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FARM LEVEL TECHNOLOGY ASSESSMENT IN SUB-SAHARAN AFRICA: A CASE STUDY IN MALI

A Thesis

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ABSTRACT

Farm Level Technology Assessment in Sub-Saharan Africa:

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The agricultural sector in Sub-Saharan Africa has been the beneficiary of significant expenditures for technology improvements. However, the implementation of the technologies that have been developed for the Sub-Sahara has met with limited success. As funding agencies reevaluate their role in the economic progress of the Sub-Sahara, the economic benefits of these new technologies need to be evaluated to determine their effectiveness. One of the key issues in the effort to evaluate new technology is the effect that risk has on the potential outcomes of proposed technology.

The objective of this research was to evaluate the farm level impacts of implementing new technologies in Sub-Saharan Africa explicitly incorporating risk into the future outcomes of alternative technology assumptions. To achieve this objective the adoption of two improved varieties of sorghum (N'Tenimissa and Seguetana) in the Sub-Saharan nation of Mali was analyzed using a whole farm simulation model, the Technology Impact Evaluation System (TIES). The TIES model was used to estimate the empirical probability distributions of variables associated with economic well being under each technology assumption. Stochastic dominance with respect to a function was used to rank the technology alternatives for risk averse decision makers. Three

case farms were analyzed to determine the effects that implementing new technologies has on small holder farms in different agroecological regions in Mali.

The results indicate that the most preferred technology on all of the case farms in the study is Seguetana sorghum. The results further show that early adoption of this technology yields the most economically beneficial situation on all farms. The evaluation of these results through stochastic dominance shows that the preference for Seguetana technology holds under the risky conditions facing each of the case farms in Mali.

To my wife, Geneva, and my children, Damone, Dale, Bethany, and Darius

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CHAPTER I

INTRODUCTION

The growth of the agricultural sector in developing countries is an essential building block for the economic growth of those nations. Because food production is a fundamental activity in sustaining a society's well being, agriculture is a large contributor to the economic situation of third world countries. As the agricultural sector in these countries begins to make more efficient use of their resources, it's contribution to the nation's economic prosperity increases. For this reason international agencies allocate significant resources toward the advancement of agriculture in developing countries.

The distribution of wealth in developing countries is such that the bulk of agricultural producers are engaged in small-scale farming. Typically, families operating small holder farms in these nations are on the verge of poverty. These farms are characterized by a limited resource endowment primarily employed in subsistence agriculture (Valdes, Scobie, and Dillon 1979). One of the main methods that international development agencies utilize to aid small holder farms is the creation and implementation of new agricultural technologies. These technologies are designed to make agricultural production more efficient, thereby raising the farm family's consumption levels and generating more income for the farm family (Nickel 1979).

This thesis follows the style and format of the *American Journal of Agricultural Economics*.

Sub-Saharan Africa is one of the regions for which international agencies have developed technologies for the small holder farm. In the 1970's the international community had an optimistic attitude toward the economic growth of nations in Sub-Saharan Africa. Many of these countries had recently gained their independence and there seemed to be an opportunity for industrial nations to be involved in the perceived prosperity that was to come in Sub-Saharan agriculture. This perception of prosperity was largely born from the success of the Green Revolution that was occurring in Asia. However, corruption, poor policy decisions, improper planning, disease, and the harsh realities of weather in the Sub-Sahara slowed the growth of the agricultural sector and a repeat of the rapid Green Revolution was not realized (Sanders, Shapiro, and Ramaswamy 1996).

As the expectations for agricultural performance in the Sub-Sahara were not met, optimism gradually turned into pessimism and the attention of Western donors was directed toward other regions with fresh opportunities. There are, however, still efforts being made to raise the performance of agriculture to the levels of expectation that were held two decades ago, and the focus is still on creating technology to improve small scale farming (Sanders, Shapiro, and Ramaswamy 1996)

Problem Statement

The foundation of technology development for Sub-Saharan agriculture is experimental research. By definition this research is performed in a controlled laboratory setting. Once a technology is developed, the challenge is applying that

technology outside of the laboratory environment. To cross this hurdle methodologies must be developed to perform *ex-ante* analyses on the effects of introducing the new technology into the real world situations that occur in Sub-Saharan Africa. This study analyzes the introduction of two improved varieties of sorghum on small holder farms in Mali.

Part of the challenge in carrying out an *ex-ante* analysis is capturing the future uncertainty, or risk, that the agricultural sector in the Sub-Sahara will face. Much of the risk in agriculture stems from the inherent uncertainty in the biological processes that are involved in agricultural production. Another contributing factor is the environmental variability that agriculture is subject to, particularly in the drought prone Sub-Sahara. Beyond the uncertainty of nature, there is also economic uncertainty. The dynamic characteristics of economic systems create both internal and external factors of risk. As the nations that comprise the Sub-Sahara undergo the development of their economies, the risk associated with economic change is heightened. The increased variability in the biological and economic environments of Sub-Saharan Africa accentuates the need for incorporating risk into the analysis of technological impacts for agriculture.

Objectives

The objective of this research is to evaluate the farm level economic impacts of implementing new technologies in Sub-Saharan Africa explicitly incorporating risk into

the future outcomes of alternative technology assumptions. To achieve this overall objective the following specific objectives will be attained:

1. Describe the agricultural production systems found on small holder farms in Sub-Saharan Africa
2. Quantify the risk that small holder farms face in Sub-Saharan Africa
3. Generate statistically significant probabilistic forecasts of the economic outlook for small holder farms in Sub-Saharan Africa given alternative technology assumptions
4. Determine the most preferred strategies for implementing new technologies on small holder farms in Sub Saharan Africa.

Structure of the Remaining Chapters

The remainder of this thesis will be presented in five chapters. Chapter II will review the literature on farm level economic analysis in developing countries and the role of risk in economic analysis. Chapter III will present the methodology that will be used to evaluate the research problem. Results of the analysis will be presented in Chapter IV. Chapter V will summarize the research effort and present conclusions from the study including limitations and further applications of this research.

CHAPTER II

LITERATURE REVIEW

To research the hypothesis that the incorporation of risk is needed to evaluate the farm level economic impacts of technology adoption in Sub-Saharan Africa, previous farm level analyses need to be reviewed. Mathematical programming and simulation dominate the body of literature on farm level economic analysis. Both of these categories of models give the analyst the ability to model a whole farm situation including internal and external economic factors. However, the underlying assumptions behind each type of model dictate they model risk differently.

Mathematical Programming

Linear programming (LP) is the basis of mathematical programming models used to perform farm level economic analysis. The LP model is an optimizing model that seeks to maximize or minimize a given objective function subject to a set of constraints. Norton and Solis (1983) state that the decision criteria in economic applications of LP is the maximization of economic surplus. The marginal value product of the available resource is compared to the cost of employing an addition unit of those resources in a given activity. Resources are allocated to the activities in which they are most efficiently employed to maximize surplus. The results from an LP model show the opportunity cost associated with the resource use and the optimal use of resources in a steady state. Because the LP model assumes a steady state in which the

planning coefficients are known and constant, risk cannot be analyzed without altering the model's assumptions.

