotomous decision whether to adopt or not adopt; recent examples include Mercer and Pattanayak 2003, Neupane 2002, Ahmed 2001, Negatu and Parikh 1999, and Ayuk 1997.

Literature was also reviewed to determine if variables and models used to analyze the adoption decision in dry West Africa differed from those used in studies of other regions. Resource constraints and biophysical factors can be considered similar across dry West Africa. Reviewed literature showed that the variables affecting adoption in West Africa are similar to those in other parts of the world. Data collection methods and empirical models are also the same.

Pattanayak *et al.* (2003) recently evaluated 32 studies that estimated statistical models of the adoption of agroforestry and soil and water conservation technologies and found that adoption variables could be classified into five broad categories: household preferences, biophysical factors, resource endowments, economic incentives, and risk and uncertainty. Certain categories and factors were more likely to have statistically significant effects on the adoption choice. These included the categories of risk and uncertainty (78%), economic incentives (73%), biophysical factors (64%), and resource endowments (60%). Factors likely to be correlated with the adoption decision included soil quality, extension and training, tenure, savings and credit, and assets.

Following is a look at each of these broad categories of adoption determinants and the factors that fall within that category according to the Pattanayak *et al.* (2003) study. An explanation of what the factor is measuring and, in many cases, the significance of that factor as found in the Pattanayak *et al.* (2003) study, is given. Studies that reiterate the significance or non-significance of specific factors are included where appropriate to support these findings. Two additional factors identified in the literature review are included under the appropriate category.

In addition to these five categories of adoption determinants, the importance of taking into account farmer perceptions is also discussed. Literature has shown that factors measuring farmers' perceptions of an innovation can be more significant to the adoption decision than other categories of factors (Adesina and Baidu-Forson 1995; Adesina and Zinnah 1993). These factors are discussed below as a sixth category of adoption determinants.

Category 1: Household Preferences

Household preferences is a broad category measuring the influences of household specific characteristics such as risk tolerance, innovativeness, and household homogeneity. Measuring these factors is not straightforward; therefore age, gender and education are often used as proxies for household preferences. The literature suggests that households with a greater number of males and with a higher education level are more likely to adopt new technologies (Mercer and Pattanayak 2003). Age, although typically included in adoption studies, is generally not strongly correlated with adoption.

Education: This variable is typically measured as the average education level of the entire household or just the household head. This variable is easy to measure and is thus popular among adoption studies. However, statistically, this variable was only correlated with adoption about 40% of the time in the Pattanayak *et al.* (2003) study.

However, several other studies have looked at the role of education in adoption and have concluded that higher education levels lead to earlier and more effective adoption. Education is thought to improve the farmer's ability to better process the information provided about new technologies and to increase their allocative and technical efficiency (Jamison and Lau 1982; Welch 1979). Strauss *et al.* (1991) come to this conclusion for education in the adoption of new farm technologies by rice and soybean farmers in Brazil.

Age: This variable is typically measured as the average age level of the entire household or just the household head. Statistically, this variable performs poorly in explaining adoption behavior in the Pattanayak *et al* (2003) study; it was significant in only 24% of studies.

There is often inconsistency of evidence about the effect of age on innovativeness. In a study by Cotlear (1986), age was shown to have a negative influence on adoption of biological and chemical inputs, seemingly because older farmers are more conservative. However, in a study by Strauss *et al.* (1991) age was shown to have no effect on the adoption of farm inputs. Results from a study by Baidu-Forson (1999) also showed that age had no significant effect on the adoption of new technologies, specifically on land-enhancement technologies in Niger.

Gender: This variable usually measures the proportion of males in the household. For most technologies, a larger proportion of males correspond with a higher chance of adoption. This variable also reflects the resource capacity of the household (Pattanayak *et al.* 2003).

The gender variable can also capture different adoption rates of technologies by men and women. These rates tend to differ due to the unequal access of men and women to complementary inputs. Evidence suggests that female-headed households are less likely to adopt technologies than male-headed households (Doss and Morris 2001; Smale *et al.* 1991).

A recent study by Doss and Morris (2001) on gender effects in maize cropping systems in Ghana found no correlation between gender and adoption. An important omission in this study was a distinction between the gender of the farmer and the gender of the household head. The conclusion from this study was that gender per se was not associated with adoption but that the gender of the household head may be important. Franzel (1999) finds similar results in his study on improved tree fallow adoption in Africa. Despite obvious resource constraints for women (less land, capital, etc.) the adoption rates of the technology in Zambia for women and men were 26% and 30% respectively. Bonnard and Scherr (1994) determined that gender was often too narrowly defined, and that access to resources, such as use rights and control, were more important in determining access to new technologies.

Ethnicity: This variable is not commonly included in adoption studies but is usually positively correlated with adoption behavior (Pattanayak *et al.* 2003).

Category 2: Resource Endowments

Resource endowments are a measure of wealth. Measures of labor, livestock, savings, and asset holdings are all direct measures of resource endowments. The literature shows that resource endowments have a consistent and positive influence on technology adoption (Mercer and Pattanayak 2003). Abadi Ghadim and Pannell (1999) conclude in their conceptual framework of adoption of an agricultural innovation that wealth should positively affect the initial trialing of a technology since this variable decreases risk aversion by relaxing financial constraints.

Income: Measures of income are often included in adoption studies, sometimes divided by activity (such as agriculture, wage, off-farm and total). The association between income sources and adoption is usually positive, except when the households' dominant source of income is agriculture and they do not want to risk that income by investing in an unknown technology (Pattanayak *et al.* 2003).

In the literature, access to off-farm income has varying affects on adoption. If land is the limiting factor, then access to off-farm income encourages adoption of innovations that take land out of production of the "reliable" technologies. Therefore, off-farm income makes adoption of new technologies feasible. On the other hand, it can be argued that households with off-farm income are less concerned with food production than farmers who are solely reliant on their farms (Franzel 1999) and therefore would be less willing to invest in new technologies. A study in western Kenya supports the first hypothesis. Farmers who adopted improved fallows in Kenya tended to have some source of off-farm income (68%) (Franzel 1999; Swinkels *et al.* 1997).

Assets: Assets include land holdings, house type, motor vehicle, and total income. There is a consistent positive influence between assets and adoption (Pattanayak *et al.* 2003).

Labor: Labor can be measured either as the size of the family or the number of males in the family. Measures of labor are significant in 47% of studies in the Pattanayak *et al.* (2003) study.

The effect of the labor variable often depends on whether the new technology is labor saving or labor using. Most studies agree that labor scarcity is often an operative constraint in farming systems. Labor-intensive technologies are more readily adopted by households with a higher labor supply (Hicks and Johnson 1974). Harriss (1972) found that shortages of family labor explained the non-adoption of technologies in India. Franzel's (1999) study on the adoption of improved tree fallows also found that labor constraints had a significant impact on the adoption decision, as tree fallows are a relatively labor using technology.

In Madagascar, adoption of improved rice intensification systems that were supposed to result in higher yields was significantly lower than hoped. A study by Moser and Barrett

(2002) found that the additional labor needed for this rice intensification system occurred at the same time of the year that liquidity was low and labor efforts were already high. The appropriateness of this new technology for smallholders was questionable given their already limited income levels and constraints on labor, and consequently disadoption rates were also high.

Livestock: Livestock can be included under the assets variable, but are often separated out because of their key role in agricultural and agroforestry systems. The significance level of livestock is typically low, at only 33% in the study by Pattanayak *et al.* (2003).

A study by Neupane *et al.* (2002) found that livestock population was the most significant coefficient for adoption of agroforestry technologies. This was due to the promotion of fodder trees and grasses in areas where access to fodder for livestock was a major constraint.

Credit/savings: This variable is not included in many studies, but is always significant when included in the studies reviewed by Pattanayak *et al.* (2003).

When fixed costs for a new technology are large, access to capital is often considered to be a factor in the adoption decision. Large fixed investments prevent many small farms from adopting innovations quickly. Likewise, the need to access credit can prevent adoption (Bhalla 1979; Lipton 1976; Lowdermilk 1972). A number of studies have also found that lack of credit limits adoption of technologies even when fixed costs are not large (Bhalla

1979). Shortage of funds was cited as a major constraint on adoption of divisible technologies in studies by Frankel (1971) and Khan (1975). However, others have argued that lack of credit alone does not inhibit the adoption of innovations when profitability from the innovation is perceived as large. In this case, small farmers are believed to mobilize all available resources in order to acquire the necessary inputs (Feder *et al.* 1985).

Health: Communities in Sub-Saharan Africa are plagued by diseases such as HIV/AIDS, cholera, tuberculosis, malaria, yellow fever and trypanosomiasis, as well as illnesses such as acute respitory disease and diarrhea plague communities. Sickness and poor health strain labor and capital resources and lead to greater risk when deciding how to invest resources. This variable was not included in the Pattanayak *et al.* study (2003).

A recent study by Ersado *et al.* (2004) looked at the relationship between health and technology adoption. The study took place in Northern Ethiopia and evaluated the role of disease in decreasing productivity in fields, lowering income, and requiring more time spent caring for the sick. Eight hundred households were sampled and measurements of health were assessed by the number of days each person had suffered due to disease and whether or not the person was suffering from malaria. Results showed a strong negative correlation between female and child sickness and adoption of new technologies. Time sick, interpreted as lost labor (affecting resource endowments), had a larger effect on adoption than the costs associated with taking care of the sick family members.

Category 3: Economic or Market-based Incentives

It is assumed that the adopting community will prefer a technology that increases net benefits to one that does not. Economic incentives for adoption can include reduced costs or better production from the new technology. However, the adoption literature has not done a good job of including direct measures of economic incentives. When economic incentives are included, the adoption decision is influenced by variables such as price of output or cost savings (Mercer and Pattanayak 2003).

Potential income gain: This variable is most likely to be included in the adoption model for measuring economic incentives. It can be measured through subjective estimates of yield or indirect effects attributed to current levels of related activities such as farm income. The statistical significance varies, with 58% of the studies showing a positive correlation in the Pattanayak *et al.* (2003) study.

In a study by Ayuk (1997) on the adoption of live hedges, the profitability of the technology had a significant and positive relationship with adoption. By-products (fodder, fuelwood, fruits, etc.) and garden products leading to cash income were a primary incentive to adoption. A study by Baidu-Forson (1999) shows that the potential for short-term profits is positively correlated with the adoption of land-enhancing technologies in Niger. Similarly, Franzel's (1999) study on the adoption of improved tree fallows in Africa concludes that adoption increases if high-value by-products can be produced.

Distance to market: In the review by Pattanayak *et al.* (2003), this variable was included in only 26% of adoption studies. It was highly significant with the expected negative correlation; as distance increased, adoption decreased.

Price effect: This variable was included in only 16% of the sample in the Pattanayak *et al.* (2003) study and was not highly correlated with adoption decisions. Many problems arose when measuring this variable, including a lack of geographical detail and insufficient statistical variation.

Category 4: Risk and Uncertainty

Short term risk (commodity prices and rainfall) and long term risk (tenure insecurity) influence the adoption decision (Mercer and Pattanayak 2003), as well as the uncertainty of an unfamiliar technology (Feder *et al.* 1985). Information and learning are argued to be central to the adoption process. Producers initially experiment with an innovation on a trial basis. They seek information pertaining to the costs and benefits of the innovation from these trials and from other users' experiments. As they gather more information, the producers are able to increase their knowledge about the best use of the innovation and decrease their uncertainty about its potential benefits (Marra *et al.* 2003; Lindner and Pardey 1979; Warner 1974). In general, the more risk averse a farmer is, the less willing he is to change the traditional practices and try new technologies.

The risk associated with adopting a new technology can be linked to uncertainty about the potential benefit of the innovation, a lack of knowledge on how to use it, and a lack of experience using it. Risk aversion discourages adoption, as uncertainty will always be greater for the new technology than for the old (Marra *et al.* 2003). Abadi Ghadim and Pannell (1999) present a framework of adoption as a multi-stage process that involves acquisition of information and learning by doing. In 2000, Abadi Ghadim highlighted the importance of experience in providing skill improvement to the producer. Studies by Lindner *et al.* (1982), Lindner (1987), Tsur *et al.* (1990), Leathers and Smale (1992), and Feder and Umali (1993) all point to risk as a major factor limiting the adoption of new innovations.

Tenure: Tenure is usually measured as whether the farmer is the owner of the land or rents the land. The review by Pattanayak *et al.* (2003) showed unambiguously that landowners who own their land are more likely to adopt new innovations.

Lack of tenure is often hypothesized to hinder adoption since the landlord will ultimately reap the investment of any inputs on the land. However, many studies have not found a clear relationship between tenure and adoption, and the nature of the technology is thought to affect this decision. It is believed that the affect on adoption behavior may change depending on the profitability and riskiness of the new technology. Thus any observed effects of tenancy may actually be due to factors such as access to credit, input markets, and technical information (Feder *et al.* 1985).

Experience: This variable can be measured by recording previous experience with the technology, years of farming experience, or familiarity with the technology. The basic assumption is that familiarity decreases the uncertainty of adopting. When included, this variable is significant in 81% of the studies in the Pattanayak *et al.* (2003) study.

Experience is also gained by trialing a new technology, especially in the instance of new crop varieties. Trials lead to the development of skills in agronomic management and to a reduction in uncertainty about the long-term profitability of the technology. In a study assessing the dynamic nature of adoption decisions, Abadi Ghadim and Pannell (1999) conclude that information from trialing a new innovation leads to skill improvement and better decision-making.

Extension and training: Access to extension or training is typically thought to reduce the risk of adopting. It is positively correlated with adoption in the samples evaluated by Pattanayak *et al.* (2003) 90% of the time.

Extension is argued to substitute for education in some environments (Feder *et al.* 1985). A number of adoption studies have shown the significance of extension education on adoption of land-improving technologies (Baidu-Forson 1999; Feder and Slade 1984; Jamison and Moock 1984; Rahm and Huffman 1984; Jamison and Lau 1982). A study by Baidu-Forson (1999) found that extension positively influenced the adoption of land-enhancement technologies in Niger. This is a result access to improved information provided through extension (Birkhaeuser *et al.* 1991). In parts of Niger and Burkina Faso, land rehabilitation techniques have been rapidly adopted, in part due to the effective extension education in the area (Critchley *et al.* 1992). The role of information in influencing improved farm management was also significant in a study by Feather and Amacher (1994) on Best Management Practices in the US. Giving producers information regarding the economic profitability and environmental benefits of the innovation lead to higher adoption rates.

However, the extension variable is not always a significant determinant of adoption. In a study by Adesina and Baidu-Forson (1995) on the adoption of improved mangrove rice varieties in Guinea, the extension variable was not significant. This finding supported other research in the area that had found weak researcher-extension-farmer linkages. Most of the rice varieties grown in this area were obtained through farmer contacts (Zinnah *et al.* 1993), suggesting that farmers are also important sources of technology information. When the characteristics of a technology satisfy the preferences of the farmer, they often pass these technologies along to other farmers to test, thus diffusing the technology.

Membership: Involvement in a community group or cooperative is thought to mitigate some of the uncertainty associated with new technologies. However, when this variable is included, it is significant in only 44% of the studies in Pattanayak *et al.* (2003).

Caviglia and Kahn’s 2001 study on the diffusion of sustainable agricultural technologies in Brazil found that membership in a cooperative was positively correlated with the adoption decision and the extent of adoption. This was because cooperative membership allowed a means for farmers to share information on farming and to buy and sell crops.

Cooperatives also often provided free seedlings, so membership in more cooperatives provided greater access to technology inputs. Membership is also found to be of importance in a study by Neupane *et al.* (2002) on the adoption of agroforestry technologies in Nepal. Membership in a local NGO is considered to provide access to technical know-how, extension, and training.

Input provision: Access to the necessary inputs for a new technology is intuitively necessary for technology adoption to occur. Procurement of inputs, such as seed, is often a constraint in these rural farming systems, and the use of bad seed can lead to greater risk and uncertainty about a technology. This variable was not included in the Pattanayak *et al.* study (2003).

In a study in Burkina Faso (Ayuk 1997), a binary choice utility model was used to determine what factors were affecting the adoption of live hedges. Significant factors affecting the adoption decision included variables mentioned above, such as farmer's age, number of working household members, income derived from the technology, water availability, and use of fertilizers. However, it was also determined from farmer responses that good seed quality was necessary for adoption to take place. There was a marked variation in performance of seed varieties from one plot to the next. Seed type needed to be adjusted for variations in soil type (Ayuk 1997).

Category 5: Biophysical Characteristics

Biophysical characteristics impact the production costs and returns to farmers and can therefore be considered economic determinants of adoption. Factors such as soil quality, steepness of land, and plot size influence what and how much can be grown on a piece of land. The literature shows that the influences of many of the variables under this category on adoption are ambiguous, and thus vary depending on what type of technology is being introduced (Mercer and Pattanayak 2003).

Soil quality: This variable is hard to measure and is therefore not often included in adoption studies. According to Pattanayak *et al.* (2003), when soil quality is included, it is correlated with adoption decisions 83% of the time; however, the sign of the correlation varied, suggesting that some soil types may be so degraded that investment in new technologies is futile.

In a study by Shively (1997), the adoption of soil improving technologies was lower when land quality was high or when plots were old. This conclusion was logical since investing in plots with good soil quality would result in less benefit from the new soil-improving technologies. Also, farmers may choose not to invest in parcels that are old as they are viewed as exhausted.

Slope: From the Pattanayak *et al.* (2003) study, steep slope is positively correlated with adoption in agroforestry studies.

For contour hedgerow adoption in the Philippines, Mercer and Pattanayak (2003) found that steepness of slope was positively correlated with the adoption decision. This makes sense, as the technology introduced would bring more benefit to farms on steep slopes. In studies where variations in the biophysical conditions among respondents are low or where technology utility would not differ for steep slopes, this variable would not be expected to be significant.

Plot size: Plot size is a common variable across adoption studies. It is correlated with adoption in 67% of the studies in Pattanayak *et al.* (2003). However, the sign of the correlation for this variable is inconsistent across studies.

Farm size can have different effects on adoption depending on the nature of the technology. The literature suggests that plot size is correlated with a number of other important factors such as access to credit, capacity to bear risks, access to scarce inputs, wealth, access to information, and so forth. Since the effect of each of these factors on adoption varies over time and place, so does the relationship of farm size and adoption (Feder *et al.* 1985).

In Shively's (1997) study on the adoption of soil conservation technologies in the Philippines, adoption rates were higher on larger farms. This is thought to correspond with the assumption that larger farms have lower risk exposure and improved access to resources. Farm size was found to be the most significant economic factor affecting the adoption of technologies in an Ethiopian study done by Kebede *et al.* (1990). It had a positive effect on the adoption of pesticide and fertilizer use but a negative effect on the adoption of single-ox traction. The reasons for the negative effect on traction is thought to be that larger farms need more traction power, more than one set of single-ox, thus making technology adoption more costly.

Category 6: Farmer Perceptions

Even though anthropologists and sociologists have argued qualitatively that farmer's subjective assessments of agricultural technologies influence adoption behavior, most adoption studies do not consider the impact of farmers' perceptions on the adoption choice (Adesina and Baidu-Forson 1995; Nowak 1992; Kivlin and Fliegel 1966,1967). It is now believed that these perceptions of the new technology significantly impact the adoption decision. Economists have accumulated evidence from consumer demand research showing that consumer demand for products is significantly affected by perceptions of the product (Adesina and Baidu-Forson 1995; Lin and Milon 1993; Jones 1989). Farmers make rational decisions based on the appropriateness of a new innovation to their needs. While many of these factors are covered in the traditional economic utility model, some are not. The omission of these other variables in adoption models is arguably biasing findings on what factors determine adoption decisions.

In a study by Adesina and Zinnah (1993) on the adoption of different rice varieties in Sierra Leone, it was shown that farmer's perceptions were significant in explaining adoption. The empirical model included variables measuring perceptions of taste, yield, ease of cooking, and ease of threshing the harvested rice. A Tobit model was used to analyze the results. Farm and farmer specific factors were included in the model, as well as these perception variables. Results showed a significant relationship between farmer perceptions and adoption choices. This was not the case for the farm and farmer characteristics included in the model.

In a later study by Adesina and Baidu-Forson (1995), the effects of farmer perceptions on the adoption of improved sorghum varieties in Burkina Faso and improved rice varieties in Guinea were shown. A survey elicited farmer's subjective assessments of the two technologies, including food quality, yield, ease of cooking, tillering capacity, ease of threshing, drought tolerance, and tolerance under poor soil conditions. The adoption of sorghum varieties in Burkina Faso was significantly related to farmer assessments of its quality for making local food products and its performance under poor soil conditions. In Guinea, all the preference variables were found to be strongly significant to the adoption of rice varieties. It can be concluded from these papers that farmers are concerned not only with agronomic characteristics but also with non-agronomic.

More recent studies incorporating farmer's preferences into the research model are Ayuk (1997) and Negatu and Parikh (1999). In the study by Ayuk, farmer's perceptions of the advantages and disadvantages of live hedges were scaled. Results showed that farmers were interested in live hedge species that were drought resistant, grew rapidly, and were efficient in protecting their fields from animals. In the study by Negatu and Parikh, information was gathered from farm households on perceptions of marketability, grain yield, food quality, straw quality, and tolerance to cold for new wheat varieties. Among the perception, socioeconomic, environmental, institutional, and demographic variables included in the model, the measures of marketability and grain yield were the most significant in the adoption decision.

Farmers' perceptions relate not only to how the farmer views the new technology but how they view the "old" technology that is being replaced. If a farmer does not perceive a problem with her/his farming system then adoption of technologies to improve that system will not occur. There is often a lag in farmer perceptions and adjustment to that perception (Scherr and Hazell 1994). Thus, it is argued that information and extension are important tools in changing these perceptions.

Another possibility is that the "old" technology is suitable to the farmer's needs. A study on the adoption of live fences in Cameroon by Degrande and Duguma (2000) showed that farmers did not perceive soil fertility and soil erosion as major concerns, and thus were reluctant to invest in soil conservation strategies. Targeting of appropriate technologies to the community is a key factor for adoption. Another study found similar results regarding land-enhancing technologies in Niger. Baidu-Forson (1999) concluded that the probability of adoption of soil and water technologies was likely to be high in areas having large percentages of degraded farmland but not so in other areas. However, in places where farmers perceive the negative consequences of land degradation or low soil fertility, technologies to improve soil fertility are much better received. Another possibility is that farmers will perceive the problem but give priority to other problems when deciding how to invest their resources (Franzel 1999; Crowley *et al.* 1996; ARPT 1991; Ngugi 1988).