The Discrete Stochastic Programming (DSP) model allows for the incorporation of risk into an LP framework. Risk is evaluated in DSP by modeling several states of nature in which the coefficients in both the objective function and the constraints can be different for any given state of nature. Sanders, Shapiro, and Ramaswamy (1996) used a DSP model to assess the farm level effects of irrigated rice production in the Sub-Sahara. In this model, a separate set of conditions was defined for each state of nature so that several scenarios could be developed and each state could be evaluated for the optimal solution. The primary disadvantage of the DSP model is the dimensional limitation that is inherent in models using non-linear optimization algorithms. As a result of this problem the effects of risk on the possible outcomes are limited by the state space defined by the modeler.

In both the LP model and the DSP models, an optimizing algorithm is used to derive results. Therefore, the solution generated by the model indicates how the farm should employ resources given the objective function and constraints modeled. However, these results do not account for risk aversion and may not be a realistic portrayal of the actions that a decision-maker is likely to undertake. To further compound the limitations of the LP and DSP models, the assumption that each state of nature has known and constant planning coefficients restrains the evaluation of the optimal solution with respect to risk. A more complete description of farm level

responses to risk is desired to rigorously evaluate the farm level effects of technology change in the Sub-Sahara.

Simulation Analysis

Simulation is a modeling technique that reproduces random events that are statistically equivalent to the probabilistic outcomes that occur in the system being modeled. Curry, Deuremeyer, and Feldman (1989) point out that a simulation model is an empirical model that utilizes probability theory to describe the logical behavior of a system over time. The descriptive nature of a simulation model makes it feasible to perform experiments on complex systems under conditions of uncertainty.

In the field of economics, simulation experiments were initially performed to capture the risk in an investment analysis framework. In 1970 the World Bank published separate studies, by Poliquen (1970) and Reutlinger (1970) that used simulation modeling to analyze the feasibility of investments in public works. Both Poliquen and Reutlinger extend the analysis of expected net present value from a mean value to include the compete distribution of possible outcomes for net present value. Poliquen noted that the ability to derive the entire distribution of net present value is particularly important for marginal projects that have high degrees of risk. Reutlinger suggested the use of sensitivity analysis to determine the effect that individual variables have on the relative risk and the feasibility of the investment. Both studies emphasized the importance of evaluating alternative investment strategies and using the information

provided by a simulation analysis to optimize the future net present value of an investment under some criteria of risk aversion.

Richardson and Mapp (1976) developed a simulation model that applied the principles suggested by Poliquen and Reutlinger to a firm level investment analysis. This model demonstrated the ability of simulation to capture the risk facing small businesses and the usefulness of simulation as a technique for long-term planning. Richardson and Nixon (1981) extended Richardson's previous work in firm level simulation modeling to the agricultural sector with the Farm Level Income and Policy Simulation Model (FLIPSIM). FLIPSIM is a whole farm simulation model that has been used extensively for policy analysis and more recently for technology assessment. FLIPSIM combines accounting equations, identities, and probability distributions to simulate the financial activities that occur on a farm over a multi-year planning horizon. To capture the risk that the farm faces, stochastic input variables are defined with empirical probability distributions. Pro-forma financial statements are calculated for each set of outcomes that are drawn from these probability distributions. Through this iterative process, the model can simulate the distribution of a wide range of financial variables that are derived from accounting equations. These distributions can be analyzed in the context of a base scenario and an alternative scenario involving a shock to the system from a change in policy or technology.

Nyangito, Richardson, Mukhebi, Mundy, Zimmel, and Namken (1995) used the Technology Impact Evaluation System (TIES) to assess the farm level economic impacts of immunizing dairy cattle in Kenya against East Coast Fever. TIES is a

modified version of FLIPSIM capable of handling the unique issues facing developing countries. The effects of risk were quantified in the analysis by estimating probability distributions for crop and livestock enterprise yields and prices. Alternative strategies for immunization were analyzed in the model and risk preference was evaluated using stochastic dominance with respect to a function to determine the preferred immunization technology. This study demonstrated the ability of a simulation model to describe and evaluate the effects of risk on small holder farms in developing countries.

Stochastic Dominance

Stochastic dominance with respect to a function is a methodology used to identify conditions under which one risky alternative would be preferable to another. Stochastic dominance can be applied to simulation analysis by ranking the probability distributions that are generated from the simulation. Lemiex, Richardson, and Nixon (1982) used stochastic dominance to rank alternatives in a simulation analysis of crop insurance participation.

Meyer (1977) developed an approach based on the Arrow and Pratt risk aversion coefficient (RAC) to evaluate risky alternatives using stochastic dominance. Meyer used a utility function for a single decision-maker or a set of decision-makers to obtain a RAC. However it is not always feasible to obtain a utility function, particularly in developing countries. McCarl and Bessler (1989) provide an approach to obtain a RAC when appropriate utility functions are unknown. Using an upper bound equal to $5/\sigma_Y$, where σ_Y is the standard deviation on the probability distribution being analyzed, stochastic dominance can be evaluated for all risk averse decision makers.

Contribution to the Literature

Economic analyses of small holder farms in developing countries have been widely performed. However, the focus of this research, the incorporation of risk into these type of analyses, is a new area of study. This research will extend the TIES farm level simulation model to analyze cropping technologies in the countries that comprise Sub-Saharan Africa. In this manner the analysis will test the ability of TIES to model diverse environments and economic conditions for farmers, as well as update and refine the model to be able to perform more robust analyses.

CHAPTER III

METHODOLOGY

Simulation is able to describe the risk in a system through the interactions of stochastic variables and generate probabilistic projections for future outcomes. The distributions that are generated in a simulation model give a more complete description of the risk in a system than other methodologies. The TIES model in particular has been shown to accurately capture the risk that is associated with farming in developing countries. This study has applied the TIES model using case farms to evaluate the farm level economic impacts of implementing new technologies in Sub-Saharan Africa explicitly incorporating risk into the analysis.

Three case farms were identified in the Sub-Saharan nation of Mali. Regional experts identified the areas in which these farms are located to represent the agroecological environments that represent Sub Saharan Africa. The determining factor in the selection process was the annual rainfall that each area receives. The case farms in these regions have also been targeted for the introduction of two improved varieties of sorghum, the economic effects of which this study will analyze.

Overview of TIES

As outlined in Chapter II, the TIES model is a Monte Carlo simulation model that analyzes the economic and financial impacts of alternative technologies, production practices, and policies on representative or case farms in developing countries. Because

TIES is a whole farm simulation model, all on and off farm activities must be taken into account. However, since TIES' primary focus is on the production of agricultural commodities more attention is given to on farm activities. Detailed documentation of the model is available in Richardson and Mukhebi (1992).