3.3 Disadoption Determinants

While there are numerous studies that assess the rates of adoption of new technologies and the variables that affect that adoption, few studies have examined the rate and time at which a technology will be abandoned (Feder and Umali 1993). However, disadoption of technologies is a known and real phenomenon. Two disadoption studies and their general conclusions are discussed below.

Neill and Lee (2001) examine the adoption and abandonment of maize-*mucuna* farming systems in Honduras. For this study, their model is based on two discrete decisions: to adopt the system, and for those who adopted, whether to abandon it. Thus, the framework includes two dichotomous decisions, with the second decision contingent on the first. Due to the high correlation of the two equations, a bivariate probit model is used to account for the dichotomous nature of the decisions and the potential correlation between the decisions. Several exogenous factors affected the abandonment of the maize-*mucuna* farming system in this study. These included changes in land markets, the expansion of the cattle industry, modernization of the infrastructure, and biophysical factors, such as the arrival of a particularly noxious weed and recent extremes of climate.

The study found that external factors played a large part in the abandonment of the maize-*mucuna* system: road access to the community had a positive correlation with abandonment, as more economic opportunities resulted in decreased maize production. Farmers that experienced problems with the noxious weeds were also more likely to disadopt. Variables associated with continued use of the system included good management practices such as annual reseeding and having cultivated more hectares of maize and high-value crops than disadopters. The role of spontaneous diffusion for this technology is hypothesized to have had negative effects on this technology in that many farmers were not aware of the system dynamics for cultivating *mucuna*.

Another study examining the disadoption of agricultural technologies is that of Moser and Barrett (2002) on rice intensification in Madagascar. Rice intensification was promoted as a high yielding, low input alternative; however, adoption rates were low (25%) and the disadoption rate among adopters was high (40%). There were no differences in yields between those who continued using the technology and those who disadopted. Disadopters did not cite disappointment with the new rice system as an abandonment reason. The most commonly cited problems were related to time pressures, especially surrounding transplanting and weeding of the new technology.

Moser and Barrett (2002) used a probit binary choice model to estimate the rate of adoption and a Tobit model was used to analyze the extent of adoption of the rice system. However, this method was later substituted with a simple probit model of disadoption conditional on past use of the rice system. Results suggest that better-educated farmers and those with more access to labor were more likely to continue with the new system. Other relevant factors included the amount of experience with the new rice system—farmers with more experience were more likely to continue with the technology. Off-farm labor also affected disadoption, as those farmers with more off-farm labor tended to try the new system but then disadopted due to opportunity costs associated with time spent in the new rice cultivation.

3.4 Conclusion

New agricultural technologies can contribute to the economic, social, and environmental development of communities, improving their livelihoods and self-sustainability. The adoption of these new technologies can be analyzed from a sociological or economic viewpoint. The literature on adoption of agricultural technologies leans toward the use of statistical models in an economic framework. These studies seek to understand the variables that affect the farm household's decision to adopt new agricultural technologies and the constraints that prevent them from adopting by using an expected utility model that treats adoption as a dichotomous choice (adopt or not adopt) based on whether adoption yields higher net utility. Some studies also measure the extent or the intensity of adoption.

A review of the adoption literature by Pattanayak *et al.* (2003) identified five broad categories of adoption determinants: household preferences, resource endowments, economic incentives, risk and uncertainty, and biophysical characteristics. Both their meta-analysis and other literature indicates that variables falling under the categories of risk and uncertainty, biophysical characteristics, and resource endowments are most likely to be correlated with the adoption decision. Other important variables to consider in the adoption decision are farmer perceptions. How a farmer views the consumer-type qualities of a new technology (taste, ease of use) and their perceptions of its utility (whether the technology is appropriate) also affect the adoption decision.

Although disadoption of technologies is a common occurrence, there is a deficit of literature on this subject. Studies of the disadoption decision have found that a number of factors are at play. In a study by Neill and Lee (2001), cultivation problems, specifically from weeds, significantly contributed to the abandonment of *mucuna* cultivation. Farmers who displayed better management practices and who cultivated more maize crop were more likely to continue with the cultivation of the maize-*mucuna* system. Moser and Barrett (2002) found that similar variables affected disadoption as adoption in their study in Madagascar, specifically education, labor, and liquidity. Labor constraints resulted in the eventual abandonment of the new rice technology, while those farmers with more experience with the system were more likely to continue cultivating it.

CHAPTER 4: DATA

4.1 Research Design

Research was carried out using a cross-sectional survey in the two study sites in Togo and Benin. As noted in the literature review, cross-sectional surveys are the primary method of data collection for adoption studies. Babbie (1990) identifies the advantages of a survey to be that inferences can be made about some characteristic, attitude, or behavior of a population from a sample of that population. Face-to-face interviews were conducted in the local language with the aid of an interpreter from each village. As the researcher lived in the study area for two years, participant observation (researcher has cultivated, processed and transformed soybeans in the region) and direct observation (researcher has observed soybean fields, participated in site visits, and participated in educational sessions) supplement the survey findings.

A random sample was taken of farm households in each village. A farm household was defined as those who 'eat out of the same pot', since those who eat together are also the same people who raise the food, or farm, together in this society. The head of the household was taken to be that person who had the last word in farming decisions. Due to the nature of soybean technology (promotion is typically aimed at women and cultivation of non-cereal crops is the woman's job) the female head of household was interviewed when she was present. If she was not present, the male head of household was questioned. If both were present, due to cultural sensitivity, the male and female were questioned simultaneously. If neither of the above were present, any adult (defined as having 15 years or older) member of the household was questioned. Forty-four percent of the interviews were conducted with a female of the household, 20% were conducted with a male of the household, and 36% of the surveys were conducted with both a female and male household member present. The time per interview ranged from 15 to 50 minutes, with an average time of 26 minutes.

Data recorded during the surveys was rechecked at the end of each day by the researcher to verify that all questions had been answered. After all the interviews were completed, data were entered into Excel spreadsheets by the researcher. The accuracy of the data was verified in full two times by the researcher.

4.2 Sample Population

The target population for this study was the 329 households located in the villages of Koudogou, Benin and Warengo, Togo. A sampling frame was obtained from the local health center in each village; lists of households had been collected by the World Health Organization's River Blindness Eradication Campaign and were updated annually. A random sample without replacement was taken in order to achieve unbiased results. The population was stratified by village, and 45% of households in Warengo and 34% of households in Koudogou were sampled. The total sample size of 135 households was selected because it is large enough to give robust results for the population and was logistically feasible for the researcher to accomplish.

In Togo, household lists obtained from the health center were divided according to Warengo's five major clans. Each household name was given a corresponding number between 1 and 213. These numbers were placed in a sack and numbers were then chosen at random from the sack by the chief of the village. The first one hundred numbers selected were matched with their corresponding household name and written down in order of selection. This list of 100 households was then shown to the local River Blindness representative in order to disaggregate the names by neighborhood; there are 15 neighborhoods in Warengo. During this process, 4 of the households selected were noted to have moved from the area. The final number of households selected was therefore 96. The number of households surveyed in each neighborhood is given in Table 4.1.

Table 4.1: Togo households selected

Neighborhood Name	Number of Households Selected
Koupinkou	11
Takanta	10
Likoteni	05
Tagnanta	06
Yakodaka	05
Tatokawointa	03
Pokpanta	03
Koutankou	05
Nalahon	05
N'tati I	08
N'tati II	09
Kounantchakou	05
Kouhanlikou	05
Koubatikpankou	05
Yakpa	06
Koupatiekou	05
TOTAL	**96**

A local woman from Warengo was selected to act as the interpreter for this survey. She was accompanied to each household by the researcher, and the researcher recorded all data. During the survey process, homes found vacant, households that opted not to be surveyed, and households where all adult family members were unavailable on more than one visit were replaced by the closest household in that neighborhood. An additional factor was that the people in the neighborhood did not always recognize the household names recorded by the health center. Thus, not all sample households could be located. In these cases, the closest household to the last household sampled in that neighborhood was chosen. The 16 replacement households were noted as replacements in the recorded data; however, there was no differentiation between replacements due to households found vacant, households that refused to be surveyed, households where adult family members were absent, and those replaced due to not being able to locate the household based on the given family name. (Only one household refused to participate in the survey.) Interviews were conducted in Warengo between January 14 and February 10, 2004.

In the village of Koudogou, Benin, the household list obtained from the health center was numbered from 1 to 116, and the numbers were again placed in a sack. The chief of the village selected 39 numbers from the sack to meet the sample size of 135, and these numbers were matched to their household name. Household lists were already divided according to the three neighborhoods in the village and therefore no regrouping had to occur. The number of households surveyed from each neighborhood is given in Table 4.2.

Table 4.2: Benin households selected

Neighborhood Name	Number of Household's Selected
Centre	19
Ditebori	12
Ditchantcho	08
TOTAL	**39**

The chief of Koudogou selected a young man to serve as the translator for this survey. A female was requested, but the chief insisted that there were not any French-speaking females in the village. The researcher accompanied the man on each of the surveys and recorded all data. Households were replaced in Koudogou following the same criteria as described above. Interviews were conducted between March 2 and March 7, 2004.

4.3 Instrumentation

The instrument for this survey was a self-designed questionnaire (a copy can be found in Appendix I). To evaluate the adoption rate of soybeans in the village and the factors affecting this adoption, a series of close-ended questions were asked. These questions were coded for uniform interpretation of the data. To determine local perceptions of soybean utility, a series of yes/no questions were used.

A pretest of the survey instrument was conducted prior to the formal survey implementation. This allowed for any potential problems and confusion to be identified in advance. Eight households were interviewed and their responses and comments were used to refine the survey instrument. Professionals then reviewed the survey instrument, and final changes were made before the survey was implemented.

Before administering the survey instrument, the researcher applied to and received permission from North Carolina State University to carry out Human Subjects Research. At the beginning of each questionnaire, the purpose of this study was explained to the participants and their consent asked. In the one case that consent was denied, a new farm household was selected from the same neighborhood.

4.4 Study Variables

Study variables for this thesis were based on the five categories of adoption determinants and the sixth category of farmer perceptions as identified in the literature review. For each of these six categories, variables included in this survey instrument are described below. Variables not included in the literature review but that were included in this study have been added under the appropriate category and are also described below.

Category 1: Household Preferences

Education: The literature review showed that education is typically included in adoption studies but is not highly correlated with the decision process. In this study education was measured by recording whether the male and female heads of household had no education, had less than 6 years of education (primary school), or had more than 6 years of education. Education levels are hypothesized to impact the farmers' ability to understand and implement the technology. As this technology was promoted for health and environmental reasons, education could also be important in understanding the importance of improving health and soil quality.

Age: Age was measured as the age of the male and female heads of household. The exact age was recorded for each head of household; however, recollection of exact age was not always possible and many ages were nothing more than guesses. This variable does not usually show any relationship to the adoption decision, but has been found to be important in some studies with younger farmers showing more innovativeness.

Number of family members: Gender is usually measured as the proportion of males in the household. Since the technology in this study has been promoted primarily toward women, the number of men and women in the household were recorded, as well as the number of children between 5 and 15 years and children with less than 5 years. Total number of adults and children in the household were aggregated from this data as a measure of available labor.

Ethnicity: This variable is not typically included in adoption studies. It was recorded here as the family being of either Tamberma ethnicity or of another ethnicity. The majority (over 90%) of the inhabitants of this region are of Tamberma ethnicity. The origin of the family was also recorded by noting whether the fathers of the male and female household heads were originally from that village or had come from a different village.

Category 2: Resource Endowments

Income: Measures of income for this study included both agricultural (cotton, peanuts, rice, and yams) and non-agricultural (baobab tree products, millet beer, small commerce, animal husbandry) sources of income. In the literature, income sources and adoption are usually positively associated, except where the dominant source of income is agriculture and the producers do not want to risk that income by investing in the new technology. This would apply to the farming of cash crops, which was common in the study areas. Income sources were further aggregated in this study into two categories, farm and off-farm.

Expenditure: Expenditures were included in this study. Because they were not included in the meta-analysis by Pattanayak *et al*. (2003), there is no hypothesized direction of effect on adoption. Patterns of spending are difficult to gather in these societies for several reasons: honesty is difficult to obtain and the ability to remember expenditures is questionable. Monthly (for medicine, food, alcohol, and school) and yearly (for livestock vaccinations, ceremonies, school, and water) expenditures were gathered in this study to try and understand how households allocated their money, and also as a proxy for cash income.

Assets: Asset holdings and adoption are positively correlated in the literature. This study gathered data on type and number of dwellings, possession of soap, and ownership of a bicycle, radio, or motorcycle. Asset ownership was recorded as an indicator of wealth of the family.

Livestock: Livestock is treated as a separate variable due to its important role in the study areas. The number of cows, sheep, goats, and pigs owned by the household were recorded.

Labor: Labor in this study was measured as the size of the family, including the number of adult males, females, and children. Total numbers of adults and children in the household were recorded under the gender variable in Category 1. In the literature, it was shown that having more available labor resulted in higher adoption rates of technologies.

Credit/savings: This variable, although not often included in studies, is highly correlated with the adoption decision. In the sites for this study, there is limited knowledge and use of credit and savings structures. Involvement in these credit and savings structures is typically associated with education level and membership. Involvement in a savings and credit organization was recorded as a yes or no, and if yes, the type of organization was also recorded.

Health: Health is measured in this study by whether someone in the immediate family had visited a hospital or had died in the last year. If either of these had occurred, they were recorded with a yes. In the literature, a negative correlation between sickness and technology adoption was shown. Incidence of sickness or a death in the family takes away labor and income from the farm household.

Innovativeness: This variable was added to the study to determine if certain households were overall innovators (adopting several new technologies) or if adoption of multiple technologies varied depending on the technology. Innovativeness is hypothesized to occur in certain households, in that they would have adopted other new technologies as well as soybeans. The survey recorded whether households had adopted mosquito nets, improved cook stoves, or tree planting.

Nutrition: Nutritional information was gathered to assess the protein and vitamin intake of sampled households. It is not usually measured in adoption studies but since the promotion of soybean technology was based on its nutritional benefits, it is important to this study. Weekly intake of protein sources (meat/fish, eggs, soybeans, Nere seeds) and other vitamins (leafy vegetables, fruit, baobab seeds, okra) was recorded.

Category 3: Economic or Market-based Incentives

Price benefits: This variable was measured by asking respondents to give the expected price (converted to USD) they thought they could buy or sell a bowl (the local unit of measurement) of soybeans for in the market. In the literature, it has been shown that associated short-term benefits and high-value by-products are positively correlated with adoption.

Distance to market: Distance to markets and frequency of visiting those markets was recorded for this sample. Both villages frequented the same two markets and distance to these markets was comparable. In studies where this variable is included there is usually a correlation between distance to market and adoption.

Category 4: Risk and Uncertainty

Tenure: The effects of tenancy on adoption are unclear in the literature. It is typically thought that tenure is correlated with adoption. In this study tenure is recorded for each plot farmed in 2003. An average indicator of tenancy by household was then calculated by taking the average of all of a household's plots.

Extension and training: Access to extension has a strong positive correlation with the adoption decision. However, the importance of farmer-to-farmer transfer of technological information has also been established in the literature. Three variables were used to evaluate extension: who introduced the farmer to the technology (other farmers or extension agents), who trained the farmer how to use the technology (other farmers or extension agents), and if the farmer ever received formal education about the technology (recorded as yes or no).

Membership: In the literature, membership in organizations was a significant factor in the adoption decision as they often provided access to information and to inputs. In the study areas for this thesis, individuals involved in one organization tend to be more active in other village groups and better educated. Membership of male and female heads of household in an organization was recorded as yes or no for this study, and if yes, the type of organization was recorded as well.

Access to inputs: Procurement of inputs for a new technology would be necessary to alleviate uncertainty about a technology. In this study, indirect questions were used to assess access to soybean seeds and seed quality.

Extent: The extent of adoption of the soybean technology was measured as the number of hectares the household cultivated in soybeans. It is hypothesized that as a farmer becomes more comfortable with a technology, the larger the extent of cultivation will be.

Distance to field: While not included under the five categories of adoption determinants, distance to fields was recorded in this survey. For each plot farmed in 2003, the distance in kilometers from the farmer's house was recorded. The average distance to a farmer's fields was then calculated. Livestock destruction of soybean crops was common and therefore distance to fields was considered a risk for farm households.

Category 5: Biophysical Characteristics

Soil quality: The literature shows a strong correlation between this variable and technology adoption, when the technology enhances soil quality. For these technologies, studies have shown that adoption does not usually occur if the land is viewed as having good soil quality or is too severely degraded. This variable was measured for all fields in this study by categorically ranking harvests for each plot in 2003 as below average, average, or better than average. The average harvest quality was then calculated for each household by averaging harvests for each plot farmed.

Slope: Slope was measured in this study by asking whether land was flat or hilly for all farm plots. A total average slope was also calculated by taking the average for all plots. Slope is typically correlated with the adoption of agroforestry and soil and water conservation technologies.

Plot size: Plot size is typically correlated with adoption in the literature, but the sign is inconsistent. Plot size in hectares was recorded for all plots farmed in the previous year in this study. The total number of plots and total hectares farmed was also recorded for each household.

Category 6: Farmer Perceptions

Nutritional benefit: Households were asked if they felt soy was good for their health or not. It was hypothesized that households would perceive nutritional benefits of soybeans as this is the main promotion strategy in both villages, and extension efforts by health and voluntary organizations had been high.

Environmental benefit: Households were asked if they thought soybeans improved soil fertility. It was hypothesized that households would not perceive the environmental benefits of soy as there is little promotion of soybeans for this reason and most cultivators are not growing soy in a way as to reap these benefits (the root system is not left in the ground during the dry season).

Marketability: Households were asked if they thought soybeans could be sold in the local market. It was hypothesized that the community does not perceive soybeans as marketable since soybeans were not commonly sold or purchased in the nearby markets. A common complaint of farm households was that there was nowhere to sell their harvested soy.

Ease of preparation: Women often commented on the difficulty of preparing soybeans for food, even though most food processing in the area is time consuming. Households were asked if they thought soybeans were difficult to prepare for food.

Fertilizer need: Farmers often noted that soybeans needed fertilizer (specifically inorganic fertilizers) in order to grow well. Households were asked if they thought soybeans needed fertilizer (inorganic or organic) in order to judge perceptions on possible limiting inputs to cultivation.

4.5 Descriptive Statistics of the Study Areas

Data collected for this thesis support much of what was presented in Chapter 2 about the two villages. Household structure and livelihoods are similar for the two study sites, with family structure and agricultural production nearly identical between villages. One deviation from the expected similarities was income sources for the two villages. Cash cropping is much more important in Togo, and income sources for women differed slightly between the two villages. Also, the adoption of new farm and health technologies by the two villages differed, in that adoption rates were consistently higher in Benin.

Household data for Koudogou, Benin and Warengo, Togo show that family size and structure were similar between the two villages (Table 4.3). Both villages had a median family size of 6, comprised of 3 adults and 3 children. The median age for male household heads was 43 and for females, 31.5. Education levels of the two villages did differ. In Benin 70.3% of male household heads and 83.3% of female household heads had no education, to Togo's 37.5% for males and 58.1% for females. In Togo, an unusually high percentage (19.3%) of males had some form of higher education. In rural areas such as these, education levels are usually quite low and few people have more than 6 years of education.

Table 4.3: Household characteristics: Togo versus Benin

Household Characteristics	Total (n=135)	Togo (n=96)	Benin (n=39)
Total number of family members (median)	6	6	6
Total number of adult members (median)	3	3	3
Total number of children (median)	3	3	3
Father's age (median)	43 (n=125)	43 (n=88)	43 (n=37)
Father's education level:			
No education	47.2%	37.5%	70.3%
Less than 6 yrs	38.4%	43.2%	27%
More than 6 years	14.4%	19.3%	2.7%
Mother's age (median)	31.5 (n=178)	31.5 (n=136)	33 (n=42)
Mother's education level:			
No education	64%	58.1%	83.3%
Less than 6 yrs	35.4%	41.2%	16.7%
More than 6 yrs	0.6%	0.74%	0

Both villages rely heavily on agriculture, with 100% of respondents having farmed in 2003 (Table 4.4). In Benin, respondents farmed a median of 5 farm plots and in Togo, 6 farm plots. The total hectares farmed per household were similar for the two villages, at 1.7 hectares for Benin and 1.8 hectares for Togo. Both villages cultivated high percentages of sorghum or millet intercropped with cowpea, voignouz (a local groundnut), rice, and fonio (a local grain crop, similar to wheat). In Togo, many more households were cultivating the cash crop cotton, (79.2%), as compared to Benin (15.4%). Nearly all households in Benin (100%) and Togo (96.9%) owned livestock, confirming the importance of livestock to this ethnicity.

Table 4.4: Crops cultivated in 2003

Crops planted in 2003	Total (n=135)	Togo (n=96)	Benin (n=39)
Total parcels farmed (median)	5	6	5
Total hectares farmed	1.8ha	1.8ha	1.7ha
Percent of respondents who cultivated:			
Sorghum or Millet with Cowpea	99.3%	99%	100%
Maize	40%	34.4%	53.8%
Peanuts	60.7%	65.6%	48.7%
Voignouz	85.9%	81.3%	97.4%
Rice	71.9%	69.8%	76.9%
Fonio	64.4%	64.6%	64.1%
Yams	9.6%	10.4%	7.7%
Cotton	60.7%	79.2%	15.4%
Livestock	97.8%	96.9%	100%

Income sources for the two study sites were expected to be similar due to the similar resource constraints. However, survey results show that income sources vary between the two villages (Table 4.5). While almost 80% of respondents received income from growing cotton in Togo, less than 16% of respondents in Benin listed this as a source of income.

Other differences were in the income sources for women. Women in Koudogou more frequently earned income from selling baobab products, at 64%, while in Warengo only 23% earned income from this activity. Women in Warengo were more likely to earn income from selling local millet beer (33%) compared to women in Koudogou (13%). However, one caveat to this is that gathering accurate data on income sources is difficult, as many people were reluctant to divulge how they made their money, especially in front of another villager.

Table 4.5: Income sources

Income Sources	Total (n=135)	Togo (n=96)	Benin (n=39)
Percent of respondents earning income from:			
Cotton	60.7%	79.2%	15.4%
Peanuts	13.3%	17.7%	2.6%
Baobab products	34.8%	22.9%	64.1%
Local beer	27.4%	33.3%	12.8%
Animal husbandry	23.7%	32.3%	20.5%

Finally, data collected showed patterns in adoption behavior for the two villages (Table 4.6). Innovative households were defined as those that owned mosquito nets, had improved cook stoves, had planted trees around their home, or had adopted soybeans. Across the board, adoption rates were higher in the village of Koudogou, suggesting that differences associated with being located in Benin versus Togo were having an impact on adoption of new technologies.

Table 4.6: Adoption patterns

Assets	Total (n=135)	Togo (n=96)	Benin (n=39)
Mosquito nets	8.9%	4.2%	20.5%
Improved cook stove	35.6%	19.8%	74.4%
Ever planted trees at house	79.3%	75%	89.7%
Soybeans	54.1%	39.6%	89.7%

CHAPTER 5: EMPIRICAL ANALYSIS

Data collected on adoption and disadoption were first analyzed through descriptive statistics that compared the mean or median across populations. Econometrics is then used to model the probability of adoption and disadoption. For this study, adoption is treated as a dichotomous variable; the variable is assigned a "1" if the household had adopted the new technology, and a "0" if they had not (i.e., if they had never planted soybeans). Disadoption is also treated as a binary choice, with a "1" assigned if the household disadopted and a "0" if they did not (i.e., if they were still planting soybeans in the survey year).

For dependent variables that are binary choices, three types of models have been proposed in the literature: linear probability, logit, and probit models. The linear probability model has many drawbacks, particularly in that predicted possibilities can be greater than one and that distributions are non-normal (Ayuk 1997; Judge *et al.* 1985; Capps and Kramer 1985). Logit and probit models overcome these problems because both are based on a cumulative distribution function. It has been shown that neither of the models has any advantage over the other (Ayuk 1997; Capps and Kramer 1985) and for small samples outcomes should be identical (Ayuk 1997; Maddala 1983). Both probit and logit models were estimated, and the resulting coefficients were indeed very similar; only probit model results will be presented below.

A third model looks at the duration of use of the new technology—estimating the number of years a household employed the soybean technology—considering the same independent variables used to model the original adoption decision. The duration of use model was estimated using three different models—Tobit, Poisson, and the Heckman two-stage—and results were similar for all three. A Tobit model is typically used when the dependent variable is censored at zero and when the same independent variables influence the probability of adopting and the duration of adoption in the same direction, the Heckman. Tobit results will be presented below. The statistical program Limdep is used to estimate all of the models presented here.

5.1 Descriptive Statistics: adopters versus non-adopters

Descriptive statistics were calculated from the total 135 observations to identify similarities and differences between adopters and non-adopters of the soybean technology. For continuous data, this included calculating the mean, median, standard deviation, minimum and maximum. For categorical and binary data, percentages were calculated for each possible response. Of the 135 respondents, 73 households had adopted the technology and 62 had not.

Household characteristics (Table 5.1) of adopters and non-adopters of soybeans were similar, with the median household consisting of 3 adult members and 3 children. A higher education level for males in adopter households is observed at 19.7% compared to 7.4% for non-adopters. Memberships in a community organization or a savings and credit scheme were both higher for adopters, at 38.4% and 19.2% versus only 17.7% and 8.1% for non-adopters.

Table 5.1: Household characteristics: adopters versus non-adopters

Household characteristics	Adopters (n=73)	Non-Adopters (n=62)
Total number of family members (median)	6	6
Total number of adult members (median)	3	3
Total number of children (median)	3	3
Father's age (median)	40	42
Father's education level		
No education	42.3%	53.7%
Less than 6 yrs	38%	38.9%
More than 6 yrs	19.7%	7.4%
Mother's age (median)	33	38
Mother's education		
No education	61.8%	67.8%
Less than 6 years	38.2%	32.2%
Member of an organization	38.4%	17.7%
Participated in savings & credit organization	19.2%	8.1%

Income sources (Table 5.2) for the two groups show that more adopters earned income from off-farm sources (93.2%) compared to farm sources (58.9%), while non-adopters were as likely to earn from off-farm (79%) as farm (75.8%) sources. These income sources differed individually for the two groups in that non-adopters were more likely to gain their income from cash crops, 71% for cotton and 21% for peanuts, compared to 52.1% and 6.8% for adopters. Adopters on the other hand were more likely to receive income from specific off-farm sources: 39.7% sold baobab products and 32.9% sold millet beer compared to 29% and 21% for non-adopters. The one exception to this trend is the higher percentage of off-farm income from animal husbandry practices by non-adopters (32.3% to 16.4%).

Table 5.2: Income sources

Income source	Adopters (n=73)	Non-adopters (n=62)
Income from farm sources	58.9%	75.8%
Cotton	52.1%	71%
Peanuts	6.8%	21%
Income from off-farm sources	93.2%	79%
Baobab products	39.7%	29%
Millet beer	32.9%	21%
Animal husbandry	16.4%	32.3%
Small commerce	20.5%	12.9%

Households that adopted soybeans also tended to adopt other new technologies, such as mosquito nets (13.7%), improved cook stoves (53.4%), and planting trees (84.9%) (Table 5.3). Non-adopters of soybeans had low rates of adoption for other technologies, with the exception of planting trees near the home (72.6%). For asset ownership, adopters also fared better. Adopting households were more likely to own soap, a radio, and a bicycle. Large percentages of both groups owned livestock, as would be expected from the culture.

Table 5.3: Adoption patterns and assets

Assets	Adopters (n=73)	Non-Adopters (n=62)
Mosquito net	13.7%	3.2%
Improved cook stove	53.4%	14.5%

Table 5.3 (continued)

Planted trees at house	84.9%	72.6%
Owned soap	61.6%	33.9%
Owned a radio	60.3%	27.4%
Owned a bicycle	71.2%	46.8%
Owned livestock	98.6%	96.8%

Crops planted (Table 5.4) by the two groups were similar, with adopting households, on average, cultivating 6 parcels to 5 for non-adopters. High percentages of adopters farmed subsistence crops, such as sorghum and cowpea, rice, voignouz, and fonio. Non-adopters were more likely to farm cash crops such as cotton (71% to 52,1%) and yams (12.9% to 6.8%) but many also grow sorghum and cowpea, rice, and voignouz.

Table 5.4: Crops cultivated in 2003

Crops planted in 2003	Adopters (n=73)	Non-Adopters (n=62)
Total parcels farmed (median)	6	5
Sorghum or Millet with Cowpea	100%	98.4%
Maize	52.1%	25.8%
Peanuts	65.8%	54.8%
Voignouz	91.8%	79%
Rice	75.3%	67.7%
Fonio	68.5%	59.7%
Yams	6.8%	12.9%
Cotton	52.1%	71%

Table 5.5 presents the perceptions of adopters and non-adopters towards soybeans. A high percentage of adopters and non-adopters perceived that soybeans improved nutrition (95.9% and 91.9%) and that soybeans could be sold in markets as a source of income (97.3% and 95.2%). Both groups also felt that soybeans needed some type of fertilizer to grow (83.6% and 75.8%). However, adopters of soybeans were more likely to perceive that soybeans improved soil fertility (76.7% to 46.8%) and that soybeans were easy to prepare for home consumption (76.7% to 58.1%).

Table 5.5: Farmer perceptions

Perceptions	Adopters (n=73)	Non-adopters (n=62)
Soy is good for you	95.9%	91.9%
Soy improves soil fertility	76.7%	46.8%
Soy is easy to prepare for food	76.7%	58.1%
You can sell soy in the market	97.3%	95.2%
Soy needs fertilizer to grow	83.6%	75.8%

5.2 The Empirical Model for Adoption

5.2.1 Adoption model

The dependent variable, SOY, in the empirical model measures the probability of adopting the technology of cultivating soybeans and takes the value of “1” if the farm household had ever planted soybeans and a “0” if they had not. The independent variables for the empirical model come from the 6 categories of adoption determinants discussed in the literature review. The goal was to keep at least two variables from each category introduced in the theoretical model. However, for biophysical factors only one variable was found appropriate to include in this model. These categories include: household preferences, resource endowments, economic incentives, risk and uncertainty, and biophysical characteristics, with the additional category of farmer perceptions.

First, a full model including all variables expected to be significant and representing all categories was estimated. Then, insignificant variables were eliminated leaving a parsimonious model. The model was robust to dropping non-significant variables (i.e., signs and significance of other variables did not change) and therefore only the full model will be reported below. Results from the parsimonious model can be found in Appendix II. The variable measuring extension and training (SOYEDU) could be argued to be endogenous and was dropped from the model to see if any changes occurred. There were no changes in the significance or signs of other variables, so SOYEDU is included in the model below.

A full list of the variables queried for in this study was presented in Chapter 4. The 16 independent variables employed for the empirical model were chosen based on their t-values, the literature review, exogenous versus endogenous variables, and personal experience in the research area. Descriptions of all of the variables used in the full empirical model are presented in Table 5.6, along with the variable name and category, its mean and standard deviation, and its expected sign in the empirical model.

Table 5.6: Variables included in adoption model

Variable name and description	Category	Mean (Standard deviation)	Expected Sign
SOY: The dependent variable in the study. A 1 indicates that the household had cultivated soybeans at some times; a 0 indicates that the household had never cultivated soybeans.			
COMM: A dummy variable representing the name of the village where the survey took place. A 1 represents the village of Warengo, Togo and a 0 represents the village of Koudogou, Benin.		0.711 (0.455)	--
FEDUC: A categorical variable differentiating between male heads of household who had no education, had attended primary school (up to 6 years of education), and had advanced beyond primary school (more than 6 years of education)	Household preferences	1.688 (0.756)	+
NOMEN: A numeric measure of the total number of men (defined as having 15 years or more) living in the household.	Resource endowments	1.407 (0.840)	+
TOTAGINC: A dummy variable measuring whether the household derived income from farm sources (cotton, peanuts, and animal husbandry). A one was given if they derived income from some farm source and a zero was given if they did not derive income from a farm source.	Resource endowments	0.830 (0.697)	--
BIKE: Measured as the possession of a bicycle. The household is given a 1 if they possessed a bike and a 0 if they did not.	Resource endowments	0.600 (0.492)	+
FAM: A measure of whether the household had any family members living outside of their village. A 1 was given if they did have family outside the village and a 0 if they did not.	Resource endowments	0.711 (0.455)	+
TOTFARM: A numeric measure of the total number of parcels a household had farmed in the previous year.	Resource endowments	4.985 (1.583)	+
HOSP: A dummy variable measuring whether any member of the household had visited a hospital (not the local health center) in the past year. A 1 was given if someone had visited and a 0 was given if they had not.	Resource endowments	0.504 (0.502)	--
PRXSOY: The stated price a household said a bowl of soybeans could be bought or sold for in their local market. Prices have been converted to USD.	Economic incentives	1.156 (0.500)	+
MRKT1: A dummy variable recording visitation of the local market in Nadoba, Togo. A 1 indicates that they had visited the market in the past month, and a 0 that they had not.	Economic incentives	0.874 (0.333)	+

Table 5.6 (continued)

MBR: Measured as a 1 if the male or female household head was involved in any formal or informal organizations and a 0 if the household was not.	Risk and uncertainty	0.289 (0.455)	+
AVGDIST: Aggregated from all of the household's plots for the previous year, a measure of the average number of kilometers their fields were from their home.	Risk and uncertainty	1.319 (1.382)	--
AVGHARV: Aggregated from all of the household's plots in the previous year, this variable was an index of their harvest levels. A 1 represented an above normal harvest, a 2 represented a normal harvest, and a 3 represented a below normal harvest.	Biophysical characteristics	1.632 (0.554)	+/--
IMPSOIL: A measurement of the farmer's perception of whether soybeans improve soil fertility. A 1 was given if the farmer believed soybeans improve soil fertility, a 0 was given if they did not believe this, and a 0.5 was given if the farmer did not know.	Farmer perceptions	0.804 (0.267)	+
FTSOY: A measurement of the farmer's perception of whether soybeans need fertilizer. A 1 was given if the farmer believed soybeans needed fertilizer, a 0 was given if they did not believe this, and a 0.5 was given if the farmer did not know.	Farmer perceptions	0.856 (0.311)	--

The COMM variable was included to determine if the location of the village had an influence on the adoption decision and its expected effect is hypothesized to be negative; the descriptive statistics show that respondents living in Benin had higher adoption rates than Togo. FEDUC is hypothesized to be positively related to the decision to adopt soybeans or not. Educated farmers may have a better understanding of the health and environmental benefits derived from cultivating soybeans. Since male heads of household have the final say in household farming decisions, their education level was hypothesized to be more influential than the female education level, which is not included in this model. NOMEN is expected to be positively related to soybean adoption, as more men in the household would represent more available labor. In a season when labor scarcity is a problem, access to more labor would lend itself to the ability to try new technologies. TOTAGINC measures the investment in agricultural incomes by the household, including cotton and peanut cultivation. Based on the literature review about having large investments in agricultural income, the expected sign is hypothesized to be negative. BIKE is included as a measure of assets. It is expected to be positively related to the adoption decision. For FAM, it was hypothesized that access to resources/family outside of the village site would have a positive relationship with adoption. TOTFARM is assumed to be positively related to adoption, since a farmer with more parcels of land in cultivation could be considered to have more land resources. HOSP is hypothesized to have a negative effect on adoption as incidence of sickness and health were shown in the literature to consume labor and capital, negatively impacting adoption opportunities. PRXSOY is hypothesized to be positively related to adoption since the economic incentive to cultivate a crop that could be sold for a higher price would provide incentive to adopt the new technology. MRKT1 measures visitation to a market and is assumed to have a positive effect. From the literature review we saw that access to markets allowed for information exchange and inputs to be bought and sold. SOYEDU is expected to have a positive relationship based on the hypothesis that extension and training reduce risk and uncertainty. It is expected that membership in an organization (MBR) would provide more access to technology information and inputs, and would therefore be positively related to adoption. AVGDIST is hypothesized to be negatively related to adoption, as fields further away from the household would be more susceptible to livestock destruction. The effect of AVGHARV could be negative or positive. If farmers were trying to improve their soil fertility and adoption of soybeans was occurring for this reason, then AVGHARV would have a positive impact on adoption: farmers with poorer soil would be more likely to adopt. If farmers thought their land was too degraded to invest time in soil management or in experimenting with new crops, AVGHARV would have a negative impact on adoption: farmers with poorer soils would be less likely to adopt. The perception that the new technology improves soil fertility (IMPSOIL) is expected to be positively related to adoption, while the perception that the technology requires fertilizer in order to grow (FTSOY) is expected to be negatively related to adoption. On the basis of these 16 variables the full model estimated for this study is:

Y = B (C) + B1 (Household Preferences)+ B2 (Resource Endowments) + B3 (Economic Incentives) + B4 (Risk and Uncertainty) + B5 (Biophysical Characteristics) + B6 (Farmer Preferences) + E

Where,

Y = SOY

B = COMM

B1 = (FEDUC)

B2 = (NOMEN, TOTAGINC, BIKE, FAM, TOTFARM, HOSP)

B3 = (PRXSOY, MRKT1)

B4 = (SOYEDU, MBR, AVGDIST)

B5 = (AVGHARV)

B6 = (IMPSOIL, FTSOY)

E = Error term

Alternatively, the model can be represented as SOY= f (COMM, FEDUC, NOMEN, TOTAGINC, BIKE, FAM, TOTFARM, HOSP, PRXSOY, MRKT1, SOYEDU, MBR, AVGDIST, AVGHARV, IMPSOIL, FTSOY).

5.2.2 Results

Results from the probit analysis for the adoption of soybeans are presented in Table 5.7. Seventy-three respondents, or 54%, had adopted soybean cultivation (y=1). The model fit the data reasonably well as shown by the Log likelihood function and Veall/Zimmerman pseudo R-squared. The percentage of correctly predicted respondents was 82%.

Table 5.7: Probit regression of adoption

Variable	**Coefficient**	**P-value**	**Marginal effect**	**P-value**
Constant	1.05	0.465	0.387	0.461
COMM	-2.89	0.000	-0.674	0.000
FEDUC	0.65	0.008	0.240	0.008
NOMEN	0.18	0.447	0.676E-01	0.445
TOTAGINC	-0.43	0.120	-0.157	0.121
BIKE	-0.29	0.413	-0.106	0.401
FAM	0.57	0.188	0.214	0.188
TOTFARM	0.22	0.098	0.813E-01	0.098
HOSP	-0.72	0.045	-0.259	0.036
PRXSOY	0.627E-01	0.823	0.230E-01	0.824
MRKT1	-0.17	0.821	-0.601	0.814
SOYEDU	0.55	0.131	0.192	0.101
MBR	0.68	0.086	0.231	0.060
AVGDIST	0.19	0.152	0.711E-01	0.150
AVGHARV	-0.58	0.094	-0.212	0.096
IMPSOIL	0.50	0.458	0.182	0.459
FTSOY	-0.72	0.291	-0.263	0.286
Log likelihood	**-47.57**			
Veall Zimmerman pseudo R^2	**0.64**			
% Correctly Predicted	**82**			
N	**122**			

Nine of the 16 variables were significant in the adoption model. Variables significant at the 1% level include FEDUC and COMM. HOSP was significant at the 5% level. At the 10% level, the variables TOTFARM, MBR, and AVGHARV are significant. Additional variables significant at the 15% level include TOTAGINC, SOYEDU, and AVGDIST. Whether the variable has a positive or negative influence on adoption and its marginal effect will be discussed below under the respective category.

However, the largest effect came from the dummy variable for community, which did not fall under any of the categories. Farmers who live in Togo were less likely to adopt soybeans than farmers in Benin, as indicated by the negative coefficient on COMM. This variable had the largest negative marginal effect in the model. The probability of adopting soybeans decreased 67% if the household was located in Warengo, Togo, holding all other household characteristics equal. This is not unexpected as the descriptive statistics in Chapter 4 showed a much higher rate of adoption for respondents in Benin.

Category 1: Household Preferences

The variable included from household preferences, FEDUC, were significant at the 1% level. FEDUC has a positive correlation with the adoption decision—households with higher education levels for the male head of household (FEDUC) were more likely to adopt soybean cultivation than households with less education. This variable also has the largest positive marginal effect on the adoption decision. When the education obtained by the male head of household goes from none (level 1) to more than 6 years (level 3), the household is

24% more likely to adopt the new technology. Because this was a categorical variable, a marginal increase per level change cannot be assigned.

The positive effects of education are most likely due to the fact that more education allows for a better understanding of the benefits of the new technology. If households cannot make the connection between adding soybeans to their diet and better nutrition for their children, they will be less likely to adopt a crop promoted almost exclusively for its health benefits. Another possibility is that materials and programs promoting soybeans are designed for people with formal education.

Category 2: Resource Endowments

Three of the five resource endowment variables were significant. Agricultural income (TOTAGINC) was significant at the 15% level and had a negative correlation with the adoption of soybeans, presumably because high incidences of cash cropping did not allow households to invest the time or resources into the new technology. If a family earned income from agricultural sources, they were 16% less likely to adopt the new technology. The majority of agricultural income was earned from cash cropping of cotton; the labor and capital needed to invest in this cash crop would limit the ability of a household to invest in any new technologies and such a farmer would not want to take the risk of losing income by investing in an alternative farming technology.

TOTFARM was significant at the 10% level and had a positive correlation with the adoption decision; households with more land in cultivation were more likely to adopt the new crop. Having more parcels of land in cultivation could be a measure of land resources. Having more available land could impact the ability to trial new crops and as we see in this model, farming more parcels does have a positive impact on the adoption decision. However, this variable had one of the smallest marginal probabilities at only 8%, limiting the impact of this variable in comparison to other significant variables.

Health (HOSP) was significant at the 5% level and had a negative correlation with adoption. If a member of the immediate family had visited the hospital in the past year the probability of adopting soybeans decreased by 26%. This was the second largest negative influence on the adoption decision, after that of COMM. Visitation to the hospital may indicate poor overall health for a family. A sickness in the family also implies significant losses in labor and capital resources during the previous farming season, which would have a direct impact on a household's ability to adopt.

Resource endowment variables NOMEN, BIKE, and FAM were not significant in the adoption model. NOMEN is considered to be a measure of labor for a household. This variable did have the expected positive correlation with adoption but was highly insignificant. This might be due to the fact that while soybeans would not be labor saving, they would not be so labor-intensive as to prohibit initial adoption. BIKE does not have the expected correlation with adoption. While this sign is unexpected, the variable is highly insignificant and transportation assets may not affect the ability to adopt soybeans. Lastly, the variable FAM has the expected positive correlation with adoption but is insignificant only at the 19% level. Having family outside the village was assumed to provide access to wealth resources and information, and while this is presumably happening, it was not having a statistically significant impact on the adoption decision.

Category 3: Economic Incentives

Neither of the two economic incentive variables was significant in this adoption model. They were actually the most insignificant to the adoption decision (at the 82% level). The lack of significance of these variables may be due to the fact that little economic activity involving soybeans was occurring in the local markets, so expecting a high price for soybeans would not impact the adoption decision. Distance to markets varied little across households (standard deviation=0.333), giving little advantage for one household over the other in terms of access to markets.

Category 4: Risk and Uncertainty

The three risk and uncertainty variables included in this model were statistically correlated with adoption. Extension and outreach (SOYEDU) was significant at the 15% level and had a positive effect on the adoption decision. Having participated in a soybean extension session increased the marginal probability of adopting soybeans by 19%. For those people who had been in contact with extension agents, the uncertainty about adopting soybeans had been reduced. Education on the utility of the technology and demonstrations on how to cultivate and use the technology had a positive influence on adoption. Inputs, such as grain, were also more readily available through extension agents in this region, presumably leading to the positive correlation with adoption.