The computations in TIES are performed with a series of table lookup functions, accounting equations, and identities. Figure 3.1 is a simplified schematic summarizing the functional relationships in the model. Stochastic crop prices and yields are generated with table lookup functions from empirical probability distributions provided by the analyst. Crop production, sales, and on farm use for both family consumption and livestock feed, are calculated using mathematical accounting equations. Identities are used to calculate receipts for crops and livestock as well as changes in herd dynamics. It is important to note that TIES does not use any econometric relationships.

Stochastic Values

The functional equations in TIES are calculated for each year of the planning horizon, and, if run stochastically, for each iteration of the simulation. Figure 3.2 depicts this iterative procedure. To obtain stochastic results, the analyst must input the mean value and ten percentage deviates from the mean for each stochastic variable. The mean value and deviations for each stochastic variable define the empirical probability distribution from which TIES draws a correlated random number for each iteration.

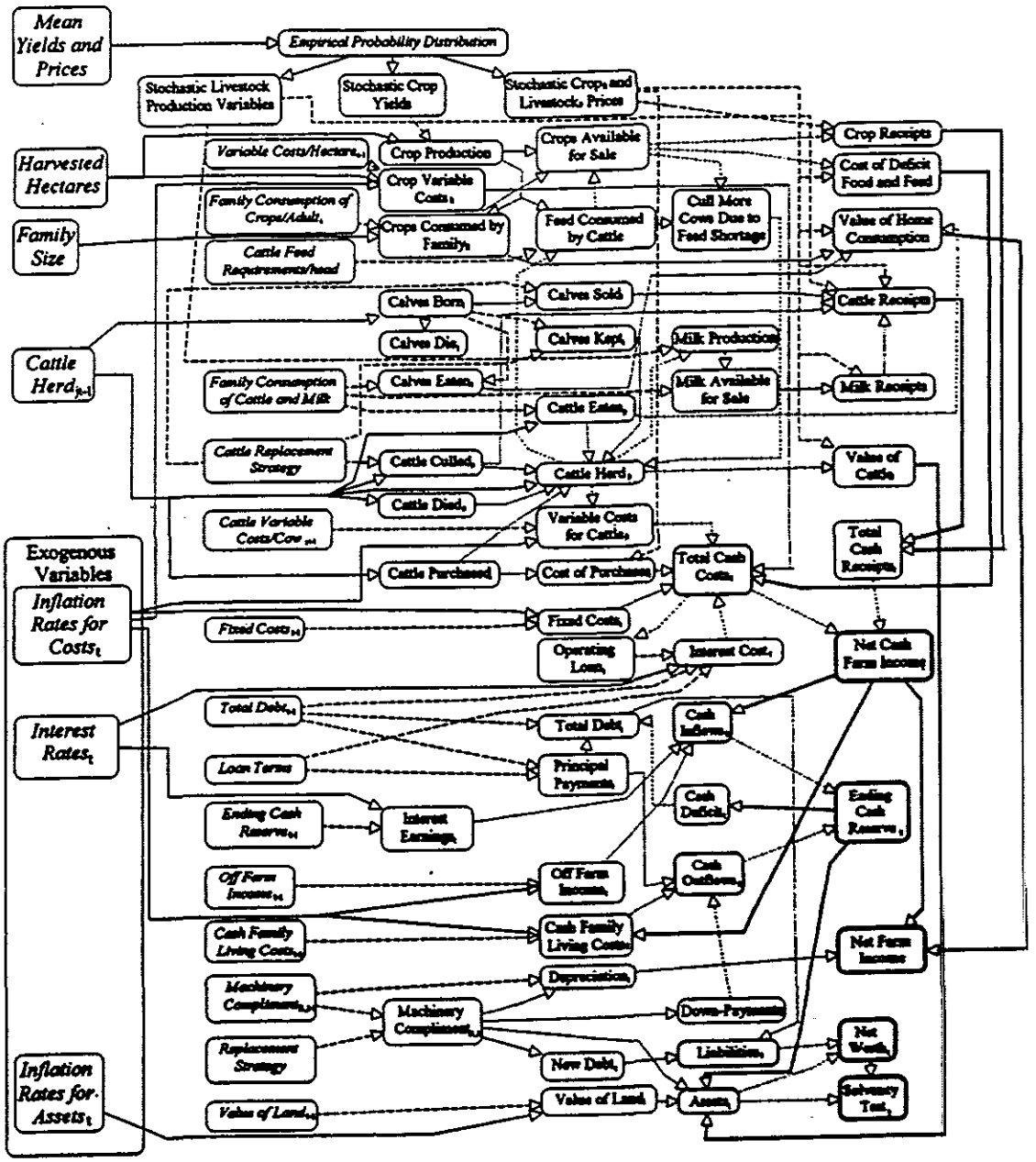

Figure 3.1. Simplified Schematic of Annual Calculations for TIES.