The variable indicating membership (MBR) in an organization was positively significantly (at 10%) related to adoption. Membership in community groups provides support, access to information, and training. Being a member in just one organization made the probability of adopting soybeans 23% more likely in this study. This variable had the second largest positive marginal effect on the adoption decision, after that of FEDUC. Members of organizations in these communities tended to be the more active and informed citizens. After becoming a member, access to information, inputs, and education would be reciprocated, thus positively influencing the adoption decision.

AVGDIST was hypothesized to have a negative effect due to the problems with livestock destruction of soybean fields. The variable was significant at the 15% level but had a positive correlation with the adoption decision. One explanation for the positive sign could be the fact that the average distance to fields was calculated from all parcels farmed in the survey year, which is not necessarily the same as in the years that soybeans were cultivated. Thus, this variable did not capture the impacts of livestock destruction on soybean fields. There is also a possibility that there was undetected correlation with another variable in the adoption model. This variable displayed the smallest marginal probability, 7%, on the adoption decision.

Category 5: Biophysical Characteristics

AVGHARV was the only biophysical variable included in the model. It was significant at the 10% level and had a negative correlation with the adoption decision. A farmer that had a below normal harvest was 21% less likely to adopt soybeans than a farmer with a normal harvest (and likewise for normal versus above normal). These findings support the hypothesis that farmers with fields of poorer soil quality were not as likely to make soil management investments. One would expect the opposite if farmers were adopting soybeans to improve soil fertility. However, if not familiar with the soil-improving capabilities, it would have actually been more risky for a farmer with less productive soils to invest in the new technology. Not knowing how the new crop would produce, they were more secure growing the crops they knew would perform well under their poor soil conditions.

Category 6: Farmer Perceptions

Neither of the farmer perception variables in this model was significant in explaining the adoption decision. Both had the expected sign: IMPSOIL had a positive correlation with adoption and FTSOY had a negative correlation with adoption. As with SOYEDU, these variables could be endogenous to technology adoption—the perception that soybeans improve soil fertility or need fertilizer may be a consequence of adopting or not adopting soybeans and not vice versa.

5.2.3 Interaction terms for the adoption model

To determine if any of the independent variables had an effect in only one of the two communities, separate models were run with the Benin and Togo data sets. The adoption model was estimated with the 16 independent variables for each community and then any signs of variables that changed between the independent models and the full model (all the respondents) were recorded. However, due to the fact that only 4 households had never adopted the technology in Benin, there was not enough variation to conduct these tests for the Benin data set. Therefore, only results with the Togo data set could be compared to the full adoption model. While we cannot analyze this information quantitatively, qualitatively we see that all variables have the same influence on adoption for the full model and for the Togo model. Estimation results with the Togo data set can be found in Appendix III.

5.3 Descriptive Statistics: disadopters versus continued adopters

Of the 73 (54.1%) households that had adopted soybeans in the study sample, 21 (28.8%) of the farm households had not planted soybeans in the farming season immediately prior to the survey. Thus, a high proportion of households can be considered "disadopters;" in other words they adopted but then abandoned the technology. Descriptive statistics for this subset of 73 households were calculated to compare the 52 continued adopters and the 21 disadopters. Similarities between the two groups existed for household characteristics, including family size, income sources, crops farmed in 2003, and adoption of other health/farm technologies. Characteristics of soybean farming differed in that disadopters experienced more problems with growing soybeans and had cultivated smaller areas of soybeans in the past. Stated reasons by disadopters for not planting in 2003 included health reasons, labor constraints, and a lack of grain.

Household characteristics for continued adopters and disadopters of soybeans were similar (Table 5.8). However, male heads of household for continued adopters had a lower age, 39 compared to 45, and a higher education level than disadopters; women heads of household for continued adopters also had a lower age, 33.5 compared to 37.6, and higher education level than disadopters. Membership in an organization or a savings and credit scheme was higher for continued adopters, at 40.4% compared to 21.2% of disadopters. Income sources for the two groups were similar; however, a higher percentage of disadopters were involved in off-farm income activities (95.2% to 86.5%). Total number of plots farmed in 2003 was higher for continued adopters, at 6 parcels, than for disadopters, at 4 parcels. The percentages of respondents cultivating different crop types were similar across groups and are not reported here. Finally, innovativeness of the two groups (adoption of mosquito nets, cook stoves, and planting trees), perceptions of soybean utility (is good for you and improves soil fertility) and perceptions of soybean characteristics (easy to prepare, can be sold in market, and needs fertilizer) were similar for both groups, and are therefore not reported here.

Table 5.8: Household characteristics: disadopters versus continued adopters

Household characteristics	Total Adopters (n=73)	Continued Adopters (n=52)	Disadopters (n=21)
Total number of family members (median)	6	6.5	6

Table 5.8 (continued)

Total number of adult members (median)	3	3	3
Total number of children (median)	3	3	3
Father's age (median)	40	39	45
Father's education level			
No education	42.3%	41.2%	45%
Less than 6 yrs	38%	37.3%	40%
More than 6 yrs	19.7%	21.6%	15%
Mother's age (median)	33	33.5	37.6
Mother's education			
No education	61.8%	57.1%	70.4%
Less than 6 years	38.2%	41.3%	29.6%
Member of an organization	38.4%	40.4%	33.3%
Participated in savings & credit organization	19.2%	21.2%	14.3%
Income from farm sources	58.9%	59.6%	57.1%
Income from non-farm sources	89%	86.5%	95.2%
Total plots farmed in 2003	6	6	4

The two groups' experience with soybeans differed in some important aspects (Table 5.9). The average number of years soybeans were farmed for continued adopters was higher at 2.4 years to 1.5 years for disadopters. Both groups had high percentages of respondents that learned about soybeans from a friend or family member. More disadopters had received formal soybean education, but only by a small percentage (42.9% to 38.5%). Disadopters reported having had more problems with cultivating soybeans, at 52.4% to 36.5%. Large percentages of both groups had been taught how to make soybean products and had used their soybeans to produce *dawadawa*.

Table 5.9: Soybean characteristics

Soybean characteristics	Total Adopters (n=73)	Continued Adopters (n=52)	Disadopters (n=21)
Number of years farmed soybean	2.1	2.4	1.5
Learned about soy from a friend/family	60.3%	61.5%	57.1%
Received formal soy education	39.7%	38.5%	42.9%
Had problems with cultivating soybeans	41.1%	36.5%	52.4%
Taught how to make soy products	75.3%	73.1%	81%
Used harvested soy to make *dawadawa*	90.9%	97.4%	76.5%
Used harvested soy to make soy porridge	12.7%	7.9%	23.5%

Disadopters were asked why they had not planted soybeans during the 2003-planting season. Reasons stated by the 21 disadopters for not planting soybeans included family/health reasons, lack of grain, too much work, and previous problems with livestock destruction (Table 5.10). Over 50% of the respondents stated that either health or labor constraints contributed to the disadoption of the technology. More than 20% of the respondents had abandoned the technology because they did not have access to the key input, soybean grain.

Table 5.10: Farmer's stated reasons for disadoption

Reason for abandonment	Disadopters (n=21)
Family/health reasons	38.1%
No soybean grain	23.8%
Too much work	19%
Previous livestock problems	9.5%

5.4 *The Empirical Model for Disadoption*

5.4.1 *Disadoption model*

The dependent variable in the empirical model for disadoption measures the probability that the household had abandoned the technology of cultivating soybeans. The variable, called DISADOPT, is given a "1" if the farm household disadopts and a "0" if they do not. The independent variables for the empirical model come from the 6 categories of adoption determinants discussed in the literature. These categories include: household preferences, resource endowments, economic incentives, risk and uncertainty, biophysical characteristics, and farmer perceptions.

First, a model containing only exogenous variables was estimated. Second, a model was estimated that contained significant variables from this first model and new variables measuring soybean attributes that could be endogenous. Since variables significant in the first model were also significant in the second model, only the second model will be presented below. The first model, containing only exogenous variables, is presented in

Appendix IV. The 12 independent variables used in the disadoption models were selected based on their t-values, the literature review, exogenous versus endogenous variables, and personal experience in the research area. A description of all of the variables used is presented in Table 5.11, along with the variable name and category, its mean and standard deviation, and its expected sign in the empirical model.

Table 5.11: Variables included in disadoption model

Variable name and description	Category	Mean (Standard Deviation)	Expected Sign
DISADOPT: The dependent variable in this model. A 1 indicates that the household had disadopted the technology; a 0 indicates that the household had continued adopting.			
FEDUC: A categorical variable differentiating between male heads of household who had no education, had attended primary school (up to 6 years of education), and had advanced beyond primary school (more than 6 years of education)	Household preferences	1.803 (0.821)	--
MEDUC: A categorical variable differentiating between female heads of household who had no education, had attended primary school (up to 6 years of education), and had advanced beyond primary school (more than 6 years of education)	Household preferences	1.376 (0.454)	--
BIKE: Measured as the possession of a bicycle. The household is given a 1 if they possessed a bike and a 0 if they did not.	Resource endowments	0.712 (0.456)	--
TATA: Measured as the possession of the traditional form of house dwelling. A 1 is given if they owned a tata and a 0 if they did not. (Exogenous model only)	Resource endowments	0.959 (0.655)	--
TOTFARM: A numeric measure of the total number of parcels a household had farmed in the previous year.	Resource endowments	5.288 (1.338)	--
PRXSOY: The stated price a household gave for a bowl of soybeans in their local market. Price is reported in USD.	Economic incentives	1.173 (0.477)	--
AVGHARV: Aggregated from all of the household's plots in the previous year, this variable was an index of their harvest levels. A 1 represented an above normal harvest, a 2 represented a normal harvest, and a 3 represented a below normal harvest. (Appendix IV)	Biophysical characteristics	1.618 (0.483)	+

Table 5.11 (continued)

AVGDIST: Aggregated from all of the household's plots for the previous year, a measure of the number of hectares their fields were from their home.	Risk and uncertainty	1.421 (1.596)	+
SOYPROB: A dummy variable measuring whether past soybean harvests were problematic. A 1 is given if the past harvests were problematic and a 0 if they were not.	Risk and uncertainty	0.411 (0.495)	+
EXTENT: A numerical number of the hectares of soybeans the household had cultivated the last year they cultivated the crop.	Risk and uncertainty	0.120 (0.821E-01)	--
SOILSOY: A dummy variable measuring the type of soil the crop was grown on. A 1 represented clayey soil and a 0 sandy soil.	Biophysical characteristics	0.151 (0.360)	+
IMPSOIL: A measurement of the farmer's perception of whether soybeans improve soil fertility. A 1 was given if the farmer believed soybeans improved soil fertility, a 0 was given if they did not believe this, and a 0.5 was given if the farmer did not know.	Farmer perceptions	0.877 (0.232)	--

The variables FEDUC and MEDUC are both hypothesized to be negatively related to the disadoption decision, as higher education levels would provide a better understanding of health and farm benefits of the technology and deter disadoption. The resource asset variable BIKE is expected to be negatively related to the disadoption decision as resource/wealth is hypothesized to allow for continued investment in the technology. TOTFARM is expected to have a negative effect on the disadoption decision. This variable can be considered a proxy for land and labor resources available to the household; having access to these resources is expected to favor continued adoption. PRXSOY is hypothesized to be negatively related to disadoption since those who expected a higher price for soybeans would have an economic incentive to continue cultivating the crop. AVGDIST is hypothesized to be positively related to disadoption since farmers with fields further away from their homes would be at more risk of livestock destroying their fields. Past problems with soybean cultivation (SOYPROB) is hypothesized to positively affect the disadoption decision. Problems such as poor grain production and livestock destruction were common in the area and having these problems would contribute to uncertainty about the technology. EXTENT is expected to have a negative impact on disadoption as those farmers cultivating larger parcels of soybeans in theory have more experience and success with the crop and are therefore more likely to continue cultivation. Soybeans grown on clayey soils would not have grown well due to water logging. Therefore, SOILSOY is hypothesized to be positively related to disadoption; farmers growing soybeans on clayey soils would be more likely to disadopt the technology. The perception that soybeans improve soil fertility (IMPSOIL) is expected to have a negative impact on disadoption. If farmers believed they were receiving soil benefits from soybeans they would not be expected to abandon the technology. Based on this the estimated equation for disadoption can be expressed as:

Y = B (Household Preferences) + B2 (Resource Endowments) + B3 (Economic Incentives) + B4 (Risk and Uncertainty) + B5 (Biophysical Characteristics) + B6 (Farmer Preferences) + E

Where,

Y = DISADOPT

B1 = (FEDUC, MEDUC)

B2 = (BIKE, TOTFARM)

B3 = (PRXSOY)

B4 = (AVGDIST, SOYPROB, EXTENT)

B5 = (SOILSOY)

B6 = (IMPSOIL)

E = Error term

Alternatively, the disadoption model can be represented by: DISADOPT= f (FEDUC, MEDUC, BIKE, TOTFARM, PRXSOY, AVGDIST, SOYPROB, EXTENT, SOILSOY, IMPSOIL).

5.4.2 Results

Results from the probit analysis for the disadoption of soybeans based on exogenous variables and soybean attribute variables are presented in Table 5.12. The fit of this model is stronger than the purely exogenous model (presented in Appendix IV), with a Veall/Zimmerman pseudo R-squared of 0.63 and 83% of the respondents predicted correctly.

Table 5.12: Probit regression of disadoption

Variable	Coefficient	P-value	Marginal Effect	P-value
Constant	5.271	0.010	1.010	0.020
FEDUC	-0.679	0.176	-0.130	0.134
MEDUC	-1.410	0.045	-0.270	0.043
BIKE	-1.156	0.037	-0.287	0.059
TOTFARM	-0.440	0.030	-0.842E-01	0.083
PRXSOY	-1.413	0.102	-0.271	0.077
AVGDIST	0.442	0.020	0.847E-01	0.027
SOYPROB	0.719	0.200	0.148	0.206
EXTENT	-8.053	0.025	-1.542	0.031
SOILSOY	1.942	0.012	0.612	0.006
IMPSOIL	1.495	0.237	0.286	0.232
Log likelihood	**-22.78**			
Veall Zimmerman pseudo R^2	**0.63**			
% Correctly Predicted	**83**			
N	**69**			

When the model contains both exogenous and soybean variables, 8 variables are found to be significant to the disadoption decision. The variables MEDUC, BIKE, TOTFARM, AVGDIST, EXTENT, and SOILSOY are all significant at the 5% level. One additional variable, PRXSOY, becomes significant at the 10% level. While FEDUC does not have a significant coefficient, its marginal effect is significant at the 15% level. The sign of each coefficient and its marginal effect will be discussed under the respective category.

Category 1: Household Preferences

Variables brought into the disadoption model from household preferences were the education of men and women, FEDUC and MEDUC. Education level of female heads of household was significant at the 5% level and had the expected negative correlation. The variable for male education was only significant at 18% in the probit model, but looking at the marginal effects, it too influences the decision to disadopt. For every additional level of education for the male head, the probability of disadoption decreases by 13%; for the female head the probability of disadoption decreases by 27%. After having decided to try the new technology, education level continues to influence the decision to continue with the new technology.

Category 2: Resource Endowments

Under resource endowments, the variables BIKE and TOTFARM were significant. The bicycle variable was not significant in the adoption model but becomes significant here at the 5% level, having a negative correlation with disadoption. The marginal effect of this variable was large: with the possession of one bike, the likelihood of disadoption decreases by 29%. Owning a bicycle would provide several advantages to a family. First, the possession of a bike leads to better mobility. This mobility would provide access to more farmers, and possibly more opportunities to see and learn about the new technology. The farmer would also have better access to markets and have the opportunity to buy soybean seeds. In addition, having a bicycle would allow a farmer to better survey fields that are at a distance from the home, preventing livestock destruction of soybeans or other crops, leading to better harvests.

TOTFARM was also significant at the 5% level and had the expected negative correlation with the disadoption decision. Farming more parcels decreased the likelihood of disadoption. This variable can be considered a measure of available land resources. The marginal probability of this variable, however, was not large, decreasing the chance of disadoption by just 8%. This variable had similar effects on the adoption decision.

Category 3: Economic Incentives

For economic incentives, the one variable included in the model was price beliefs of soybeans (PRXSOY). It was significant at the 10% level with a negative effect of 27%. Thus, farmers expecting a higher price for soybeans were more likely to continue cultivating the crop. This effect may have occurred because disadopters felt that soybeans would not receive a high price in the market and therefore their low economic value (marketability) impacted their decision to disadopt. Also, this subset of households is more likely to have had experiences with soybean sales. So, despite the problems discussed in the adoption section with this variable—that there was little market activity of soybeans—an expected higher price does keep farmers from disadopting suggesting that at some level market value of soybeans was affecting farmer decisions.

Category 4: Risk and Uncertainty

Three variables under risk and uncertainty were included in the model and two were significant. The variable EXTENT was negatively correlated with the disadoption decision. Those households that cultivate larger amounts of soybeans are intuitively the farmers that have trialed soybeans for longer, are more comfortable with growing them, and know how to use them in daily life. They can be considered to have more experience with the technology and therefore would have already eliminated much of the risk associated with continued adoption. An increase of one hectare in the area of cultivated soybeans decreases the probability of disadopting the technology by 154%. This was the largest negative marginal effect, in part because a marginal change of one hectare is quite large relative to the area typically cultivated.

The average distance (AVGDIST) to fields was significant here and had the expected positive effect, unlike what was seen in the adoption model. As distance increased, farmers were more likely to disadopt the technology, possibly due to destruction of soybeans by livestock they could not monitor. Since the majority of respondents in this model did cultivate soybeans in 2003, AVGDIST can be considered a more accurate measure than for the adoption model. Despite its significance, the marginal effect of this variable is small compared to other variables, at only 8%.

SOYPROB was expected to affect disadoption; however, while this variable had the expected positive effect on disadoption it was only significant at the 20% level. Reasons for the insignificance may have arisen from the measurement of this variable. As an open-ended question, most respondents would immediately answer that they had no problems in cultivating soybeans; yet upon further probing or a direct question about a specific problem, they were more likely to answer yes. Therefore, this survey question probably did not accurately measure all instances of soybean problems.

Category 5: Biophysical Characteristics

The one variable representing biophysical characteristics was the type of soil that the soybean crop was cultivated on. The two types of soil were broadly defined as clay and sand (where sand came to represent everything that was not clayey). SOILSOY was positively correlated with disadoption at the 5% level. Farmers that cultivated soybeans on clayey soil were 61% more likely to disadopt than those who cultivated on sandy soil. This was the largest positive marginal effect. Much of the soil in the area had large amounts of clay and rocks, and water permeability was limited, severely impacting soybean growth. Agronomic principles of soybeans were not covered in the extension education, and thus it was left up to the farmer to experiment where the new crop grew best. As clayey soils would be some of the worst lands the farmers owned, it would make sense that they would experiment with a new crop here. However, the disappointing results would lead to higher rates of disadoption.

Category 6: Farmer Perceptions

The one perception variable in the disadoption model measured whether respondents thought soybeans improved soil fertility. This variable was not significant in the disadoption model. Descriptive statistics for this perception shows that there was little variability in responses of disadopters and continued adopters on this variable; thus, the variable has limited explanatory power.

5.4.3 Interaction terms

To determine if any of the independent variables were only having an effect for one of the two communities, separate models were run for the Benin and Togo data sets. The disadoption model was estimated with exogenous and soybean variables for each community and then any variables that changed signs between the independent models and the full model (all the respondents) were recorded. Three variables (TOTFARM, PRXSOY, AVGDIST) were found to differ between the models. For each of these variables a Wald Test was carried out, two of these variables (PRXSOY and AVGDIST) were significant for this test, suggesting that the hypothesis that the effects of the variable on the two villages was equal was false. Therefore, interaction terms were created for these two variables. Results from the probit model with these interaction terms follow (Table 5.13).

Table 5.13: Probit regression of disadoption: interaction terms

Variable	Coefficient	P-value	Marginal Effect	P-value
Constant	4.759	0.023	0.890	0.049
FEDUC	-0.586	0.262	-0.110	0.237
MEDUC	-1.454	0.052	-0.272	0.044
BIKE	-1.126	0.042	-0.312	0.059
TOTFARM	-0.381	0.083	-0.712E-01	0.168
PRXSOY	-0.980	0.291	-0.183	0.82
PRXCOMM	-1.014	0.350	-0.189	0.333
Chi2 (Prob Chi2>value)	7.49 (0.006)			
AVGDIST	0.275	0.417	0.515E-01	0.396
DISTCOMM	0.436	0.373	0.816E-01	0.388
Chi2 (Prob Chi2>value)	3.10 (0.078)			
SOYPROB	0.607	0.277	0.121	0.297
EXTENT	-7.855	0.033	-1.469	0.045
SOILSOY	2.223	0.014	0.695	0.002
IMPSOIL	1.516	0.260	0.283	0.268
Log likelihood	**-22.18**			
Veall Zimmerman pseudo R^2	**0.64**			
% Correctly Predicted	**83**			
N	**69**			

Variables significant in the disadoption model presented in Section 5.4.2 are also significant in this model (with the exception of FEDUC which was only significant in its marginal effects). However, the two variables (PRXSOY and AVGDIST) that are also components of the interaction terms no longer have significant coefficients. These results can be interpreted as follows: the insignificance of the original variables PRXSOY and AVGDIST tell us that there is no impact of these variables on disadoption in Benin, the insignificance of the interaction terms PRXCOMM and DISTCOMM tell us that there is no significant difference in the term between Benin and Togo, and the significance of the Wald Test (Chi2 and Prob Chi2>value) tells us that the variable does have a significant impact on disadoption in Togo.

Therefore, we can conclude that two of the eight significant variables in the disadoption model were only significant for the respondents from the village in Togo. The expected price of soybeans and the average distance to fields had no significant effect on disadoption for the respondents in Benin. The continued significance of the other 5 variables demonstrates the robustness of these variables in explaining the disadoption decision.

5.5 Duration of Technology Adoption

In addition to estimating adoption and disadoption, the survey elicited information on the duration of adoption. A model was estimated to determine what affects the decision of how many years to cultivate the new technology. This allowed us to determine if the variables that affected the duration of adoption were the same or different than the variables that affected the initial adoption decision. The dependent variable for this model is the number of years a household cultivated soybeans, or NOYRSOY. The variable indicates the exact number of years a household grew the crop. The maximum number of years was 10, so this variable has a range of 0 to 10 years. The same 16 independent variables used in the adoption model in Section 5.2.1 are used to explain the duration of soybean adoption. For a review of the 16 independent variables, refer to Table 5.6.