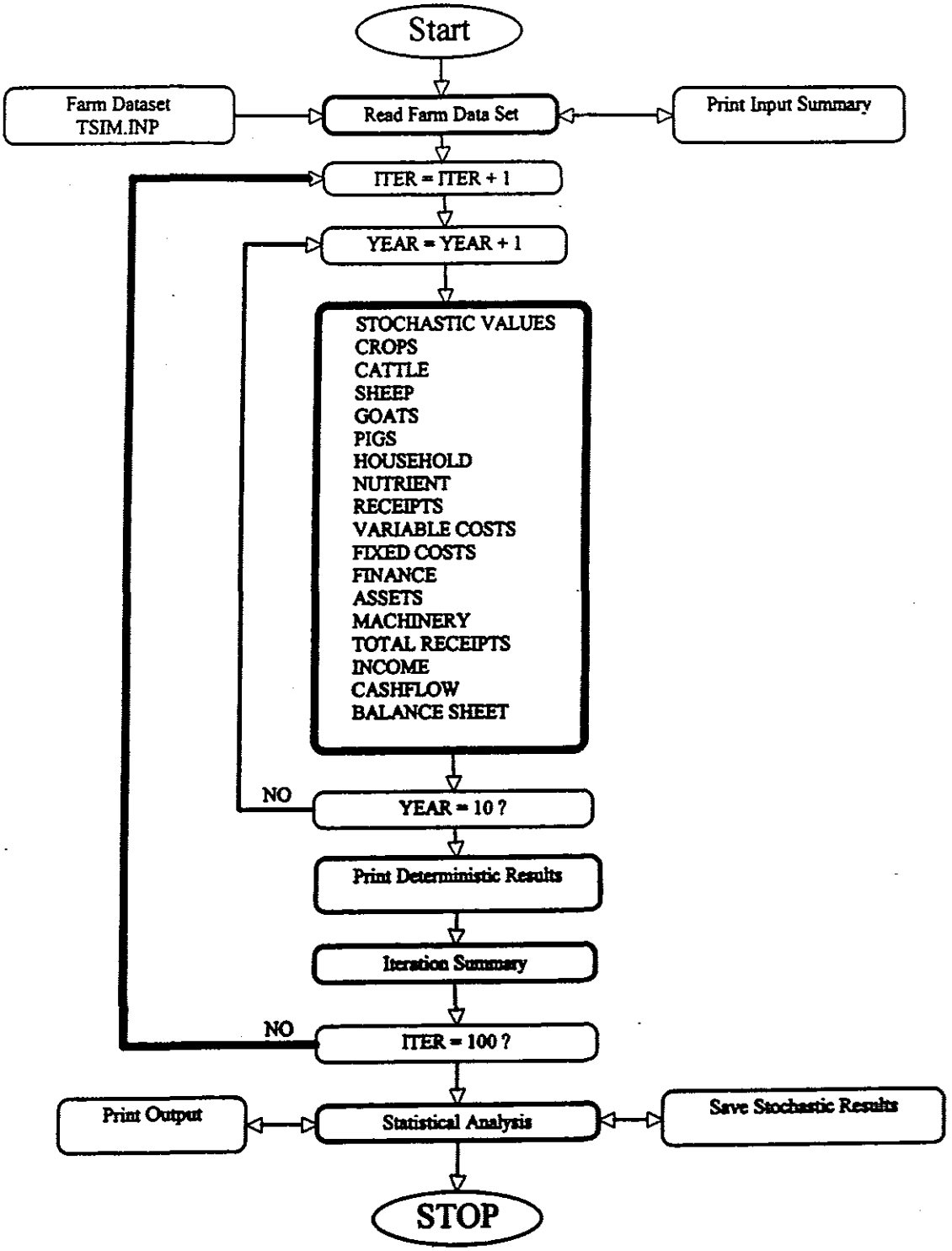

Figure 3.2. Flowchart of the Iterative Procedure for Simulation in TIES.

Crop Production

For the case farms in Mali, the primary farming activity is the production of crops. TIES is capable of simulating 20 different crops. Production is calculated in each year of the planning horizon from yield per hectare and harvested hectares. Crop production is first available for consumption by the farm family and then for either sale or livestock feed, based on the composition of the individual farm.

Livestock Production

The farms that were analyzed in this study are, for the most part, not engaged in livestock production; however, there are oxen and goats present on some of the farms. Birth rate, death loss, culling rate, family consumption, and sales for each class of animal determine herd dynamics. The value of livestock is calculated from sales price, except for oxen, which are also considered for their economic value as a farm labor resource.

Household

Family activities also play an important role in modeling the whole farm situation. In developing countries, the primary utilization of crop production on small farms is family consumption. In this analysis, family consumption is determined by the historical consumption patterns of the family. Nutritional requirements can also be used to determine family consumption. If crop production exceeds family consumption needs, the surplus is allocated to either livestock feed or sale. The family members' off farm activities are considered in relation to the revenue that they bring in for the family.

Financial Outcomes

TIES organizes output in the form of the basic financial statements. The income statement is the summation of all cash receipts and expenses. Net cash farm income is the total cash receipts minus the total cash expenses. Net farm income is the net cash farm income minus depreciation and the value of non-cash costs, plus the value of family consumption and the change in value of livestock.

The cash flow statement is comprised of net cash farm income from the income statement and off farm income as credits and down payments for machinery and livestock, principal payments, and cash household living expense as debits. Cash flow deficits are reconciled by borrowing against equity. If the borrowing against the equity is not sufficient in covering the cash flow deficit, the farm is declared insolvent and the iteration is terminated.

A balance sheet with detailed enterprise summaries is also provided. At the end of the planning horizon the market values for land, machinery, and livestock are estimated. Cash on hand is taken from the cash flows statement. Liabilities are calculated on the long term and intermediate assets as the remaining balances after existing loans are amortized adding new loans to cover cash flow deficits or machinery and livestock purchases. Net worth is the difference between assets and liabilities.

Case Farms

The first step in developing case farms is determining the actual farms that will be modeled. This selection is done with the help of regional experts and the local

extension agents in the areas being considered. After regional experts identify case farms, the economic and technical data that are required as inputs in the TIES model are collected in a farm interview process. In this process an agricultural economist familiar with TIES accompanied by the local extension agent interviews the operator of each farm. The interviewer is aided by an extensive survey that was developed specifically to gather TIES data. Through the interview process the economist can collect the data required to appropriately model the farm while receiving interactive feedback from the farmer and the extension specialist.

The case farms selected for this study are located in three regions of Mali. From north to south those regions are Mopti, Segou, and Koulikoro. Each of these regions contain a major city that acts as the primary marketplace. However, perishable goods are sold in the villages where the case farms are located. Because the farms are engaged in subsistence agriculture, less than half of the farms' production is sold in either marketplace.

Mopti

The case farm in Mopti has 10 hectares of cropland that is planted to millet, cowpeas, sorghum, peanuts, groundnuts, and sesame. Peanuts have historically been the main revenue crop grown on the farm. The average annual rainfall in Mopti is between 400 to 600 mm with a 90 to 120 day rainy season. The household contains 12 people, 7 of whom are working age. The head of the household is employed off of the farm as a tailor.

Segou

The case farm in Segou is on the edge of Mali's cotton producing region. The rainy season in Segou is between 120 and 150 days with a rainfall averaging 600 to 800 mm annually. This farm uses 18 hectares of cropland to produce cotton, sorghum, millet, peanuts, and maize. Over 40 percent of the cropland is planted with cotton, as it generates the most revenue for the farm. Of the 21 members that make up the farm household 12 are of working age.

Koulikoro

The case farm in Koulikoro is the farm that receives the most rainfall ranging from 800 to 1200 mm annually during the 150 day rainy season. This contributes to the wider variety of crops that are grown on this farm's 20 hectares of cropland. Maize, sorghum, cotton, millet, peanuts, rice, and fonio are grown on the Koulikoro farm with cotton being the most profitable crop. The household consists of 17 individuals with several family members employed outside of the farm.

Technology

The specific technology that this study analyzes is the introduction of improved sorghum varieties in the case farm setting. With funding from the United States Agency for International Development (USAID) scientists from the Institut D'Economie Rurale (IER) and International Sorghum and Millet (INTSORMIL) Collaborative Research Support Program (CRSP) have developed two improved varieties of guinea-type sorghum, N'Tenimissa and Seguetana, that are adapted to the

rainfall zones that are found in Mali. N'Tenimissa is a white-seeded sorghum that is tolerant of head bugs. Field tests for the N'Tenimissa sorghum have shown a 25 percent yield increase over local varieties. The Seguetana variety is also tolerant of head bugs but was developed as a striga-resistant sorghum. In field tests, yields for Seguetana increased by 33 percent over indigenous varieties. It is important to note that yield increases provided by INTSORMIL were the same for all of the regions in this study.

Farm Level Assumptions

This study assumed that the improved sorghum varieties would be introduced and cultivated in the same cropping system that is used to cultivate the local varieties of sorghum that are present on the case farms. Current farming practices include the use of animal traction and manure, ridge tilling, and harvesting crops by hand. The case farms in Segou and Koulikoro use small amounts of inorganic fertilizer on cotton, the main cash crop, and maize, the main foodstuff.

Although consumption patterns will likely change under conditions of higher yields, limitations in consumption data created the need to keep farm family consumption at 1997 levels over the ten year planning horizon. Family size and off-farm income were also set at existing levels.

Macroeconomic Assumptions

Because of data limitations, the macroeconomic decision variables in TIES, such as the inflation rate, remained constant. The Mali Agriculture Sector Model (ASM) was used to determine the changes in crop prices under the two technology scenarios. The

percent change in regional prices for each crop was calculated in Mali ASM under both scenarios and applied to the prices given by the farmers on the case farms. These changes were assumed to be accurately calculated in Mali ASM.

Stochastic Dominance

To determine the technology scenario that is most preferred by a risk averse decision maker, the probability distributions of net present values generated by TIES for each scenario was evaluated using stochastic dominance with respect to a function (STODOM). The use of STODOM predicated the need for acquiring the decision-maker's utility function.

An upper and lower bound on the Arrow and Pratt risk aversion coefficient was used to determine the efficient set of scenarios for a given level of risk aversion. The upper bound was set at $5/\sigma_Y$, where σ_Y is the standard deviation of the net present value Y, and the lower bound was set at zero. A sensitivity analysis was conducted to determine the effect that a given level of risk aversion would have on the ranking of scenarios by altering the bounds of the risk aversion coefficient.

CHAPTER IV

RESULTS

This chapter presents the results of the technology assessments for the case farms in Mali. The first section reviews the results of the TIES analysis segmenting each farm as a separate treatment. The second section is a discussion of the STODOM analysis. In the final section the findings of the study are summarized.

TIES Results

The initial step in the study was the establishment of a base scenario for the farms in each region, from which technology alternatives were analyzed. This process was performed as a joint effort between modelers in the U.S. and agents from Mali. The deterministic results from this baseline were then validated by regional experts from Mali and prepared for alternative technology scenarios. Two technology scenarios were used, N'Tenimissa sorghum and Seguetana sorghum. The effects of introducing these technologies were then divided by rates of adopting the new technology into low adoption, non-adopters, and full adoption.

In the low adoption scenario, the improved sorghum technology is adopted on the case farm but is not widely adopted by the region or the nation. The additional production of sorghum at regional and national levels is not significant enough to cause price shifts, in the low adoption scenario. The case farm can reap the rewards of a higher sorghum yield without the effects of price changes. In the non-adopters

scenario, the improved sorghum technology has been widely adopted at the regional and national level but has not been adopted on the case farm, i.e., the case farm is a non adopter. Agricultural prices in the non-adopters scenario will change due to the outward shift in the supply of sorghum caused by the increased yield of the improved sorghum varieties. Price changes for the case farms were derived from the Mali ASM model and are presented in Table 4.1. The case farm will be subject to the new price regimes at a lower yield than the regional average. In the full adoption scenario, the improved sorghum technology has been adopted at the regional and national levels as well as on the case farm. Both the yield and the price effects from the improved sorghum varieties will be represented on the case farm under the full adoption scenario.

TIES was used to simulate 10 years of activity on each farm. Stochastic results from this simulation were generated for the ten year planning horizon and validated by the regional experts. Key variables were summarized in tables for each farm under all scenarios. This section presents those tables and analyzes the results that they summarize. The general format of the discussion is to present the base and then compare the base to the adoption rates for the two technologies. Because the effects of the technologies were quite similar, differing only in the magnitude of their effects, they will be presented together.

Mopti

The farm in Mopti had the highest relative risk on income of the farms in the analysis. The reason for this high risk is in the most part due to the weather and soil conditions in Mopti. Because of it's harsh weather conditions and poor soil, Mopti is

Table 4.1. Changes in the Regional Prices of Crops for N'Tenimissa and Seguetana Technology From Mali ASM for the Crops Grown on the TIES Case Farms as Percenatge Changes From the Base

Region	Crop	N'Tenimissa	Seguetana
Mopti			
	Cowpea	-24.16	-24.18
	Groundnuts	-38.63	-38.63
	Millet	-51.36	-51.38
	Peanuts	-38.63	-38.63
	Sesame	0.00	0.00
	Sorghum	-6.00	-6.42
Segou			
	Cotton	0.00	0.00
	Maize	12.08	12.98
	Millet	-51.36	-51.38
	Peanuts	-38.63	-38.63
	Sorghum	-6.45	-6.90
Koulikoro			
	Cotton	0.00	0.00
	Fonio	20.65	20.65
	Maize	16.99	17.96
	Millet	-50.61	-50.64
	Peanuts	-23.21	-23.21
	Rice	20.65	20.65
	Sorghum	-6.29	-6.73

the most difficult region in this study to farm. The farming conditions in Mopti limit both the crop mix and the yields on the case farm. As a result of the limitations, Mopti is the region that dedicates most of its agricultural resources to subsistence farming.

Base

The high risk on the case farm in Mopti is represented by the coefficient of variation of 167.22 on the net present value for the farm. The coefficient of variation is the standard deviation divided by the mean and can be used to measure the relative risk that the farm faces. The coefficient of variation for net present value can be used across scenarios for an individual farm to evaluate the changes that occur under different conditions. Average annual net cash farm income over the ten year planning horizon was the lowest of the farms in the study under current conditions at 20,760 fcfa or about $36 at the current exchange rate of 575 Mali Francs to 1 U.S. Dollar (Table 4.2). The primary reason for this low level of income is the high percentage of production that is consumed by the farm family. The farm's real net worth or equity will decline by an average of 25 percent over the 10 year planning horizon. There is a 77 percent probability of lower real equity.

Low Adoption

Increased sorghum yields make the projections for the financial health of the case farm in Mopti better than the baseline projections for that farm. N'Tenimissa has a yield 25 percent greater than indigenous varieties and Seguetana has a yield increase of 33 percent. These yield increases allow the Mopti farm to maintain subsistence levels in lean years and sell more in normal years. Average annual net cash farm income on

Table 4.2. Implications of Introducing Improved Varieties of Sorghum on the Case Farm in Mopti, Assuming Low Adoption

	Base	N'Tenimissa	Seguetana
Probability of B/C >= 1.0[a] (%)	64	96	97
Probability of Survival[b] (%)	100	100	100
Probability of Economic Success[c] (%)	64	96	97
Probability of Lower Real Equity[d] (%)	77	40	24
Net Present Value,[e] 1000 fcfa			
Mean	37.64	118.62	149.82
Std. Dev.	62.93	77.89	79.28
Present Value Ending Net Worth,[f] 1000 fcfa			
Mean	201.19	334.36	390.10
Std. Dev.	106.87	152.50	158.61
Benefit Cost Ratio[g]			
Mean	1.81	3.52	4.22
Std. Dev.	1.30	1.78	1.84
Change in Real Net Worth[h] (%)			
Mean	-25.48	23.84	44.48
Std. Dev.	39.58	56.48	58.74
Average Annual Cash Receipts,[i] 1000 fcfa			
Mean	42.27	56.59	61.65
Std. Dev.	10.88	11.64	11.90
Average Annual Cash Expenses,[j] 1000 fcfa			
Mean	21.51	19.26	18.39
Std. Dev.	3.73	3.48	2.96
Average Annual Net Cash Farm Income,[k] 1000 fcfa			
Mean	20.76	37.32	43.26
Std. Dev.	13.08	13.99	13.86

[a]Probability of B/C >= 1.0 - Chance that the farm will generate a Benefit Cost ratio greater than or equal to one.