This model can be calculated in two ways, through a combined model such as a Tobit or Poisson, or through a 2-step selection model, such as the Heckman selection model. All three of the above models were run to identify determinants of the duration of adoption. Results were similar for the three models, suggesting that robust determinants were found for the number of years the technology was adopted. Poisson and Heckman results can be found in Appendix V. The Heckman results show that the independent variables influence the probability of ever planting soybeans (adoption) and the number of years soybeans are planted (duration) in the same direction. Variable signs were consistent, suggesting that a Tobit was appropriate.

The Tobit model can be represented as NOYRSOY= f (FEDUC, NOMEN, COMM, TOTAGINC, BIKE, FAM, TOTFARM, PRXSOY, MRKT1, SOYEDU, MBR, HOSP, AVGHARV, AVGDIST, IMPSOIL, FTSOY). Results from the Tobit model on the number of years of adoption are presented in Table 5.14.

Table 5.14: Tobit model of duration of adoption

Variable	Coefficient	P-value
Constant	-2.505	0.142
Sigma	1.911	0.000
FEDUC	1.212	0.000
NOMEN	0.385	0.122
COMM	-4.612	0.000
TOTAGINC	-0.272	0.473
BIKE	-0.130	0.789
FAM	0.596	0.267
TOTFARM	0.415	0.021
PRXSOY	0.218	0.603
MRKT1	0.832	0.237
SOYEDU	0.465	0.328
MBR	0.511	0.287
HOSP	-0.554	0.235
AVGHARV	-0.140	0.748
AVGDIST	0.150	0.291
IMPSOIL	0.668	0.461
FTSOY	-0.385	0.562
Log likelihood function	**-170.59**	
N	**122**	

Many of the variables that had shown significance in the adoption model become insignificant in the Tobit model; these include soy education, health, average harvest, and average distance. However, three of the same variables remained significant in the duration model: male education level, community, and total number of farms. Only one new variable becomes significant in the Tobit model: the number of men. The number of men in the household was also significant in the Poisson and Heckman selection models (Appendix V).

This new variable, NOMEN, is a measure of labor for a household. While not impacting the initial adoption decision, it does become significant in explaining the duration of adoption or how many years a family will cultivate the new crop. The labor variable has a positive effect on the number of years a household cultivates soybeans, significant at the 12% level. Thus, a family with more labor is more likely to have a longer duration of adoption. While the new technology was not labor-demanding enough to exclude the adoption of soybeans by labor-scarce families, it does seem to become an issue over time as the household has to decide if it has enough labor to sustain adoption. For those families with less labor resources, labor soon becomes a constraint and consequentially, they cultivate the crop for fewer years.

CHAPTER 6: FINDINGS AND IMPLICATIONS

Findings are presented below in the context of the five research questions posed in Chapter 1. The two key questions are addressed first through findings from the empirical analyses for the adoption and disadoption models. While the significance of these variables has already been discussed in Chapter 5, variables are now considered in the context of the literature review and the 6 broad categories of adoption determinants. Descriptive statistics are referred to when necessary. The three secondary questions are addressed by drawing on survey responses and participant observations from the study area. Lastly, implications of the findings from this thesis on agricultural and development policy and technology adoption are discussed and additional research needs considered.

6.1 Key Research Questions

Question 1: What is the adoption rate of soybeans by households in the villages of Warengo, Togo and Koudogou, Benin and what factors are significantly correlated with the adoption decision?

The adoption rate of the soybean technology in the research area was determined to be 54.1%. A probit model was employed to estimate the effects of variables from the five categories of adoption determinants and a sixth category of farmer perceptions. Results from this binary choice model show that variables significant in explaining the adoption decision include community; male education from the category of household preferences; agricultural income, health, and total parcels farmed from the category of resource endowments;

membership, extension, and average distance from the category of risk and uncertainty; and past harvests (soil quality) from the category of biophysical characteristics.

We can therefore conclude that four of the five categories included in the Pattanayak *et al.* (2003) meta-analysis were important to adoption of this technology. Only variables from the category of economic incentives were not significant in this study. The sixth category added by the researcher also proved to be insignificant to the adoption decision for the soybean technology. For the four categories that were significant, there were large marginal effects from at least one variable, rendering it impossible to say that one category had more influence than the others. The dummy variable for community also had a large marginal effect on the adoption decision.

The COMM variable is not found in the literature. Inclusion of this variable in this study allows us to acknowledge the statistical correlation between living in Benin versus Togo and the respondent's likelihood of adoption. This variable had the largest negative marginal effect on adoption, but this variable, by itself, does not help future project designers identify constraints to adoption, and the significance of this finding will be considered further under Question 4.

The literature suggests that higher education levels should affect the adoption decision, in that education level influences a person's allocative and technical efficiency (Jamison and Lau 1982; Welch 1979). The ability of educated persons to process technical information is thus higher. This theory holds true for this study in that male education was the most influential positive variable on the decision to adopt. For this study, education level would be important not to grasp the technology of the new crop but to understand the importance of adopting the technology—soybean cultivation is not necessarily complex, but understanding the benefits of soybean cultivation is.

In the literature, the relationship between agricultural income and adoption was dependent upon the technology. We find in this study that farmers who earned income from farm sources, particularly cash crops, were less likely to adopt the new technology. The reason for this is that households relying predominately on agricultural sources of income would not want to take the risk of investing in an unknown agricultural technology, for fear of losing some of their income (Franzel 1999). Another constraint would be the significant household resources demanded by cash cropping, particularly of cotton, and the marginal returns of the crop.

Assets, such as land holdings, were found to have a positive influence on adoption in the Pattanayak *et al.* (2003) study. In this thesis, total parcels farmed, had a significant positive effect on adoption, presumably due to its proxy for land resources. Having more land resources would alleviate many of the constraints to adopting a new technology.

In the literature review, the impact of health on technology adoption was considered in the Ersado *et al.* (2004) study on the role of disease and sickness on lost labor and capital. The study concluded that labor lost from sickness was limiting technology adoption in areas where high labor constraints already existed. The variable measuring for health in this thesis was negatively correlated with the adoption decision and had one of the largest negative marginal effects, at 26%. Many farmers in the area complained of labor constraints and sickness in the family. Having sent an immediate family member to the hospital would have resulted in both high capital costs for the previous year (sometimes noted to be as high as $300USD/visit) and a strain on labor supply as multiple family members would have actually had to be at the hospital for long periods of time (family members are expected to provide meals for the sick person). Having visited a hospital could also be an indicator of overall poor health in the family.

Economic incentives were found to have a strong, positive influence on adoption in the literature. The lack of significance of economic variables in this model may have resulted from the lack of economic profitability of the soybean technology—little to no commerce of soybean seed or products was occurring in the research area. There may also have been greater error or 'noise' in these economic variables for the adoption model, since many of the respondents would have had no exposure to market prices of soybeans. Thus, measurements used in this thesis may not have sufficiently captured economic incentives associated with the technology.

Extension was shown in the literature review to have a positive influence on adoption (Baidu-Forson 1999; Feder and Slade 1984; Jamison and Moock 1984; Rahm and Huffman 1984; Jamison and Lau 1982) and was correlated with adoption 90% of the time in the Pattanayak *et al.* (2003) study. Access to information about a technology reduces uncertainty. Even more important is hands-on training in how to cultivate and use a new technology.

Extension had a significant positive correlation with the adoption of soybeans in this study. Access to training on how to use soybeans in food preparation, on how to cultivate soybeans, and access to soybean grain was mostly limited to extension agents in this region.

As expected from the literature review, membership in an organization had a positive correlation with the adoption decision. Membership is associated with access to technological information, inputs, and extension (Caviglia and Khan 2001; Neupane *et al.* 2002). In this study, many of the organizations people were involved in were women's groups, agricultural cooperatives, and health and school-related groups. All of these groups would attract more involved and active citizens, as well as provide an outlet for discussion on farm, health, and community issues.

The average distance to fields was not included in the literature review but was added to this study due to the high level of incidences with livestock destruction, particularly of soybean fields. However, the sign of this variable was not as expected. This is most likely due to undetected correlation with another variable in the model. This variable also did a poor job of determining risk associated with livestock and soybean fields, as many of the respondents did not grow soybeans the previous year. The low marginal effect of this variable limits its impact on the adoption decision.

The variable measuring for soil quality in effect measured for the performance of the previous years' harvest. In the literature this variable was highly correlated with adoption, however the sign of the correlation varied (Pattanayak *et al.* 2003). In this study, soil quality had a negative correlation with the adoption decision, or farmers with poorer soil quality were 21% less likely to adopt than farmers with average soil quality. Instead of the usual conclusion that fields are too depleted or risky to invest in the new technology, the fact that most adopters were not aware of the soil improvement benefits of soybeans implies that poor soil quality merely increased the risk involved in cultivating a new crop.

Despite arguments in the literature on the importance of farmer perceptions in determining adoption, none of the perception variables in this study were significant in the empirical model. While these variables do not help explain constraints to the adoption decision in this study, they can still help us interpret the utility farmers perceived they derived from soybeans and some interesting user characteristics, discussed under Question 3.

Question 2: What is the disadoption rate of soybeans by households in the villages of Warengo, Togo and Koudogou, Benin and what factors are significantly correlated with the disadoption decision?

For the 73 respondents that had adopted the soybean technology, 21 (28.8%) of these had disadopted. Eight variables were found to be significant to the disadoption decision in the empirical model. These variables were male and female education level under the category of household preferences; asset ownership and total parcels farmed under resource endowments; the price beliefs of soy under economic incentives; extent and average distance to fields under risk and uncertainty; and soil type under biophysical characteristics. In addition to the probit disadoption model, a Tobit on the duration of soybean cultivation revealed another significant variable that impacts how many years a farmer can adopt the technology—the labor variable.

All 5 of the categories given in Pattanayak *et al.* (2003) are significant in the disadoption decision. The sixth category of farmer preferences is insignificant. Again it is difficult to say that one category exudes greater power than another. We do, however, find that some individual variables have a very large marginal effect. The variable with the largest marginal probability to positively impact disadoption is whether the crop was grown on clayey or sandy soils. Distance to fields also had a positive impact on disadoption. The variable with the largest probability to negatively impact disadoption is the amount of hectares the adopter had previously cultivated soybeans on. However, the magnitude of this impact is a result of the scale used to measure this variable—it reflects an eight-fold increase in area of soy farmed for the average household. The education levels of both male and female heads of household, owning a bicycle, total number of parcels farmed, and the expected price of soybeans also negatively affected the disadoption decision in this model.

In the disadoption literature, Barrett and Moser (2002) find education to be significant in the adoption and disadoption of improved rice cultivation. Similarly, education remains significant in this model, being negatively correlated with disadoption for both male and female heads of household. Education is thus both important to the initial adoption of the technology and the continued cultivation. The education level of the female is significant here, but only male education was significant in the adoption model. This is because the technology of soybeans differs from many technologies in that it is the responsibility of the women to cultivate non-cereal crops, to prepare food items, and to monitor child nutrition. Thus, after the male decides to trial the new crop, women would be the ones making the decision as to the appropriateness of the technology to their household. Women who found the technology to be useful or who could better understand the connection between growing soybeans and providing a better diet for their children, would be less likely to disadopt.

The area of soy farmed has the largest marginal probability on disadoption, for every increase in the number of hectares cultivated, the decision to disadopt decreased by 154%. The magnitude of this variable, however, cannot be directly compared to other variables due to the fact that it measures an increase of eight times the amount of soybeans cultivated by a typical farm household. This increase is unrealistic, and consequentially, a one-fold increase in cultivated area would have a much smaller marginal effect on disadoption. The effect of this factor can be interpreted as follows: having a larger area planted with the new technology instills confidence with the technology and potentially measures for more experience growing the crop. In the literature review it was discussed that trialing a crop leads to adoption (Abadi Ghadim and Pannell 1999). As a farmer becomes more comfortable with a technology they employ it more and more and are less likely to disadopt. Barrett and Moser (2002) also find that experience with the new crop system is positively correlated to continued adoption.

The variable measuring for type of soil displays a positive effect on disadoption and had the largest positive marginal effect. Thus, farmers that cultivated their soybeans in clayey soil were more likely to disadopt the crop than those who grew it on sandier soils. Not knowing the proper agronomic principals of the crop led to disadoption. A study by Neill and Lee (2001) in the literature review also concluded that a lack of knowledge of the systems dynamics in a new cropping system contributed to the eventual disadoption of the introduced crop in their study.

Labor was not included in the disadoption model but was included in a Tobit model on the duration of adoption. In this model the labor variable, NOMEN, did become significant at the 5% level. This suggests that while labor was not restricting to initial adoption, labor later became a component of constraint for this technology. Households who did not have adequate labor resources could not afford to cultivate the crop for as many years as those households with more labor resources. Barrett and Moser (2002) also find labor to be a significant factor in their disadoption study.

There is no literature connecting resource assets of bicycles, land resources, distance to fields, or expected price of the technology to disadoption and an interpretation of why these variables were significant for this study was discussed in Section 5.4.2.

Additional determinants of disadoption

Three additional factors identified in the survey instrument and through participant observation are hypothesized to have been affecting the disadoption decision in the research area. However, there were no measures of these variables that could be included in the empirical analysis for disadoption and measures come from respondent’s stated reasons for disadopting. The three additional variables—health, labor constraints, and access to inputs (reported in Section 5.4.1)—reiterate findings from the empirical analyses of adoption and duration.

In the survey, family and health problems were the number one reason stated for disadopting soybeans at 38%. During the survey, many respondents reported that women had been too sick to take on the additional labor of cultivating this new crop. Labor was also cited as a constraint for 19% of the respondents. This factor was observed in the study area and women often complained that they did not have enough time to invest in this new technology. Lastly, seed quality and access to grain were constant problems observed by the researcher. Almost 24% of disadopters cited access to grain as having led to abandonment.

Results from other parts of this study support respondent statements that these variables were affecting disadoption, possibly just as much or more than variables found to be statistically significant in the probit model. Sickness or health was statistically significant in the adoption decision, and thus the continued effect of this variable on disadoption is intuitive. Sickness contributes to labor constraints, which were also cited as a reason for abandonment. Labor became a significant variable when estimating the duration of adoption; more labor resulted in being able to cultivate the crop for longer. Total parcels farmed can also be considered a proxy for labor resources; the negative effect of this variable on disadoption supports the stated response that labor constraints contributed to disadoption. Finally, procuring inputs, seed, is essential for any agricultural technology to succeed. While there is no empirical research to support this, stated responses from other sections of the survey instrument, as well as direct observation, support the theory that a lack of access to inputs led to disadoption.

6.2 Subsidiary Research Questions

Question 3: What are the perceptions of farmers towards soybean utility and farming in the region?

Understanding farmer perceptions toward soybeans in the region helps extension agents to understand the perceived benefits and knowledge about the technology. This category was not significant to either the adoption or disadoption models, probably because it is correlated with the category of household preferences. Despite this insignificance, these perceptions provide insight into how farmers view the new technology and can help shape future extension efforts. In general, both adopters and non-adopters perceived soybeans to be a health benefit, to be marketable, and to need fertilizer to grow. Adopters were more likely to perceive the environmental benefits of soybeans and to find them easy to prepare.

To answer this question we can look at the descriptive statistics presented for adopters and non-adopters in Section 5.1. More than 90% of respondents perceived the health benefits of the new technology. The high percentages of both adopters and non-adopters perceiving the health benefits of soybeans suggests that promotion of the health benefits of the new technology had been successful in the two villages.

It was hypothesized that households would not perceive the soil-improving benefits of soybeans, as there is little promotion of soybeans for this reason. Of the 60% of respondents who did perceive this benefit, 77% were adopters of the technology and 47% were non-adopters. The fact that adopters were more likely to perceive the environmental benefits indicate that either some soil-improvement was being observed in their cultivation systems or that they had been exposed to more education on soy.

There were also differences between adopters and non-adopters on perceptions of the ease of use of soybeans. Adopters of soybeans felt that preparation of soy foods was not difficult (77%) but non-adopters were split on whether they felt preparation was easy or not (58% thought it was easy). This distinction probably arose due to adopters increased experience and knowledge in preparing soybean products.

Despite the hypothesis that respondents would not perceive soybeans as marketable, more than 90% of adopters and non-adopters perceived this benefit. This was surprising since little commerce of soybeans was occurring in the markets. However, the fact that nothing is limited from being sold in the markets would possibly make respondents agree that soybeans too can be sold there. If the question had been more specific in terms of profits or current markets for soybeans, the answer may have been different.

A high percentage of both adopters and non-adopters felt some type of fertilizer was needed for effective soybean cultivation. The perceived necessity to add fertilizer to soybeans in order to entail a good harvest is one that farmers have come to on their own, as little to no agronomic training on soybeans was provided in extension programs in the area.

In conclusion, from information gathered on farmer perceptions, it can be assumed that health benefits are well known for soybeans but environmental benefits need to be more widely promoted by extension agents. Preparation of food products also needs to be further addressed by extension agents as many non-adopters felt it was difficult to process soybeans. Further training and education on soybean processing could mitigate this perception and increase adoption. In terms of marketability, respondents perceive that soybeans can be sold in local markets, and extension agents should capitalize on this belief and try to develop markets for soybean products. Finally, researchers should further investigate the perceived need for fertilizers. If this is merely a misconception then it needs to be distilled, as it is likely to affect adoption. However, if soybeans are not growing well without fertilizer, improved seed varieties need to be introduced to address this problem.

Question 4: How do the adoption rates and the variables that affect those adoption rates compare between two villages of similar ethnicity, livelihoods, and extension history but different geopolitical characteristics?

This question can be answered by referring to the descriptive statistics calculated in Section 4.4 and results from the empirical models. We find that adoption rates of all new technologies (soybeans, mosquito nets, improved cook stoves, tree plantings) were higher for the village of Koudogou, Benin. The importance of the respondent's village is also demonstrated in the empirical model for adoption. In this model, the COMM variable displays the largest effect on the adoption decision, having a negative marginal effect of 67%. Thus, respondents residing in Togo have a 67% less chance of adopting the soybean technology. The COMM variable is not included in the disadopt model in this thesis, but was insignificant in explaining disadoption in earlier models. COMM is significant however in the Tobit model of duration, having a negative effect on the number of years a household implements the technology. Again, showing a negative relationship between living in Togo and the technology.

To explain this difference in adoption rates, separate models were run for Togo and Benin to determine if there were different variables leading to these rates of adoption. Results from the adoption model were inconclusive in that lack of variation in the Benin data set did not allow this model to be run. However, the same variables influenced the adoption decision in the same direction for the Togo data set as in the combined adoption model. Whether some of these variables had different effects in Benin is unknown. In the disadoption model, separate models were run for each community. Results showed that 5 variables explained the disadoption decision in both communities. Two additional variables contributed to the disadoption decision in Togo but not Benin, these were the variables of price beliefs of soybeans and average distance to fields.

Overall, the variables affecting the decision to adopt or disadopt are found to be relatively similar between the two villages. However, the difference in adoption rates is still high for all technologies. One qualitative explanation for this is the level of exposure each village had to the introduced technology. Before research on this thesis began, exposure and extension efforts in the two villages were thought to be similar; however, this was found not to be the case for many of the technologies.

There are many things to learn from trying to answer this question. The first is that adoption rates are higher in the village of Benin, where extension has been occurring longer and in a more concentrated way. Analytically this says a lot about the effects of extension on adoption and the temporal aspect of adoption. In a climate of similar ethnicity, livelihoods, and resource constraints, having a more focused extension effort with the resources to implement that extension led to higher adoption rates for many of these technologies (most notably improved cook stoves and tree plantings). Having been exposed to the technology for a longer time period also resulted in higher rates of adoption (most notably for soybeans).

The adoption of improved cook stoves for Koudogou (74% versus 20% for Togo) was being effected by the presence of an NGO working in the village, primarily on cook-stove adoption. This NGO formed committees in the village that would go to every house requesting a cook stove and build it for them. This NGO was also subsidizing tree planting in the village, making the overall cost of buying a tree seedling less than one US cent. As for soybeans, extension history started earlier in Benin (early 80's) versus the more recent history of extension in Togo (mid 90's).

Yet, while many of these differences can be explained away by more directed or longer extension efforts in the area, this does not explain the higher rates of adoption of mosquito nets, where presumably no extension has occurred or even to some extent soybeans, where no direct extension occurred in Koudogou. Extension efforts on soybeans were established earlier in Benin, but nothing directly in the study village. The only possible explanation is that due to the high mobility of these people and the access to Boukoumbe (4km) where extension efforts were concentrated, some farmers were exposed to the technology and farmer-to-farmer diffusion led to the widespread adoption of the technology. Hypothetically, in 10 more years, similar results would be seen for soybean adoption rates in the village of Warengo, Togo. As for mosquito nets, extension cannot account for adoption. The only hypothesized reason for adoption differences is the access to the technology. Mosquito nets were not available in Warengo, Togo but in a town 9km from Warengo. Mosquito nets were available in Koudogou. Thus having convenient access to the technology inputs could have affected adoption rates.

A last observation is that the adoption of planting trees around the house was remarkably high in both villages despite subsidized tree costs in Benin. Of course, there was also extension in Togo on tree plantings, but these were not subsidized or as widely spread. One difference in the tree planting technology is that it is not new or introduced; people have been planting trees in these communities for centuries. Thus, one can hypothesize that a larger proportion of the population will adopt a technology that has well-established value. Trees planted around the house provide multiple benefits that are recognized throughout the area: shade, food, and fuel, just to name a few. Of course, having people plant more trees, getting people to plant certain tree species, or having people plant trees in their fields would take more extension effort and resources.

Results from the statistical analysis lead one to conclude that adoption rates do differ between the two villages. A look at the empirical models does not result in any significant differences in variables that explain these decisions between villages, suggesting that similar constraints were affecting each village. A thorough analysis of the qualitative findings suggests that a lot of these differences arise from extension—in both length and effort. The political situation in each of these countries directly contributes to the extension opportunities. As described in Chapter 2, extension opportunities are much more developed in Benin. If similar opportunities were to occur in Togo, it should not be unexpected that high rates of adoption for these technologies would occur there as well.

Question 5: Do the categories used to assess the adoption of new agricultural technologies fit when the given technology has been promoted almost exclusively for its nutritional benefits or are different variables affecting adoption?

Considering only the 5 broad categories identified in Pattanayak *et al.* (200), we find that 4 of the 5 are consistently important to both the adoption and disadoption decisions for this technology. These 4 categories included household preferences, resource endowments, risk and uncertainty, and biophysical factors. All 4 of these categories had interesting and robust variables, signs and effects of these variables were as expected, the probit models fit the data reasonably well, and significant variables can be supported by the literature on technology adoption.

The category that did not show significance in this study was economic incentives. While this category shows significance for many of the studies considered in the meta-analysis, the primary difference in this study is the use of the technology for home consumption. The economic, or market, importance of soybeans is therefore not a significant factor in the decision to adopt. We do find that the variable of price beliefs becomes significant in the disadoption decision, probably because it is measuring more for familiarity with the soybean technology than profitability.

In summary, soybeans are an agricultural technology and the 5 categories used in the theoretical model apply to the various factors that would constrain adoption of this technology. The 5 categories are general enough to be applicable to all farm technologies, despite their intended benefits. As a technology having been promoted for nutritional benefits, one might assume that some measure of nutritional impact would be necessary. While this knowledge would definitely be beneficial, it is not the objective of adoption studies to determine the impact of the technology.

6.3 Implications of Findings

The implications of findings from the empirical models are applicable not only on the local scale but can be generalized to most agricultural extension programs in West Africa. Reasons for this are that findings are not a result of the agro-ecological or socio-cultural characteristics of the study area but result from the social realities, agricultural policies, and extension and training efforts occurring in the area, many of which are regional. Findings reiterate not only what has been seen in many previous adoption studies (the effects of education, extension, and experience on adoption) but also draw attention to the significance of some lesser-known variables (cash cropping and health). Significant determinants of adoption and disadoption can be broadly categorized into those that need to be addressed on a large (national or international) scale and those that need to be addressed on a small (regional) scale.

On a large scale, issues of education, health, and the dependence on unsustainable agricultural practices are influencing the adoption and disadoption rates of agricultural technologies. The irony is that many of these same technologies are being implemented to improve the health and sustainable agricultural practices in these areas. There is therefore a difficult and complex interconnectedness of health, education, and agriculture that must be addressed at a national or even international level if changes are to occur. In addition to the need for stronger emphasis at the national and international level, extension agents should strive to design programs that specifically target groups that are constrained by lower education and poorer health.

In this study, education is a significant factor in both the adoption and disadoption decision. The positive effects of education have been established in the literature. For health or environmental technologies, being able to make the connection between the need for improved health or improved soil fertility would be a first step in deciding whether to adopt a technology or not. People must understand the needs of their bodies (for protein) or the needs of the soil (for nitrogen) and then be able to understand how a plant can provide these needs. For an uneducated person, making these connections is not entirely logical.

Education has been found to play a role in nutrition, food security, income, and sustainable agricultural practices in developing countries. It is thus logical to understand how education would also affect the adoption of soybeans and other new technologies. Implications of this are that a stronger emphasis on improving education for both men and women must be in place in these countries. National and international efforts to improve education levels will provide the impetus for continued development. On a smaller scale, extension programs must better target this gap of not reaching less educated people. Different teaching methods and materials need to be developed that can engage the skills of less educated people.

Having visited a hospital had a negative effect on the adoption of this technology and poor health was a stated reason for disadoption. In the literature review, incidence of sickness was shown to have negative impacts on the adoption of technologies due to the loss of labor and capital resources. The loss of these resources can be detrimental to an already marginal household. In effect, these families can no longer commit the resources needed to invest in a new technology and are putting themselves at a greater risk if they do take their marginal resources and invest in the unknown technology. Incidence of sickness can also pinpoint a larger underlying problem of unhealthiness in a family.

Improving health in developing countries is a prime national and international agenda. However, reaching the most needy can become complicated by the fact that these are the same people who are too sick to be able to help themselves. Health policies must factor in this cycle and provide stronger and more comprehensive programs targeting the sick.

Extension programs must also be aware of the impact of sickness on adoption of technologies and make stronger efforts to address this constraint in the adoption process.

A third factor affecting adoption of agricultural technologies on a large scale is the reliance on unsustainable agricultural practices, most notably cash cropping. Cash cropping, especially of cotton in West Africa, has revolutionized farming. Farmers invest large amounts of their land and labor resources into the production of a crop that will provide them with some monetary benefit, however marginal. Not only are these agricultural systems degrading the environmental and human health[6] of these areas but they are also preventing the adoption of more sustainable forms of agriculture, in that farmers are less likely to take their land out of cash crop production for fear of losing some of their income and the fact that cash cropping demands most of their land and labor resources. This is a conflicting interest between the needs of men and women household members. While women may desire to cultivate soybeans, males ultimately determine access to land and labor.

Despite the spread of commercial agriculture, for many small-scale farmers, investing in these systems leaves them in a more vulnerable state than farmers that do not make these investments. Investing in cash crops may lead to more material possessions, and arguably more wealth, but it rarely has positive effects on nutrition, food security, long-term capital, or the willingness to invest in more sustainable technologies. While restrictions on growing cash crops cannot be enforced, the negative consequences of cash cropping need to be reflected in national policies (and probably international policies as well). Technologies that

[6] A study by Huss-Ashmore and Curry (1994) on the effects of cash cropping on nutrition found a noticeable trend in the negative effects of reliance on cash crops, especially cotton, on food consumption and nutritional status in rural Swaziland.

are more beneficial to the health of the people or the environment, and thus lead to a more sustainable development of these regions, need to be able to compete with cash crops such as cotton.

While the above factors should be addressed predominately on a large scale, national or even international, there are several factors impacting the adoption of agricultural technologies on a more local scale. Most notably is the problem of mitigating risk and uncertainty about a new technology. In this study, variables that had the most impact on adoption and disadoption decisions were those associated with extension efforts, experience with the technology, agronomic knowledge, and membership in organizations. Other important variables on the local level were labor and land resources, soil quality and type, and expected price of the technology.

The effects of extension and training on adoption have been established in the literature. Findings from this thesis also conclude that extension education positively affects the adoption decision and experience or trialing of the technology prevents disadoption. For a new technology to be successful extension efforts and training/trialing of the technology need to be in place, and the needed inputs must be procured. On the ground, extension agents can address issues of risk and uncertainty through education and information about a new technology and through providing hands-on trialing of the technology. In addition to the effects of extension in the empirical models, the effects of extension are further seen in this thesis through the comparison of the two study villages, where higher rates of adoption in Benin can largely be explained by either longer or more effective forms of extension and training. This does not underscore the diffusion of technologies by farmers; they too can presume this role of “extension” agent if they are thoroughly knowledgeable and skilled in the technology themselves.

In addition to extension education on the utility of a technology, an important factor in agricultural technologies is the need to disperse agronomic information. A lack of agronomic information was a significant factor in the disadoption of the technology in this thesis, as those farmers experimenting in clayey soils soon disadopted the technology. In cultivating a new crop, farmers should be considered unskilled as to the agronomic conditions that are most suitable for that crop. Soil type, time of planting, and maintenance of the crop will all be important factors in ensuring a good harvest. Not understanding these agronomic principles can make the adoption of the technology seem risky for many farmers; and for those that do adopt, not having a good harvest the first time around leads to uncertainty about the technology and contributes to disadoption. In any new agricultural or agroforestry technology, training in agronomic principles is just as important as understanding the utility of a technology and how to use the technology, because if farmers cannot be successful at implementing the new technology they will not adopt or will eventually disadopt.

In addition to agronomic principles, extension agents need to ensure that high quality inputs are procured for the new technology. Access to seed and good seed quality was shown to affect adoption in the literature and affected disadoption in this study. Despite a lack of empirical results on access to seed, observations in the study area and stated responses confirmed the inaccessibility of seed and overall low seed quality for the soybean technology. Providing inadequate inputs for a technology leads to higher rates of uncertainty for the technology and in many cases, abandonment.

Another regional implication from this study is the effectiveness of community groups in building local capacity and contributing to the adoption of new technologies. Groups, whether in the developing world or developed world, are a device for discussions, education, and training. Participation in a community group provides a farmer with unique skills and opportunities he or she may never learn elsewhere, it also provides a means for access to new information. Skill and capacity building are essential to community development. Knowing this, extension agents should not only target their projects to currently established community groups but can aide in this capacity building by establishing new agricultural groups or by teaching capacity building skills in their trainings.

Local factors of labor and land resources, soil quality, and expected price can all be considered constraints to the adoption decision. Labor in this study affects the number of years the technology is implemented and is a stated reason for disadoption. Having more access to land resources (number of parcels farmed) positively contributes to the ability to adopt this technology and negatively effects the disadoption decision. In terms of extension programs, farmers with more labor and land resources will be more likely to adopt this technology and continue adopting. Designing technologies that can be implemented by households with labor and land constraints, notably correlated with poorer households, is a continued need of extension programs.

Soil quality, as measured through past harvests, has an ambiguous effect in this study. Farmers with better past harvests were more likely to adopt, and of those adopters, farmers with better past harvests were more likely to abandon the technology. Therefore, the effects of past harvests/soil quality for extension are difficult to determine, and it can be assumed that more promotion on the benefits of the technology for soil improvement might reverse the ambiguous effects seen here. Lastly, the expected price of soybeans provided an incentive not to disadopt, but had no significant effect on the adoption decision, and thus its overall effects are unclear. However, taken with results from farmer's perceptions on marketability, it is credible to believe that better-established soybean markets would significantly influence soybean adoption, considering the fact that people already view it as a marketable commodity.

In conclusion, results from this study emphasize the importance of both national factors on adoption, such as education, health, and cash cropping, and also the importance of local factors on technology adoption, such as extension, training, and membership. These results can be used to design better soybean extension programs in the study area and in other areas and to make recommendations for policies that will lead to higher rates of adoption for agricultural technologies.

On a large scale, policy workers should strive to make education and health goals a reality in developing countries. These two components limit many aspects of development, including the ability to adopt new technologies that are aimed at bringing improvements to rural livelihoods. On the ground, extension programs should strive to do a better job at reaching these marginal populations, as they are the ones in most need of the technology but least able to adopt. Agricultural policies in less-developed countries need to reassess the effects that cash crops are having on their social and environmental communities and design policies that encourage more sustainable development of human and environmental systems. New technologies that are not marketable cannot compete with commodities like cotton; national incentives should be in place to promote the adoption of important health and environmental technologies. One possible way to do this would be through the establishment of national markets.

Regionally, rigorous extension and training is needed to disseminate a technology successfully. This extension must be holistic, providing information not only about the utility of a technology, or providing inputs for a technology, but also teaching and demonstrating the more technical aspects of how to use the technology. A clear focus should be put on the agronomic principles when introducing a new agricultural technology. Emphasizing extension and training efforts, specifically in regards to agronomic principles of the technology, will mitigate risk and uncertainty about the technology. Membership in community organizations should also be capitalized on when designing extension programs. While targeting these groups can lead to better rates of adoption, the importance of capacity building in community development should not go unnoticed and should be reciprocated whenever possible by extension programs. Labor resources also play a role in the number of years a household adopts the technology, this constraint, as well as constraints in land resources and marketability are all important factors to consider in designing a local extension program.

6.4 Additional Research Needs

As a result of the research done for this thesis, three research needs were determined: the need to better understand the nutritional impact of the soybean technology in the region; the need to better understand the agronomic principles, biophysical characteristics, and economic incentives of soybeans; and the need to better understand the role of health and cash cropping on technology adoption.

6.4.1 Understanding the nutritional impact of soybeans

One of the primary reasons soybeans are being promoted in West Africa is to provide better nutrition, especially to children and women. This study did not explore the nutritional impacts of adopting soybeans, as it was focused on the determinants of adoption. However, in order to determine if the technology is appropriate, studies need to assess the impact that soybeans are in actuality having on nutrition in the region. This study provides some preliminary looks at the nutrition status of adopters and non-adopters (Table 6.1). While these results are not rigorous, they do suggest that households interested in better nutrition (as measured by vitamin servings) are more likely to adopt soybeans and that adoption of soybeans increases protein in the diet (as measured by number of protein servings). Protein intake was aggregated from the number of servings of meat/fish, groundnuts, cowpeas, nere seeds, and soybeans respondents said they consumed per week. Vitamin intake was aggregated from the number of servings of baobab seeds, okra, and leafy vegetables respondents said they consumed per week.

Table 6.1: Weekly nutritional intake

Food	Adopters (n=73)	Non-adopters (n=62)
Protein servings	21	12.5
Vitamin servings	15	12

A study in the Benue state of Nigeria claims that yes, soybean-producing families do have higher rates of child nutrition (Sanginga *et al.* 1999). Yet, it was also shown in that report and in this study that the main use of soybeans is in making *dawadawa* and the practice of making porridge or other soy foods has not been significantly adopted in these areas. A study in Mexico concluded that the nutrition of a community was determined not only by the nature of the agricultural intervention but by the farmer's access to basic productive resources, such as good land, wage labor opportunities, ecological conditions, and agricultural policy (DeWalt *et al.* 1990). In light of this, it would be useful to further investigate the actual impacts that soybeans themselves have on health in these areas.

6.4.2 Understanding the agronomic principles, biophysical characteristics, and economic incentives of soybeans

In addition to research on nutritional impacts, further development of agronomic principles needs to take place for soybeans. While the IITA carries out research on this crop, this information has not been disseminated to extension agents in West Africa. Agronomic knowledge was found to be significantly affecting disadoption of soybeans in this study. Access to good seed was determined to be a problem, and closer collaboration with research organizations such as IITA could address this. Questions regarding the impact of limiting nutrients and rhizobium inoculation on soybean growth should also be further investigated in the study region. The improved seed varieties being developed by IITA might help address some of these questions.

For an agricultural technology, one would assume that biophysical factors would have played a more significant role. However, many of the variables measured in this survey could not be observed because interviewing took place in the dry season. Therefore, the variables of soil quality, plot size and slope were not as rigorous as would have been hoped. More technical information should be gathered on the biophysical constraints to adopting soybeans in this region, ultimately contributing to the agronomic knowledge needed for the region.

Ambiguous and highly insignificant variables were discovered form the economic variables measured in this study. While market access has been described as a constraint in the region, farmer's perceived soybeans to be marketable. This was shown in the large marginal effect that expected price of soybeans had on the disadoption decision. Further research on the economic incentives and constraints to soybean adoption would be useful, especially studies that consider the by-products of this technology, such as selling soybean foods in local markets. In the literature, Ayuk (1997), Baidu-Forson (1997, 1994) and Franzel (1999) show the importance of by-products in technology adoption. The by-products derived from cultivating soybeans, such as *dawadawa* and western-style foods, were important for home consumption and for market commerce (tofu was becoming a popular food item sold in the local market). These food-based by-products may be a better indicator of economic incentives to adopting soybeans.

6.4.3 Understanding the role of health and cash cropping on technology adoption

In the technology adoption literature, there was not a lot of information on the role of health or cash cropping in adoption decisions; instead only a few studies even considered the effects of these variables. Results from this study showed a significant and large negative impact of health on technology adoption. Health or sickness was also the most stated reason for disadoption in the study. Given these findings, and similar findings in the literature, there is a need to further study and develop the role that health/sickness has on technology adoption.

Cash cropping or agricultural income was found to have a negative impact on adoption in this study. Many subsistence farmers are investing heavily into cash cropping as an economic livelihood in this region and international and national policies support this practice. As mentioned above, income from cash crops is not likely to result in improved nutrition for women and children. Cultivation, and home consumption, of a technology such as soybeans would have a more direct and significant effect on health. Few studies were found that critically looked at the effects of cash cropping on technology adoption. If these practices are in fact negatively impacting the adoption of more sustainable and arguably suitable technologies, then the implication of this needs to be explored.

REFERENCES

Abadi Ghadim, A.K. (2000). Risk, Uncertainty and Learning in Farmer Adoption of a Crop Innovation, Unpublished Ph.D. Thesis, Faculty of Agriculture, University of Western Australia, Nedlands, Western Australia.

Abadi Ghadim, A.K. and D.J. Pannell. (1999). A conceptual framework of adoption of an agricultural innovation. *Agricultural Economics* 21: 145-154.

Adesina, A.A. and J. Baidu-Forson. 1995. Farmer's perceptions and adoption of new agricultural technology: evidence from analysis in Burkina Faso and Guinea, West Africa. *Agricultural Economics* 13: 1-9.

Adesina, A.A. and M.M. Zinnah. 1993. Technology characteristics, farmer's perceptions and adoption decisions: A Tobit model application in Sierra Leone. *Agricultural Economics* 9: 297-311.

AFVP (Association Français Volontaires du Progress). 1998. Plan Rapport Activités. Lome, Togo.

Ahmed, M.M., P.V. Preckel, T.G. Baker, and M. Lopez-Pereira. 2001. Modeling the impact of technological change on nutrition and marketed surplus. *Agricultural Economics* 25: 103-118.

ARPT. 1991. Report of an Informal Survey on Degraded Lands in Eastern Province, Zambia. Department of Agriculture, Adaptive Research Planning Team, Chipata, Zambia.

Ayuk, E.T. 1997. Adoption of Agroforestry Technology: The Case of Live Hedges in the Central Plateau of Burkina Faso. *Agricultural Systems* 54: 189-206.

Babbie, E. 1990. *Survey Research Methods, Second Edition*. Wadsworth Publishing Company, California.

Baidu-Forson, J. 1994. Adoption of soil and water conservation practices in the Sudano-Sahelian Zone: constraints and incentives. In: Napier, T.L., Camboni, S.M., El-Swaify, S.A. (Eds.), Adopting Conservation on the Farm: an International Perspective on the Socioeconomics of Soil and Water Conservation, 13. Soil and Water Conservation Society (U.S.), Ankeny, IA, pp. 157-169.

Baidu-Forson, J. 1999. Factors influencing adoption of land-enhancing technology in the Sahel: lessons from a case study in Niger. *Agricultural Economics* 20: 231-239.

Baron-Sandmo, A. 1971. On the Theory of the Competitive Firm under Price Uncertainty. A*merican Economic Review* 61: 65-73.

Bhalla, S.S. 1979. Farm and Technical Change in Indian Agriculture, In Agrarian Structure and Productivity in Developing Countries, Berry, R. and W. Cline (Eds.). Baltimore: Johns Hopkins University Press.

Biggs, S.D. 1990. A multiple source of innovation model of agricultural research and technology promotion. *World Development* 18: 1481-1499.

Birkhaeuser, D., R.E. Evenson, and G. Feder. 1991. The economic impact of agricultural extension: a review. *Economic Development and Cultural Change* 40: 607-650.

Bloem, A.A. 2001. Effect of Annual Legumes on Soil Nitrogen and on the Subsequent Yield of Maize and Grain Sorghum. *South Africa Journal of Plant and Soil* 2: 56-61.

Bonnard, P. and S. Scherr. 1994. Within gender differences in tree management: is gender distinction a reliable concept? *Agroforestry Systems* 25: 71-93.

Brabant, P., S. Darracq, K. Egue, and V. Simmonneaux. 1996. Togo Human-Induced Land Degradation Status, ORSTROM Institute Française de Recherche pour le Development en Coopération, Collection Notice Explicative No.112, Paris.

Capps, O., Jr. and R.A. Kramer. 1985. Analysis of food stamp participation using qualitative choice models. *American Journal of Agricultural Economics* 67: 49-59.

Caviglia, J.L. and J.R. Kahn. 2001. Diffusion of Sustainable Agriculture in the Brazilian Tropical Rain Forest: A Discrete Choice Analysis. *Economic Development and Cultural Change* 49 (2).

Caviglia-Harris, J.L. 2003. Sustainable Agricultural Practices in Rondônia, Brazil: Do Local Farmer Organizations Impact Adoption Rates? *Economic Development and Cultural Change* 52 (1): 23-50.

Cotlear, D. 1986. Farmer education and farm efficiency in Peru: The role of schooling, extension services and migration. World Bank Discussion Paper, Education and Training Series, Report no.49, The World Bank, Washington, D.C.

Crowley, E.L., M.J. Soule, and S.E. Carter. 1996. Off-farm Income and Farming in Western Kenya. Consultancy Report to USAID/Kenya, Nairobi, Kenya.

Critchley, W.R.S., C.P. Reij, and S.D. Turner. 1992. Soil and water conservation in sub-Saharan Africa: towards sustainable production by the rural poor. A report prepared for the International Fund for Agricultural Development by the Centre for Development Cooperation Services, Free University, Amsterdam.

Dashiell, K. 1998. Selling Soybeans in Africa. International Development Research Centre (IDRC). Nayudamma Information Bank. Viewed at: http://www.idrc.ca/nayudamma/soybean_2ehtml.

David, S. 1995. What do farmers think? Farmer evaluations of hedgerow intercropping under semi-arid conditions. *Agroforestry Systems* 32: 15-28.

Degrande, A. and B. Duguma. 2000. Adoption Potential of Rotational Hedgerow Intercropping in the Humid Lowlands of Cameroon. Agricultural Research and Extension Network 103.

DeWalt, K.M., B.R. DeWalt, J.C. Escudero, and D. Barkin. 1990. Shifts from maize to sorghum production: Nutrition effects in four Mexican communities. *Food Policy*: 395-407.

Doss, C.R. and M.L. Morris. 2001. How does gender affect the adoption of agricultural innovations? The case of improved maize technology in Ghana. *Agricultural Economics* 25: 27-39.

Ersado, L., G. Amacher, and J. Alwang. 2004. Productivity and Land Enhancing Technologies in Northern Ethiopia: Health, Public Investments, and Sequential Adoption. *American Journal of Agricultural Economics* 86(2): 321-331.

Ethnologue Website. Viewed at:
http://www.ethnologue.com/show_language.asp?code=TBZ.

Feather, P.M. and G.S. Amacher. 1994. Role of information in the adoption of best management practices for water quality improvement. *Agricultural Economics* 11: 159-170.