[b]Probability of Survival - Chance that the farm will not be declared insolvent, i.e., equity to asset ratio greater than the minimum of 0.19.

[c]Probability of Economic Success - Chance that the farm will earn a return on initial equity greater than 0.1260.

[d]Probability of Lower Real Equity - Chance that the farm will experience a decrease in net worth after adjusting for inflation.

[e]Net Present Value - After-tax net return to initial equity, assuming an after-tax discount rate of 0.1260

[f]Present Value Ending Net Worth - Discounted value of farm's net worth in the last year simulated.

[g]Benefit Cost Ratio - The ratio of present value for annual returns divided by the present value of annual costs.

[h]Change in Real Net Worth - Percentage change in real net worth over the simulation period, 1997-2006.

[i]Cash Receipts - Total cash receipts from crops and other farm related activities.

[j]Cash Expenses - Total cash costs for crop production, including interest and fixed cash costs; excludes depreciation.

[k]Annual Net Cash Income - Total cash receipts minus total cash expenses; excludes family living expenses, principal payments, and costs to replace capital assets.

the Mopti farm increases by 80 percent over the base under N'Tenimissa technology and 108 percent over the base under Seguetana technology (Table 4.2). The change in real net worth is positive for both technologies and the probability of lower real equity decreases by 48 percent under N'Tenimissa and 69 percent with Seguetana. When compared to the base, the relative risk for net present value on the Mopti farm is reduced by 60 percent under N'Tenimissa and 68 percent under Seguetana.

Non-Adopters

Regional price changes for the crops grown on the Mopti farm are not significantly different between the two improved technology alternatives and range from a 50 percent drop in the price of millet relative to the base to no change in the price of sesame (Table 4.3). Low prices force average annual net cash farm income to decrease by 72 percent from the base under both the N'Tenimissa and Seguetana scenarios. There is a 22 percent probability of having lower real equity than the base. Net present value on the case farm in Mopti is negative for a non-adopter under both scenarios of technological change.

Full Adoption

The full adoption scenario assumes that all sorghum is produced utilizing the technology being analyzed, either N'Tenimissa or Seguetana. The result for the farm is higher yields and lower prices. The change from the base in average annual net cash farm income for the case farm in Mopti is 10 percent when N'Tenimissa is used and 36 percent when Seguetana is used (Table 4.4). Real net worth increases over the base for both scenarios and the probability of lower real equity decreases by 53 percent for

Table 4.3. Implications of Introducing Improved Varieties of Sorghum on the Case Farm in Mopti, Assuming Non-Adopters

	Base	N'Tenimissa	Seguetana
Probability of B/C >= 1.0[a] (%)	64	24	24
Probability of Survival[b] (%)	100	100	100
Probability of Economic Success[c] (%)	64	24	24
Probability of Lower Real Equity[d] (%)	77	94	94
Net Present Value,[e] 1000 fcfa			
Mean	37.64	-17.31	-17.45
Std. Dev.	62.93	41.16	41.11
Present Value Ending Net Worth,[f] 1000 fcfa			
Mean	201.19	147.08	146.92
Std. Dev.	106.87	72.70	72.63
Benefit Cost Ratio[g]			
Mean	1.81	0.78	0.78
Std. Dev.	1.30	0.76	0.76
Change in Real Net Worth[h] (%)			
Mean	-25.48	-45.53	-45.59
Std. Dev.	39.58	26.93	26.90
Average Annual Cash Receipts,[i] 1000 fcfa			
Mean	42.27	27.82	27.79
Std. Dev.	10.88	6.41	6.40
Average Annual Cash Expenses,[j] 1000 fcfa			
Mean	21.51	21.91	21.91
Std. Dev.	3.73	3.03	3.03
Average Annual Net Cash Farm Income,[k] 1000 fcfa			
Mean	20.76	5.91	5.87
Std. Dev.	13.08	8.26	8.25

[a]Probability of B/C >= 1.0 - Chance that the farm will generate a Benefit Cost ratio greater than or equal to one.

[b]Probability of Survival - Chance that the farm will not be declared insolvent, i.e., equity to asset ratio greater than the minimum of 0.19.

[c]Probability of Economic Success - Chance that the farm will earn a return on initial equity greater than 0.1260.

[d]Probability of Lower Real Equity - Chance that the farm will experience a decrease in net worth after adjusting for inflation.

[e]Net Present Value - After-tax net return to initial equity, assuming an after-tax discount rate of 0.1260

[f]Present Value Ending Net Worth - Discounted value of farm's net worth in the last year simulated.

[g]Benefit Cost Ratio - The ratio of present value for annual returns divided by the present value of annual costs.

[h]Change in Real Net Worth - Percentage change in real net worth over the simulation period, 1997-2006.

[i]Cash Receipts - Total cash receipts from crops and other farm related activities.

[j]Cash Expenses - Total cash costs for crop production, including interest and fixed cash costs; excludes depreciation.

[k]Annual Net Cash Income - Total cash receipts minus total cash expenses; excludes family living expenses, principal payments, and costs to replace capital assets.

Table 4.4. Implications of Introducing Improved Varieties of Sorghum on the Case Farm in Mopti, Assuming Full Adoption

	Base	N'Tenimissa	Seguetana
Probability of B/C >= 1.0[a] (%)	64	86	94
Probability of Survival[b] (%)	100	100	100
Probability of Economic Success[c] (%)	64	86	94
Probability of Lower Real Equity[d] (%)	77	36	19
Net Present Value,[e] 1000 fcfa			
Mean	37.64	69.87	99.59
Std. Dev.	62.93	55.09	54.34
Present Value Ending Net Worth,[f] 1000 fcfa			
Mean	201.19	300.16	355.27
Std. Dev.	106.87	109.61	110.16
Benefit Cost Ratio[g]			
Mean	1.81	2.54	3.19
Std. Dev.	1.30	1.20	1.22
Change in Real Net Worth[h] (%)			
Mean	-25.48	11.17	31.58
Std. Dev.	39.58	40.60	40.80
Average Annual Cash Receipts,[i] 1000 fcfa			
Mean	42.27	41.27	45.92
Std. Dev.	10.88	7.46	7.78
Average Annual Cash Expenses,[j] 1000 fcfa			
Mean	21.51	18.51	17.70
Std. Dev.	3.73	3.04	2.38
Average Annual Net Cash Farm Income,[k] 1000 fcfa			
Mean	20.76	22.76	28.21
Std. Dev.	13.08	9.62	9.30

[a]Probability of B/C >= 1.0 - Chance that the farm will generate a Benefit Cost ratio greater than or equal to one.

[b]Probability of Survival - Chance that the farm will not be declared insolvent, i.e., equity to asset ratio greater than the minimum of 0.19.

[c]Probability of Economic Success - Chance that the farm will earn a return on initial equity greater than 0.1260.

[d]Probability of Lower Real Equity - Chance that the farm will experience a decrease in net worth after adjusting for inflation.

[e]Net Present Value - After-tax net return to initial equity, assuming an after-tax discount rate of 0.1260

[f]Present Value Ending Net Worth - Discounted value of farm's net worth in the last year simulated.

[g]Benefit Cost Ratio - The ratio of present value for annual returns divided by the present value of annual costs.

[h]Change in Real Net Worth - Percentage change in real net worth over the simulation period, 1997-2006.

[i]Cash Receipts - Total cash receipts from crops and other farm related activities.

[j]Cash Expenses - Total cash costs for crop production, including interest and fixed cash costs; excludes depreciation.

[k]Annual Net Cash Income - Total cash receipts minus total cash expenses; excludes family living expenses, principal payments, and costs to replace capital assets.

N'Tenimissa and 75 percent for Seguetana. Relative risk for net present value on the Mopti farm is reduced by 53 percent for the N'Tenimissa scenario and 67 percent for the Seguetana scenario.

Although the outlook of the farm's financial outlook is improved with the introduction of N'Tenimissa or Seguetana sorghum with full adoption, it is important to note the effect that moving to full adoption has on the early and non-adopters. In the initial stages of adoption the early adopters will experience a situation similar to that of the low adoption scenario. Further along as prices adjust to increased supply, the early adopters will experience a downward turn in average annual net cash receipts and net present value. Non-adopters will see positive results as they adopt the new technology and price adjustments will have already been made and the increased yield will in turn increase average annual net cash farm income.

Segou

The case farm in Segou is located on the edge of Mali's cotton producing region. Cotton is one of the major revenue producing crops that is grown in Mali. The crop mix on the Segou farm reflects the revenue that the production of cotton generates. Over one third of the land on the farm is dedicated to cotton and, over 80 percent of receipts are generated by the sale of cotton. The crop mixes on the other two farms in the analysis have a stronger emphasis on foodstuffs.

Base

The high income level of the farm in Segou is indicated by the farm's 2,367,180 fcfa ($4,117) average annual net cash farm income (Table 4.5). This income can be

Table 4.5. Implications of Introducing Improved Varieties of Sorghum on the Case Farm in Segou, Assuming Low Adoption

	Base	N'Tenimissa	Seguetana
Probability of B/C >= 1.0[a] (%)	100	100	100
Probability of Survival[b] (%)	100	100	100
Probability of Economic Success[c] (%)	100	100	100
Probability of Lower Real Equity[d] (%)	0	0	0
Net Present Value,[e] 1000 fcfa			
Mean	12413.39	13181.67	13429.27
Std. Dev.	1056.58	1064.96	1068.06
Present Value Ending Net Worth,[f] 1000 fcfa			
Mean	22358.38	23777.15	24233.86
Std. Dev.	1949.15	1964.57	1970.30
Benefit Cost Ratio[g]			
Mean	15.02	15.89	16.17
Std. Dev.	1.19	1.20	1.21
Change in Real Net Worth[h] (%)			
Mean	10299.15	10959.04	11171.46
Std. Dev.	906.57	913.74	916.41
Average Annual Cash Receipts,[i] 1000 fcfa			
Mean	2695.89	2838.87	2885.05
Std. Dev.	195.24	196.86	197.46
Average Annual Cash Expenses,[j] 1000 fcfa			
Mean	328.70	328.48	328.39
Std. Dev.	0.37	0.35	0.30
Average Annual Net Cash Farm Income,[k] 1000 fcfa			
Mean	2367.18	2510.39	2556.65
Std. Dev.	195.27	196.90	197.49

[a]Probability of B/C >= 1.0 - Chance that the farm will generate a Benefit Cost ratio greater than or equal to one.

[b]Probability of Survival - Chance that the farm will not be declared insolvent, i.e., equity to asset ratio greater than the minimum of 0.19.

[c]Probability of Economic Success - Chance that the farm will earn a return on initial equity greater than 0.1260.

[d]Probability of Lower Real Equity - Chance that the farm will experience a decrease in net worth after adjusting for inflation.

[e]Net Present Value - After-tax net return to initial equity, assuming an after-tax discount rate of 0.1260

[f]Present Value Ending Net Worth - Discounted value of farm's net worth in the last year simulated.

[g]Benefit Cost Ratio - The ratio of present value for annual returns divided by the present value of annual costs.

[h]Change in Real Net Worth - Percentage change in real net worth over the simulation period, 1997-2006.

[i]Cash Receipts - Total cash receipts from crops and other farm related activities.

[j]Cash Expenses - Total cash costs for crop production, including interest and fixed cash costs; excludes depreciation.

[k]Annual Net Cash Income - Total cash receipts minus total cash expenses; excludes family living expenses, principal payments, and costs to replace capital assets.

largely attributed to the sale of cotton. The Segou has no probability of lower real equity. Relative risk on the case farm in Segou, as measured by the coefficient of variation on net present value, is much less than the risk on the Mopti farm. The coefficient of variation on the net present value for the Segou farm is 8.51 as compared to the

coefficient of variation on the case farm in Mopti of 167.22. The net present value of the farm in Segou under current conditions is 12,413,390 fcfa.

Low Adoption

Low adoption of the technologies will allow the farm in Segou to see the advantage of higher sorghum yields at current prices. Although sorghum is second in planted acres behind cotton, the increases due to yield have only a small effect on the financial health of the farm. The additional revenue generated from the higher yielding sorghum is less than 5 percent of the total deterministic revenues on the farm under the N'Tenimissa scenario and only 6 percent under Seguetana. Average annual net cash farm income increases by 6 percent for N'Tenimissa and 8 percent for Seguetana (Table 4.5). The farm's net present value is also increased by 6 percent for the N'Tenimissa scenario and 8 percent for the Seguetana scenario. Relative risk on the Segou farm's net present value is not changed significantly from the base.

Non-Adopters

As is the case with the low adoption scenario, the changes due to the sorghum technologies have a small effect on the non-adopters. The prices for most foodstuffs drop considerably but the price for cotton is unchanged under both improved

technology alternatives. In both the N'Tenimissa scenario and the Seguetana scenario, the average annual net cash farm income decreases by 4 percent from the base (Table 4.6). Net present value for the farm in Segou also decreases by 4 percent. Relative risk is again not changed significantly from either the base or the low adoption scenario.