Feder, G. and R. Slade. 1984. The acquisition of information and the adoption of technology. *American Journal of Agricultural Economics* 66: 312-320.

Feder, G., R. E. Just and D. Zilberman. 1985. Adoption of agricultural innovations in developing countries: a survey. *Economic Development and Cultural Change* 33: 255-297.

Feder, G. and D.L. Umali. 1993. The Adoption of Agricultural Innovations: A Review. *Technological Forecasting and Social Change* 43: 215-239.

Food and Agriculture Organization (FAO) of the United Nations. 1997. Food and Nutrition for Africa – A Resource Book For Teachers of Agriculture. Rome.
Viewed at:
http://www.fao.org/documents/show_cdr.asp?url_file=/docrep/W0078E/W0078E00.htm.

FAO National Soil Degradation Maps. Viewed at:
http://www.fao.org/landandwater/agll/glasod/glasodmaps.jsp?

Frankel, F.R. 1971. India's Green Revolution-Economic Gains and Political Costs. Princeton: Princeton University Press.

Franzel, S. 1999. Socioeconomic factors affecting the adoption potential of improved tree fallows in Africa. *Agroforestry Systems* 47: 305-321.

Future Harvest. April 9, 2001. *Research Gives Birth to Nigerian Soybean Industry: Tofu Fights Hunger and Earns Cash for Women Farmers and Entrepeuners*. Viewed at: http://www.futureharvest.org/pdf/soybeanbkgnd.pdf.

Galiba, M. 2003. Agricultural Technology Adoption: Major Step to Development and Market Access. Paper presented at the Fourth Annual Global Development Conference, Cairo.

Griliches, Z. 1957. Hybrid corn: an exploration in the economics of technological change. *Econometrica* 25: 501-523.

Harriss, B. 1972. Innovation Adoption in Indian Agriculture-the high-yielding variety program. *Modern Asian Studies* 6.

Hicks, W.H. and R. Johnson. 1974. Population Growth and the Adoption of New technology in Taiwanese Agriculture. Working Paper in Economics no. 1974-E6. Columbia: University of Missouri.

Huss-Ashmore, R. and J.J. Curry. 1994. Diet, Nutrition, and Agricultural Development in Swaziland. *Nutrition and Agriculture* 107-120.

IZF (Investir en zone franc). Viewed at: http://www.izf.net/izf/index.htm.

IITA (International Institute of Tropical Agriculture). Viewed at: www.iita.org.

Jamison, D. and L. Lau. 1982. Farmer Education and Farm Efficiency. Johns Hopkins Press for the World Bank, Baltimore MD.

Jamison, D. and P.R. Moock. 1984. Farmer education and farm efficiency in Nepal: the role of schooling, extension services and cognitive skills. *World Development* 12: 67-86.

Jones, A.M. 1989. A double-hurdle model of cigarette consumption. *Journal of Applied Econometrics* 4: 23-29.

Jones, K. 2004. Fieldwork.

Judge, G., W. Griffiths, R. Hill, H. Lutkepohl, and T. Lee. 1985. *The Theory and Practice of Econometrics*, 2nd edition. John Wiley, New York.

Just, R. E. and D. Zilberman. 1983. Stochastic structure, farm size and technology adoption in developing agriculture. *Oxford Economic Papers* 35: 307-328.

Kebede, Y., K. Gunjal, and G. Coffin. 1990. Adoption of New Technologies in Ethiopian Agriculture: The Case of Tegulet-Bulga District, Shoa Province. *Agricultural Economics* 4: 27-43.

Khan, M.H. 1975. The Economics of the Green Revolution in Pakistan. Frederick A. Praeger, New York.

Kivlin, J.E. and F.C. Fliegel. 1966. Attributes of innovations as factors in diffusion. *American Journal of Sociology* 72: 235-248.

Kivlin, J.E. and F.C. Fliegel. 1967. Differential perceptions of innovations and rate of adoption. *Rural Sociology* 32: 78-91.

Konlani, S., Lamboni, C., Améyapoh, Y. and de Souza, C. 1999. Microbiology and Biochemical Composition of “Tonou”, a Food Condiment from Fermented Seeds of Parkia biglobosa (Locust Bean) and Soybean. *Food Biotechnology* 13(3): 217-225

Koudeti, N.K. 1996. La Région Naturelle de Keran-Est. AFVP. Lome, Togo.

Leathers, H.D. and M. Smale. 1992. A Bayesian approach to explaining sequential adoption of components of a technological package. *American Journal of Agricultural Economics* 68: 519-527.

Lin, C.T.J. and J.W. Milon. 1993. Attribute and safety perceptions in a double-hurdle model of shellfish consumption. *American Journal of Agricultural Economics* 75: 724-729.

Lindner, R. K and P.G. Pardey. 1979. The micro processes of adoption - a model. 9th Congress of the Australian and New Zealand Association for the Advancement of Science, Auckland.

Lindner, R. K., P.G. Pardey, and F.G. Jarrett. 1982. Distance to information source and the time lag to early adoption of trace element fertilizers. *Australian Journal of Agricultural Economics* 26: 98-113.

Lindner, R.K. 1987. Adoption and diffusion of technology: an overview. In Technological Change in Postharvest Handling and Transportation of Grains in the Humid Tropics, B.R. Champ, E. Highly, and J.V. Remenyi (eds.), ACIAR Proceedings Series, Australian Centre for International Agricultural Research, No. 19, pp. 144-151.

Lipton, M. 1976. Agricultural Finance and Rural Credit in Poor Countries. *World Development* 4: 543-54.

Lowdermilk, M. 1976. Diffusion of Dwarf Wheat Production Technology in Pakistan’s Punjab. Ph.D. dissertation, Cornell University.

Maddala, G.S. 1983. Limited dependent and qualitative variables in econometrics. *Econometric Society Monograph* 3, Cambridge University Press, Cambridge.

Marra, M. and D.J. Pannell and A.A. Ghadim. 2003. The Economics of Risk, Uncertainty and Learning in the Adoption of New Agricultural Technologies: Where Are We on the Learning Curve? *Agricultural Systems*, 75(2/3): 215-234.

Meller, J.W. and B.F. Johnston. 1984. The world food equation: interrelations among development, employment and food consumption. *Journal of Economic Literature* 22: 531-574.

Mercer, E., and S.K. Pattanayak, 2003. "Agroforestry Adoption by Smallholders." In Forests in a Market Economy, E. Sills and K. Abt (eds.). Forestry Sciences Series by Kluwer Academic Publishers, Dordrecht. Pages 283-299.

Moser, C.M. and C.B. Barrett. 2001. The Disappointing Adoption Dynamics of a Yield-Increasing, Low External Input Technology: The Case of SRI in Madagascar. Cornell University, Unpublished.

Moser, C.M. and C.B. Barrett. 2002. Labor, Liquidity, Learning, Conformity and Smallholder Technology Adoption: The Case of SRI in Madagascar. Cornell University, Unpublished.

Negatu, W. and A. Parikh. 1999. The impact of perception and other factors on the adoption of agricultural technology in the Moret and Jiru Woreda (district) of Ethiopia. *Agricultural Economics* 21: 205-216.

Neill, S.P. and D.R. Lee. 2001. Explaining the Adoption and Disadoption of Sustainable Agriculture: The Case of Cover Crops in Northern Honduras. *Economic Development and Cultural Change* 49 (4): 793-817.

Neupane, R.P., K.R. Sharma, and G.B. Thapa. 2002. Adoption of agroforestry in the hills of Nepal: a logistic regression analysis. *Agricultural Systems* 72: 177-196.

Ngugi, D. (Ed.). 1988. Agroforestry Research Project for the Maize-Livestock System in the Unimodal Upland Plateau (Chipata and Katete) of Eastern Province of Zambia. AFRENA Report No. 10. ICRAF, Nairobi, Kenya.

Nowak, P. 1992. Why farmers adopt production technology. *Journal of Soil and Water Conservation* 47: 14-16.

Odunfa, S.A. 1985. Biochemical changes in fermenting African locust bean (Parkia biglobosa) during 'iru' fermentation. *Journal of Food Technology* 20: 295-303

Oldeman, L.R., R.T.A. Hakkeling, and W.G. Sombroek. 1991. World Map of the Status of Human-Induced Soil Degradation: An Explanatory Note, second edition, International Soil and Reference Center in cooperation with Winand Staring Center, Organization of the United Nations, and International Institute for Aerospace Survey and Earth Sciences, Wageningen.

Onofiok, N.O. and D.O. Nnanyelugo. 1998. Weaning foods in West Africa: Nutritional problems and possible solutions. University of Nigeria. Viewed at: http://www.micronutrient.org/idpas/pdf/606WeaningFoods.pdf.

Pattanayak, S.K., D.E. Mercer, E. Sills, and J. C. Yang. 2003. *Taking Stock of Agroforestry Adoption Studies*. Agroforestry Systems 57 (3): 173-186.

Pindyck, R.S. and D.L. Rubinfield. 1981. *Econometric Models and Economic Forecasts*. 2nd edition McGraw-Hill, New York.

PNUD/FAO/BEN/91/005. 1993. Etude de Faisabilite Technique et Socio-economique de Projet Amenagement de Basins Versants et de Gestion de Terroirs Villageois Dans la Sous-Prefecture de Boukombe Department de L'Atacora.

Polidoro, B. 2002. Landraces vs Modern Seed Varieties: A Case Study of Sustainable Agriculture in Northern Togo. Master's Thesis, Washington State University.

Poverty Mapping. Chronic undernutrition among children: an indicator of poverty. Viewed at: http://www.povertymap.net/mapsgraphics/graphics/undernutrition_en.cfm.

Rahm, M. and W. Huffman. 1984. The adoption of reduced tillage: the role of human capital and other variables. *American Journal of Agricultural Economics* 66: 405-413.

Ramirez, R. 2002. Effectiveness of Small-Scale Agricultural Interventions on Household Food Security: A review of the literature. International Development Research Centre: Ottawa, Canada.

Rogers, E.M. 1962. *Diffusion of Innovations*. MacMillan Company, USA.

Sanders, J.H. D.D. Southgate, and J.G. Lee. 1995. The economics of soil degradation: technological change and policy alternatives. SMSS Technical Monograph No.22, World Soil Resources, Washington, D.C.

Sanginga, N. 2003. Role of biological nitrogen fixation in legume based cropping systems: a case study of West Africa farming systems. *Plant and Soil* 252:25-39.

Sanginga, P.C., A.A. Adesina, V.M. Manyong, O. Otite, and K.E. Dashiell. 1999. Social Impact of Soybean in Nigeria's Southern Guinea Savanna. IITA, Nigeria.

Scherr, S. and P.B.R. Hazell. 1994. Sustainable Agricultural Development Strategies in Fragile Lands. Environmental and Production Technology Division Discussion Paper No.1 International Food Policy Research Institute, Washington D.C.

Scoones, I. And J. Thomson. 1994. Knowledge, power and agriculture-towards a theoretical understanding. In Scoones, I. And J. Thomson (Eds.), Beyond Farmer First, Rural Peoples'

Knowledge and Extension Practice. London: Intermediate Technology Publications, pp. 16-32.

Shao, M. 2002. *Parkia biglobosa*: Changes in Resource Allocation in Kandiga, Ghana. Master's Thesis, Michigan Technological University.
Shively, G.E. 1997. Consumption risk, farm characteristics, and soil conservation adoption among low-income farmers in the Philippines. *Agricultural Economics* 17: 165-177.

Smale, M., Z. Kaunda, H. Makina, M. Mkandawire, M. Msowoya, D. Mwale, and P. Heisey. 1991. Chimanga cha Makolo, Hybrids, and Composites: An Analysis of Farmers' Adoption of Maize Technology in Malawi, 1989-91. Economics Program Working Paper 91-04. CIMMYT, Mexico, D.F.

Strauss, J., M. Barbosa, S. Teixeira, D. Thomas, and R.Gomes, Jr. 1991. Role of education and extension in the adoption of technology: a study of upland rice and soybean farmers in Central-West Brazil. *Agricultural Economics* 5: 341-359.

Swinkels, R., S. Franzel, K. Shepherd, E. Ohlsson, and J. Ndufa. 1997. The economics of short rotation improved fallows: evidence from areas of high population density in western Kenya. *Agricultural Systems* 55: 99-121.

Tanti, R.N. 1997. Monographie Des Postes A Pourvoir Traditionnel et Moderne. AFVP. Lome, Togo.

Tanti, R.N. 2003. Personal Communication.

Tanti, R.N. and N.B. Julien. 1998. Projet Inco Somba: Etude du Milieu. AFVP and SIRAIB. Lome, Togo.

Tsur, Y. M. Sternberg, and E. Hochman. 1990. Dynamic modeling of innovation process adoption with risk aversion and learning. *Oxford Economic Papers* 42: 336-355.

UNESCO. Viewed at http://whc.unesco.org/pg.cfm?cid=31&id_site=1140.

UNEP. 1993. Dryland degradation: a global problem. Soil degradation severity in susceptible drylands, map. UNEP, Nairobi. Viewed at: http://www.nasm.si.edu/ceps/drylands/index.htm.

UNICEF. 2002 Country Statistics. Viewed at http://www.unicef.org/infoby country/.

Warner, K. E. 1974. The need for some innovative concepts of innovation: an examination of research on the diffusion of innovations. *Policy Sciences* 5: 433-451.

Welch, F. 1979. Education in production. *Journal of Political Economy* 78: 32-59.

World Facts and Figures. Viewed at: www.worldfactsandfigures.com/countries/.

Zinnah, M.M., J.L. Compton, and A.A. Adesina. 1993. Research-extension-farmer linkages within the context of the generation, transfer and adoption of improved mangrove swamp rice technology in West Africa. *Quarterly Journal of International Agriculture* 32: 201-211.

APPENDICES

APPENDIX I: Survey Instrument

INTRODUCTION

Bonjour. Je m'appelle Kelly Jones. Je suis la volontaire du Corps de la Paix a Warengo. Aujourd'hui je viens chez vous parce que je fais un questionnaire pour mon travail. Ce questionnaire est sur le soja. Il va prendre moins d'une heure de temps. Votre maison a été sélectée par chance. Je ne mettrai pas votre nom sur le questionnaire. Je voudrais parler avec la femme de la maison.
Est-ce que vous avez le temps pour faire le questionnaire aujourd'hui? Est-ce que vous avez les questions avant qu'on commence?

Village Name:
Quartier Name:
Interviewer Name:
Questionnaire Number:

Date:
What time of day:
Distance (minutes/walking) from community health center:
Distance (minutes/walking) from road:

How long did it take:
Who was present: Husband Wife Both
Any leaders/officials:
Language used: French Tamberma
Soy: Yes No

Comments:

D'abord, je voudrais vous demander les questions sur votre famille.

A. STRUCTURE DEMOGRAPHIQUE

1. Combien de personnes habitent ici (mangez les repas ensemble) ? /_____/
How many people live here?

2. Combien d'hommes (> 15)? /_____/
How many men (over 15)?

3. Combien de femmes (>15) ? /_____/
How many women (over 15)?

4. Combien d'enfants (< 5)? /_____/
How many children (less than 5)?

5. Combien d'enfants (5-15)? /_____/
How many children (between 5 and 15)?

6.Combien les va à l'école? /_____/
How many of them go to school?

7. Avez-vous la famille qui n'habite pas dans ce village ? Oui=1 Non=0 /_____/
Do you have family members who don't live in this village?
Si oui, est-qu'ils vous envoient l'argent de temps en temps? Oui=1 Non=0 /_____/
If yes, do they send money from time to time?
Est-ce que vous ils envoyez l'argent? Oui=1 Non=0 /_____/
Do you send them money?

8. Est-ce que quelqu'un ici a visitez l'hôpital dans l'année passe ? Oui=1 Non=0 /_____/
Did anybody from your family visit the hospital in the last year?

9. Avez vous le morts ici dans l'année passe? Oui=1 Non=0 /_____/
Did you have any deaths in the family in the last year?

	10. Sexe *Sex* Femme=0 *Female* Male=1 *Male*	11. Ecrire Age *Write age*	12. Education Rien=1 Primaire=2, Secondaire=3, Collège technique=4, Autre=5	13.Ethnie *Ethnicity* Tamberma=1, Autre=2	14.Nom de village de votre père *Name of father's village*
A.Chef de famille *Head of family*					
B. Femme de famille *Head female*					
C. Autre femme *Other female head*					
D. Autre femme *Other female head*					

15. Etes-vous ou votre mari un membre d'une association ou groupement ? Oui=1 Non=0 /_____/
Are you or your husband a member of any associations?
Si oui, indiquez quelle association et si c'est actif :
If yes, name the association and if it is active.

Mari *Husband*	Femme *Wife*

16. Est-ce que vous utiliser un système d'épargne et crédit ? Oui=1 Non=0 /_____/
Do you use a savings and credit system?
Si oui, indiquez quel système : 1.______________________
If yes, name the system 2.______________________

17. Pour l'agriculture en 2003, quelle culture a donnez votre famille le plus d'argent :
For your farm in 2003, which crop earned your family the most money.
Le coton /_____/ Le riz /_____/
Le mais /_____/ Les ignames /_____/
L'haricot/_____/ Le voignou /_____/
Le sorgho /_____/ L'autre___________

18. En plus de l'agriculture en 2003, quelle activité a donnez votre famille le plus d'argent :
Other than agriculture in 2003, what other activity earned your family money.
Le petit commerce /_____/ La famille qui envoie l'argent de dehors /_____/
Le tchouk /_____/ La travaille artisanal /_____/
L'élevage /_____/ L'autre____________

19. Quelles marches fréquentez-vous?
What markets do you frequent?

Lieu de marche *Place*	Kilomètres de votre maison *Distance*	Combien de fois par mois *How often*

:
B. POSSESSIONS

20. Indiquez le nombre pour chaque maison :
Indicate the number for each house.
Tata : /_____/
Traditional house
Case rectangulaire : /_____/ Plafond en paille /_____/ ou en tôle /_____/
Rectangular house *Roof in straw or tin*
Case rond : /_____/
Round house

21. Indiquez les possessions :
Indicate if they possess the following

Savon *Soap*			
Moustiquaire *Mosquito net*			
Foyer améliore *Improved cookstove*			
Radio *Radio*		Ca marché maintenant ? *Does it currently work?*	Ecoutez-vous la nouvelle? *Do you listen to the news?*
Vélo *Bicycle*		Ca marche maintenant ? *Does it currently work?*	L'avez-vous 10 années avant ? *Did you have it 10 years ago?*

Motto *Motorcycle*		Ca marché maintenant ? *Does it currently work?*	L'avez-vous 10 années avant ? *Did you have it 10 years ago?*

22. Pratiquez-vous l'élevage ? Oui=1 Non=0 /_____/
Do you have livestock?
Si oui, combien :
If yes, how many

Le vache *Cows*	
Le mouton *Sheep*	
Le chèvre *Goats*	
Le porc *Pigs*	

24. Plantez-vous jamais les arbres autour de votre maison ? Oui=1 Non=0 /_____/
Have you ever planted trees around your house?
Si oui :

Type d'arbre *Type of tree*	Nombre *Number*

Maintenant, je voudrais vous demander les questions sur les champs.

C. PARCELLES D'EXPLOITATION

25. Combien de parcelles avez-vous exploite en 2003? /_____/
How many parcels of land did you farm last year ?

Caractéristiques des parcelles *Parcelle characteristics*	PARCEL #1	PARCEL #2	PARCEL #3	PARCEL #4	PARCEL #5	PARCEL #6	PARCEL #7
26. Cultures plantées Avec quoi? *Crops planted/ With what?*							
27. Superficie *Hectares*							
28. Cultivateur *Who farmed the parcel*							
29. Distance à votre maison *Distance to house*							
30. Soja *Ever planted soy here*							
31. En les années passes plantez-vous le soja ? *In the past, have you planted soy here?* Combien d'années? *How many years?*							
32. Plantez-vous les arbres sur la parcelle? Have you *planted trees on the parcel?*							

CONTINUE ONLY IF PLANTED SOY							
33. Mode d'accès a la terre *Tenure*							
34. Engrais chimique, fumier ou compost *Chemical fertilizer, manure or compost*							
35. Plat ou escarpe *Flat or steep*							
36. Sable ou argile *Sand or clay*							
Cailloux *Rocky*							
37. Pour le recolte passe, est-que ca etes plus bon, le meme, ou plus mauvais que les annees passer ? *Was your harvest last year, better, the same, or worse than in past years?*							

Maintenant je voudrais parler à la femme sur le soja.

D. SOJA

38. Plantez-vous jamais le soja ? Oui=1 Non=0 /_____/
Have you ever planted soy?
SI NON:
39. Pourquoi :
Why?

40. Participez-vous jamais dans une sensibilisation sur le soja? Oui=1 Non=0 /_____ /
Have you ever participated in a training on soy?
Si oui, indiquez de qui:
If yes, indicate from whom.

Projet __________	Dispensaire___________
Gouvernement	Peace Corps
Missionnaires	TILAPOTI
Famille/Voisin/Ami	Autre_____________

Aller a # 53
Afterwards, go to #53

SI OUI :
41. Quel étais la première année vous avez plante le soja ?
In what year did you first plant soy?

If didn't plant in 2003, ask:
42. Pourquoi vous n'avez pas planter le soja l'année passe?
Why didn't you plant soy last year?

43. De qui avez-vous appris l'information sur le soja?
From whom/where did you first learn about soy?

Projet __________	Dispensaire___________
Gouvernement	Peace Corps

Missionnaires TILAPOTI
Famille/Voisin/Ami Autre_____________

44. Participez-vous jamais dans une sensibilisation sur le soja? Oui=1 Non=0 /_____ /
Have you ever participated in a training on soy?
Si oui, indiquez de qui:
Projet __________ Dispensaire___________
Gouvernement Peace Corps
Missionnaires TILAPOTI
Famille/Voisin/Ami Autre_____________

45. Plantez-vous le soja seul ou en association avec une autre culture?
Do you plant soy alone or in combination with another crop?

	2003	2002	2001	2000	1999	1998
Seul						
Association						
Avec quoi ? *With what ?*						

46. Avez-vous jamais les problèmes avec la cultivation de soja ? Oui=1 Non=0 /_____/
Have you had any problems growing soy? If so, what were they?
Si oui, indiquez quels problèmes:

47. Participez-vous dans une transformation de soja? Oui=1 Non=0 /_____/
Have you ever participated in a soy transformation? If so, who gave it and what did they teach?
Si oui, indiquez de quoi :
Moutarde Bouille
Formage Farine
Lait Autre
Beignet
Si oui, indiquez de qui:
Projet __________ Dispensaire___________
Gouvernement Peace Corps
Missionnaires TILAPOTI
Famille/Voisin/Ami Autre_____________

En la dernière année vous avez plante le soja :
In the last year you planted soy.
48. Quel mois plantez-vous le soja ? 48.B. Qui a cultive le soja ? *Who farmed the soy ?*
What month did you plant soy?

49. Quel était la superficie?
What was the area planted?

50. Utiliser-vous l'engrais chimique, le fumier ou le compost avec le soja?
Did you use chemical fertilizer, manure or compost on your soy?

51. Combien de bols récoltez-vous ?
How many bowls did you harvest?

52. Apres le récolte, comment utilisez-vous le soja ?
After harvesting, what did you use your soy for?

Nourriture		Quoi ?

Food		*What ?*		
Vendre le bol *Sell the bowl*		Nombre de bol? *Number of bowls?*	Combien par bol ? *Price?*	Ou ? *Where?*
Vendre le chose (formage, moutarde) *Sell cheese, mustard, etc.*		Quoi ? *What ?*	Combien ? *Price ?*	Ou ? *Where ?*
Guarder pour planter *Keep for replanting*				
Autre (spécifier)				

53. Combien pensez-vous coûte un bol de soja? /_____/
How much do you think a bowl of soy costs?

54. Est-ce que vous pensez le soja:
Do you think soy….

Déclaration	Oui	Non	Ne sait pas
1.N'est pas bon pour la santé *Is not good for your health*			
2. Améliorer le sol *Improves soil fertility*			
3. Est difficile a préparer pour manger *Is difficult to prepare to eat*			
4. Peut être vendre au marche *Can be sold at the market*			
5. Ne pas besoin le fertilisant *Does not need fertilizer*			

55.Pensez-vous vous allez planter le soja l'année prochaine? Oui=1 Non=0 /_____ /
Do you plan to plant soy next year?
If yes:
56. Qui va choisir la terrain et la superficie pour le soja?
Who will choose the land and the size of the farm for the soy?

57. Est-ce que vous pensez que votre mari comprend l'utilité de soja?
Do you think that your husband understands the usefulness of soy?

Maintenant, je voudrais vous demander les questions sur la nourriture.

E. NUTRITION

58.Pendant la semaine passe, indiquez combien de fois votre famille a mange le suivant :
Indicate the number of times your family ate the following during the past week.

Le poisson ou viande *Fish/Meat*		Soja/moutarde de soja *Soy or mustard*	
Les oeufs *Eggs*		Gumbo *Okra*	
L'arachide ou vougnzou *Groundnuts*		Legumes de jardin *Garden vegetables*	
L'haricot *Beans*		Feuilles des arbres dans le sauce *Tree leaves in sauce*	

Graine de baobab *Baobab seeds*		Fruits *Fruit*	
Graine de nyere/moutarde *Nyere seeds or mustard*			

Maintenant je voudrais vous demander les questions sur les dépenses.

F. DEPENSES

59. Pendant le mois passe, combien avez vous dépense pour:
Indicate how much you spent in the past month on the following.

Les médicaments *Medicine*	
La nourriture *Food*	
Ménager (savon, habites, etc) *Household goods*	
Fournitures pour l'école *School supplies*	
Le tchouk *Beer*	

60. Pendant l'année passe, combien avez vous dépense pour:
Indicate how much you spent in the past year on the following.

Les vaccinations de bétail *Animal vaccinations*	
Les cérémonies/ fêtes *Ceremonies*	
L'eau (pump, puit) *Water fees (pumps/wells)*	
L'écolage et l'entre des enfants *School fees and beginning of the school year*	

G. AUTRE

61. Avez-vous l'autre chose pour dire sur le sujet de pourquoi vous plantez ou ne plantez pas le soja ? *Do you have anything else to say on why you do or do not plant soy?*

APPENDIX II: Parsimonious Model of Adoption

```
probit; lhs=soy; rhs=feduc, comm,
    totaginc, fam, totfarm, soyedu,
    mbr, hosp, avgharv, avgdist,
    ftsoy, one; marginal$

 *********************************************************************
 * NOTE: Deleted     11 observations with missing data. N is now    124 *
 *********************************************************************

Normal exit from iterations. Exit status=0.

+---------------------------------------------+
| Binomial Probit Model                       |
| Maximum Likelihood Estimates                |
| Model estimated: Jan 21, 2005 at 09:43:45AM.|
| Dependent variable                SOY       |
| Weighting variable               None       |
| Number of observations            124       |
| Iterations completed                6       |
| Log likelihood function     -49.35440       |
| Restricted log likelihood   -84.63917       |
| Chi squared                  70.56954       |
| Degrees of freedom                 11       |
| Prob[ChiSqd > value] =       .0000000       |
| Hosmer-Lemeshow chi-squared =  12.80635     |
| P-value=  .04622 with deg.fr. =      6      |
+---------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
	Index function for probability				
FEDUC	.6380112821	.22667298	2.815	.0049	1.6854839
COMM	-2.914905215	.61943114	-4.706	.0000	.70161290
TOTAGINC	-.4357906346	.26711702	-1.631	.1028	.88709677
FAM	.5260563226	.41437617	1.270	.2043	.69354839
TOTFARM	.2187713856	.12218498	1.790	.0734	5.1854839
SOYEDU	.7174784590	.34886556	2.057	.0397	.29032258
MBR	.6410680952	.36850403	1.740	.0819	.29838710
HOSP	-.6889631202	.34893117	-1.974	.0483	.52419355
AVGHARV	-.4878202238	.32652629	-1.494	.1352	1.6495008
AVGDIST	.1942030868	.13237906	1.467	.1424	1.3331797
FTSOY	-.6063990784	.64015884	-.947	.3435	.86693548
Constant	1.249720378	1.1973180	1.044	.2966	

```
+-------------------------------------------+
| Partial derivatives of E[y] = F[*]   with |
| respect to the vector of characteristics. |
| They are computed at the means of the Xs. |
| Observations used for means are All Obs.  |
+-------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
	Index function for probability				
FEDUC	.2385925714	.85092922E-01	2.804	.0050	1.6854839
COMM	-.6869381276	.78125497E-01	-8.793	.0000	.70161290
TOTAGINC	-.1629695446	.99874468E-01	-1.632	.1027	.88709677
FAM	.2008428018	.15798041	1.271	.2036	.69354839
TOTFARM	.8181238940E-01	.45818203E-01	1.786	.0742	5.1854839

SOYEDU	.2473840630	.10662167	2.320	.0203	.29032258
MBR	.2240193084	.11836449	1.893	.0584	.29838710
HOSP	-.2517883240	.12286784	-2.049	.0404	.52419355
AVGHARV	-.1824266825	.12254709	-1.489	.1366	1.6495008
AVGDIST	.7262475627E-01	.49237334E-01	1.475	.1402	1.3331797
FTSOY	-.2267707790	.23745993	-.955	.3396	.86693548
Constant	.4673491000	.44248060	1.056	.2909	

(Note: E+nn or E-nn means multiply by 10 to + or -nn power.)

```
+----------------------------------------+
| Fit Measures for Binomial Choice Model |
| Probit   model for variable SOY        |
+----------------------------------------+
| Proportions P0= .427419   P1= .572581  |
| N =      124 N0=      53   N1=      71 |
| LogL =    -49.35440 LogL0 =   -84.6392 |
| Estrella = 1-(L/L0)^(-2L0/n) = .52113  |
+----------------------------------------+
|     Efron |  McFadden  |  Ben./Lerman  |
|    .47043 |    .41688  |       .74258  |
|    Cramer | Veall/Zim. |     Rsqrd_ML  |
|    .47375 |    .62838  |       .43397  |
+----------------------------------------+
| Information  Akaike I.C. Schwarz I.C.  |
| Criteria         .98959    156.55218   |
+----------------------------------------+
Frequencies of actual & predicted outcomes
Predicted outcome has maximum probability.
Threshold value for predicting Y=1 = .5000
            Predicted
------  ----------  +  -----
Actual      0    1  |  Total
------  ----------  +  -----
  0        40   13  |     53
  1        10   61  |     71
------  ----------  +  -----
Total      50   74  |    124
```

APPENDIX III: Adoption Model for Togo (n=96)

```
NOTE: COMM and MRKT1 not included due to lack of variation
probit; lhs=soy; rhs=feduc, nomen, totaginc,
    bike, fam, totfarm, prxsoy,
    soyedu, mbr, hosp,
    avgharv, avgdist,
    impsoil, ftsoy, one$

 ***********************************************************************
 * NOTE: Deleted     11 observations with missing data. N is now     85 *
 ***********************************************************************

Normal exit from iterations. Exit status=0.

+---------------------------------------------+
| Binomial Probit Model                       |
| Maximum Likelihood Estimates                |
| Model estimated: Jan 28, 2005 at 10:29:03AM.|
| Dependent variable                 SOY      |
| Weighting variable                None      |
| Number of observations              85      |
| Iterations completed                 6      |
| Log likelihood function      -37.88494      |
| Restricted log likelihood    -58.20375      |
| Chi squared                   40.63761      |
| Degrees of freedom                  14      |
| Prob[ChiSqd > value] =        .2027835E-03  |
| Hosmer-Lemeshow chi-squared =   8.25946     |
| P-value=  .31027 with deg.fr. =       7     |
+---------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
	Index function for probability				
FEDUC	.6286528487	.26494471	2.373	.0177	1.8352941
NOMEN	.9524104862E-01	.29710025	.321	.7485	1.4470588
TOTAGINC	-.6621197813	.33705791	-1.964	.0495	1.1294118
BIKE	-.9044097399E-02	.40356784	-.022	.9821	.52941176
FAM	.7963532139	.50276350	1.584	.1132	.85882353
TOTFARM	.1566882786	.14822135	1.057	.2905	5.4117647
PRXSOY	-.2731744264E-03	.66803546E-03	-.409	.6826	570.58824
SOYEDU	.6674115108	.40860516	1.633	.1024	.29411765
MBR	.9178819641	.47688944	1.925	.0543	.29411765
HOSP	-.5674125555	.40224619	-1.411	.1584	.40000000
AVGHARV	-.5141927211	.37713526	-1.363	.1728	1.5836134
AVGDIST	.1568830167	.14124008	1.111	.2667	1.5585084
IMPSOIL	.7543766337	.72499045	1.041	.2981	.75882353
FTSOY	-.4635945967	.79584432	-.583	.5602	.88235294
Constant	-1.943507074	1.5477771	-1.256	.2092	

(Note: E+nn or E-nn means multiply by 10 to + or -nn power.)

```
+---------------------------------------+
| Fit Measures for Binomial Choice Model |
| Probit   model for variable SOY        |
+---------------------------------------+
| Proportions P0= .564706   P1= .435294 |
| N =       85 N0=      48   N1=      37 |
| LogL =   -37.88494 LogL0 =   -58.2037 |
| Estrella = 1-(L/L0)^(-2L0/n) = .44460 |
+---------------------------------------+
|     Efron |   McFadden  |  Ben./Lerman |
|    .40288 |     .34910  |       .70813 |
```

```
|    Cramer | Veall/Zim. |      Rsqrd_ML |
|    .40717 |     .55963 |        .38003 |
+-----------------------------------------+
| Information  Akaike I.C. Schwarz I.C.   |
| Criteria        1.24435    142.40965    |
+-----------------------------------------+
Frequencies of actual & predicted outcomes
Predicted outcome has maximum probability.
Threshold value for predicting Y=1 = .5000
            Predicted
------  ----------  +  -----
Actual       0    1  |  Total
------  ----------  +  -----
  0         38   10  |     48
  1         10   27  |     37
------  ----------  +  -----
Total       48   37  |     85
```

APPENDIX IV: Exogenous Model of Disadoption

```
probit; lhs=disadopt; rhs=feduc, meduc,
    tata, bike, totfarm, prxsoy, avgharv,
    avgdist, one; marginal$

 ***********************************************************************
 * NOTE: Deleted      4 observations with missing data. N is now     69 *
 ***********************************************************************

Normal exit from iterations. Exit status=0.

+---------------------------------------------+
| Binomial Probit Model                       |
| Maximum Likelihood Estimates                |
| Model estimated: Jan 28, 2005 at 04:29:52PM.|
| Dependent variable             DISADOPT     |
| Weighting variable                 None     |
| Number of observations               69     |
| Iterations completed                  6     |
| Log likelihood function       -30.18933     |
| Restricted log likelihood     -40.60786     |
| Chi squared                    20.83706     |
| Degrees of freedom                    8     |
| Prob[ChiSqd > value] =        .7593105E-02  |
| Hosmer-Lemeshow chi-squared =   4.83339     |
| P-value=  .77523 with deg.fr. =       8     |
+---------------------------------------------+
+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
          Index function for probability
 FEDUC       -.3879074678      .32931412    -1.178   .2388     1.7971014
 MEDUC       -.6119824718      .49299580    -1.241   .2145     1.3792754
 TATA        -.1052608822      .34025580     -.309   .7570     .97101449
 BIKE        -.7195307586      .41101456    -1.751   .0800     .71014493
 TOTFARM     -.2551672828      .16683673    -1.529   .1262     5.3768116
 PRXSOY      -1.336545712      .63229188    -2.114   .0345     1.1855072
 AVGHARV     -.2878462943      .40333041     -.714   .4754     1.6266736
 AVGDIST      .2590519275      .13098938     1.978   .0480     1.4418823
 Constant     4.378000833      1.5231536     2.874   .0040


+-----------------------------------------+
| Partial derivatives of E[y] = F[*]   with |
| respect to the vector of characteristics. |
| They are computed at the means of the Xs. |
| Observations used for means are All Obs.  |
+-----------------------------------------+
+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+---------+--------------+----------------+--------+---------+----------+
          Index function for probability
 FEDUC       -.1098810861   .91642277E-01   -1.199   .2305     1.7971014
 MEDUC       -.1733539678      .14160893    -1.224   .2209     1.3792754
 TATA     -.2981685328E-01  .96087849E-01    -.310   .7563     .97101449
 BIKE        -.2257043087      .13677559    -1.650   .0989     .71014493
 TOTFARM  -.7228027429E-01  .47650496E-01   -1.517   .1293     5.3768116
 PRXSOY      -.3785982654      .16346264    -2.316   .0206     1.1855072
 AVGHARV  -.8153713466E-01     .11440593     -.713   .4760     1.6266736
```

```
 AVGDIST   .7338066294E-01  .37321370E-01    1.966   .0493     1.4418823
 Constant     1.240139792       .42752105    2.901   .0037
 (Note: E+nn or E-nn means multiply by 10 to + or -nn power.)

+---------------------------------------------+
| Fit Measures for Binomial Choice Model      |
| Probit   model for variable DISADOPT        |
+---------------------------------------------+
| Proportions P0= .724638   P1= .275362       |
| N =       69 N0=      50   N1=       19     |
| LogL =   -30.18933 LogL0 =   -40.6079       |
| Estrella = 1-(L/L0)^(-2L0/n) = .29458       |
+---------------------------------------------+
|     Efron |  McFadden  |  Ben./Lerman       |
|    .28741 |    .25656  |       .71509       |
|    Cramer | Veall/Zim. |     Rsqrd_ML       |
|    .28209 |    .42900  |       .26065       |
+---------------------------------------------+
| Information  Akaike I.C. Schwarz I.C.       |
| Criteria        1.13592     98.48562        |
+---------------------------------------------+
Frequencies of actual & predicted outcomes
Predicted outcome has maximum probability.
Threshold value for predicting Y=1 = .5000
            Predicted
------  ----------  +  -----
Actual      0    1  |  Total
------  ----------  +  -----
  0        46    4  |     50
  1        10    9  |     19
------  ----------  +  -----
Total      56   13  |     69
```

APPENDIX V: Poisson and Heckman Selection Model Results

Results from the Poisson model are presented below :

```
poisson; lhs=noyrsoy; rhs=feduc, nomen, comm,
    totaginc, bike, fam, totfarm,
    prxsoy, mrkt1,
    soyedu, mbr, hosp,
    avgharv, avgdist,
    impsoil, ftsoy, one$
```

```
 ***********************************************************************
 * NOTE: Deleted     13 observations with missing data. N is now    122 *
 ***********************************************************************

+---------------------------------------------+
| Poisson Regression                          |
| Maximum Likelihood Estimates                |
| Model estimated: Jan 28, 2005 at 03:46:35PM.|
| Dependent variable              NOYRSOY     |
| Weighting variable                 None     |
| Number of observations              122     |
| Iterations completed                  7     |
| Log likelihood function       -147.9938     |
| Restricted log likelihood     -213.8035     |
| Chi squared                    131.6192     |
| Degrees of freedom                   16     |
| Prob[ChiSqd > value] =         .0000000     |
| Chi- squared =   123.49218  RsqP=   .6253   |
| G  - squared =   120.84333  RsqD=   .5213   |
| Overdispersion tests: g=mu(i)  :   .447     |
| Overdispersion tests: g=mu(i)^2:  2.051     |
+---------------------------------------------+
+---------+--------------+----------------+--------+---------+----------+
|Variable | Coefficient  | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X
+---------+--------------+----------------+--------+---------+----------
 FEDUC       .6088659691      .12966684     4.696   .0000     1.6803279
 NOMEN       .1452807990   .89042061E-01    1.632   .1028     1.5327869
 COMM       -2.123521817      .33997941    -6.246   .0000     .69672131
 TOTAGINC -.5256996573E-01    .16533304     -.318   .7505     .88524590
 BIKE       -.1039780825      .23804305     -.437   .6623     .63114754
 FAM       .8235794226E-01    .21558783      .382   .7024     .68852459
 TOTFARM     .2085013241   .85135736E-01    2.449   .0143     5.2213115
 PRXSOY    .6130582386E-01    .17287390      .355   .7229     1.1663934
 MRKT1       .3844282290      .26977070     1.425   .1542     .88524590
 SOYEDU    .2891599621E-01    .21107264      .137   .8910     .29508197
 MBR         .2303027648      .20441587     1.127   .2599     .30327869
 HOSP       -.1771238946      .22108630     -.801   .4230     .52459016
 AVGHARV    -.1013163581      .20125349     -.503   .6147     1.6560500
 AVGDIST   .6892309503E-01 .63724203E-01    1.082   .2794     1.3458138
 IMPSOIL     .4944399544      .46098243     1.073   .2835     .81967213
 FTSOY      -.2340516504      .25078290     -.933   .3507     .86885246
 Constant   -1.563042855      .74236801    -2.105   .0352
 (Note: E+nn or E-nn means multiply by 10 to + or -nn power.)
```

Results from the Heckman selection model are presented below:

```
probit; lhs=soy; rhs=feduc, nomen, comm,
    totaginc, bike, fam, totfarm,
    prxsoy, mrkt1,
    soyedu, mbr, hosp,
```

```
    avgharv, avgdist,
    impsoil, ftsoy, one; hold$

select; lhs=noyrsoy; rhs=feduc, nomen, comm,
    totaginc, bike, fam, totfarm,
    prxsoy, mrkt1,
    soyedu, mbr, hosp,
    avgharv, avgdist,
    impsoil, ftsoy, one$

 ***********************************************************************
 * NOTE: Deleted     13 observations with missing data. N is now    122
 ***********************************************************************

          +-----------------------------------------------------------+
          | Sample Selection Model                                    |
          | Probit selection equation based on SOY                    |
          | Selection rule is: Observations with SOY      =  1        |
          | Results of selection:                                     |
          |                   Data points     Sum of weights          |
          | Data set              122             122.0               |
          | Selected sample        71              71.0               |
          +-----------------------------------------------------------+
+------------------------------------------------------------------------+
| Sample Selection Model                                                 |
| Two stage   least squares regression    Weighting variable = none      |
| Dep. var. = NOYRSOY  Mean=   2.140845070 , S.D.=   1.980589917
| Model size: Observations = 71, Parameters =  18, Deg.Fr.= 53
| Residuals:  Sum of squares= 134.2524146, Std.Dev.= 1.59156
| Fit:        R-squared=  .345036, Adjusted R-squared =.13495
| (Note:  Not using OLS.  R-squared is not bounded in [0,1]
| Model test: F[17, 53] = 1.64,  Prob value =.08596
| Diagnostic: Log-L =  -123.3596, Restricted(b=0) Log-L  -148.7621
|             LogAmemiyaPrCrt.= 1.155, Akaike Info. Crt.= 3.982 |
| Standard error corrected for selection.....1.6961               |
| Correlation of disturbance in regression
| and Selection Criterion (Rho)..............    .59247
+-----------------------------------------------------------------------
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
FEDUC	.9821301395	.41531078	2.365	.0180	1.8028169
NOMEN	.4225735941	.23633792	1.788	.0738	1.6197183
COMM	-3.550923567	1.3615026	-2.608	.0091	.52112676
TOTAGINC	.1327674568	.44674754	.297	.7663	.73239437
BIKE	.1933750942	.52058407	.371	.7103	.70422535
FAM	.5937192568	.56309784	1.054	.2917	.61971831
TOTFARM	.3430496657	.22090435	1.553	.1204	5.3380282
PRXSOY	.5979650229E-01	.50089386	.119	.9050	1.1830986
MRKT1	.8514904852	.65355365	1.303	.1926	.81690141
SOYEDU	.1420729200	.54716751	.260	.7951	.38028169
MBR	.3285667333E-01	.55432501	.059	.9527	.39436620
HOSP	-.1873291015E-01	.58009835	-.032	.9742	.57746479
AVGHARV	.4408894261	.54271852	.812	.4166	1.6146546
AVGDIST	.8065875454E-01	.15818592	.510	.6101	1.4160547
IMPSOIL	.2747263126	.98972404	.278	.7813	.88028169
FTSOY	-.2297725953	.65215822	-.352	.7246	.85211268
Constant	-2.967176241	1.7453605	-1.700	.0891	
LAMBDA	1.004900201	1.0956717	.917	.3591	.37440929

(Note: E+nn or E-nn means multiply by 10 to + or -nn power.)