Full Adoption

A comparison of the changes between the low adoption scenario and the non-adopter scenario indicates that there will be little change in the Segou farm in the full adoption scenario. There is not a significant change in relative risk between the base, the N'Tenimissa, and the Seguetana scenarios. Net present value for the Segou farm changes by less than 1 percent (Table 4.7). Average annual net cash farm income increases by 1 percent for N'Tenimissa and 3 percent for Seguetana. The change in real net worth and net present value of the farm change by less than 5 percent for both technology alternatives.

Koulikoro

The annual average rainfall in the Koulikoro gives this region the most favorable climate and ecology for farming. The case farm in Koulikoro is in the middle of the cotton producing region and is able to grow rice as well. However, the farmer on the case farm in this region is more concerned with subsistence than commercial agriculture and plants over half of the available cropland with maize and sorghum, two of Mali's dietary staples. Because the farm family consumes most of the maize and sorghum, cotton is the major source of revenue for the farm with rice generating the second highest revenue.

Table 4.6. Implications of Introducing Improved Varieties of Sorghum on the Case Farm in Segou, Assuming Non-Adopters

	Base	N'Tenimissa	Seguetana
Probability of B/C >= 1.0[a] (%)	100	100	100
Probability of Survival[b] (%)	100	100	100
Probability of Economic Success[c] (%)	100	100	100
Probability of Lower Real Equity[d] (%)	0	0	0
Net Present Value,[e] 1000 fcfa			
Mean	12413.39	11876.70	11874.42
Std. Dev.	1056.58	1046.45	1046.32
Present Value Ending Net Worth,[f] 1000 fcfa			
Mean	22358.38	21369.36	21365.15
Std. Dev.	1949.15	1930.32	1930.09
Benefit Cost Ratio[g]			
Mean	15.02	14.42	14.41
Std. Dev.	1.19	1.18	1.18
Change in Real Net Worth[h] (%)			
Mean	10299.15	9839.15	9837.19
Std. Dev.	906.57	897.82	897.71
Average Annual Cash Receipts,[i] 1000 fcfa			
Mean	2695.89	2595.35	2594.93
Std. Dev.	195.24	193.24	193.22
Average Annual Cash Expenses,[j] 1000 fcfa			
Mean	328.70	328.75	328.75
Std. Dev.	0.37	0.30	0.30
Average Annual Net Cash Farm Income,[k] 1000 fcfa			
Mean	2367.18	2266.61	2266.18
Std. Dev.	195.27	193.30	193.28

[a]Probability of B/C >= 1.0 - Chance that the farm will generate a Benefit Cost ratio greater than or equal to one.

[b]Probability of Survival - Chance that the farm will not be declared insolvent, i.e., equity to asset ratio greater than the minimum of 0.19.

[c]Probability of Economic Success - Chance that the farm will earn a return on initial equity greater than 0.1260.

[d]Probability of Lower Real Equity - Chance that the farm will experience a decrease in net worth after adjusting for inflation.

[e]Net Present Value - After-tax net return to initial equity, assuming an after-tax discount rate of 0.1260

[f]Present Value Ending Net Worth - Discounted value of farm's net worth in the last year simulated.

[g]Benefit Cost Ratio - The ratio of present value for annual returns divided by the present value of annual costs.

[h]Change in Real Net Worth - Percentage change in real net worth over the simulation period, 1997-2006.

[i]Cash Receipts - Total cash receipts from crops and other farm related activities.

[j]Cash Expenses - Total cash costs for crop production, including interest and fixed cash costs; excludes depreciation.

[k]Annual Net Cash Income - Total cash receipts minus total cash expenses; excludes family living expenses, principal payments, and costs to replace capital assets.

Table 4.7. Implications of Introducing Improved Varieties of Sorghum on the Case Farm in Segou, Assuming Full Adoption

	Base	N'Tenimissa	Seguetana
Probability of B/C >= 1.0[a] (%)	100	100	100
Probability of Survival[b] (%)	100	100	100
Probability of Economic Success[c] (%)	100	100	100
Probability of Lower Real Equity[d] (%)	0	0	0
Net Present Value,[e] 1000 fcfa			
Mean	12413.39	12595.51	12820.27
Std. Dev.	1056.58	1053.82	1056.34
Present Value Ending Net Worth,[f] 1000 fcfa			
Mean	22358.38	22696.76	23111.34
Std. Dev.	1949.15	1943.90	1948.55
Benefit Cost Ratio[g]			
Mean	15.02	15.23	15.48
Std. Dev.	1.19	1.19	1.19
Change in Real Net Worth[h] (%)			
Mean	10299.15	10456.54	10649.36
Std. Dev.	906.57	904.13	906.30
Average Annual Cash Receipts,[i] 1000 fcfa			
Mean	2695.89	2729.13	2771.06
Std. Dev.	195.24	194.67	195.15
Average Annual Cash Expenses,[j] 1000 fcfa			
Mean	328.70	328.41	328.32
Std. Dev.	0.37	0.30	0.24
Average Annual Net Cash Farm Income,[k] 1000 fcfa			
Mean	2367.18	2400.73	2442.73
Std. Dev.	195.27	194.69	195.15

[a]Probability of B/C >= 1.0 - Chance that the farm will generate a Benefit Cost ratio greater than or equal to one.

[b]Probability of Survival - Chance that the farm will not be declared insolvent, i.e., equity to asset ratio greater than the minimum of 0.19.

[c]Probability of Economic Success - Chance that the farm will earn a return on initial equity greater than 0.1260.

[d]Probability of Lower Real Equity - Chance that the farm will experience a decrease in net worth after adjusting for inflation.

[e]Net Present Value - After-tax net return to initial equity, assuming an after-tax discount rate of 0.1260

[f]Present Value Ending Net Worth - Discounted value of farm's net worth in the last year simulated.

[g]Benefit Cost Ratio - The ratio of present value for annual returns divided by the present value of annual costs.

[h]Change in Real Net Worth - Percentage change in real net worth over the simulation period, 1997-2006.

[i]Cash Receipts - Total cash receipts from crops and other farm related activities.

[j]Cash Expenses - Total cash costs for crop production, including interest and fixed cash costs; excludes depreciation.

[k]Annual Net Cash Income - Total cash receipts minus total cash expenses; excludes family living expenses, principal payments, and costs to replace capital assets.

Base

The farm in Koulikoro has the lowest relative risk of the case farms in this study. The coefficient of variation on the farm's net present value is 5.46 under current conditions. Average annual net cash farm income for the farm in Koulikoro is 605,390 fcfa (Table 4.8). There is a zero probability of lower real equity for this farm. The Koulikoro farm's net present value is 3,842,170 fcfa.

Low Adoption

Like the farm in Segou, most of the Koulikoro farm's revenue comes from the production of cotton and like the Segou farm this lessens the effect that the alternative technologies have on net income for the case farm. Relative risk on the farm decreases slightly for the N'Tenimissa and Seguetana scenarios. The average annual net cash farm income increases by 8 percent under N'Tenimissa and 11 percent under Seguetana, which is less than the changes in Mopti but more than those in Segou (Table 4.8). The net present value increases by 6 percent for the N'Tenimissa alternative and 9 percent for the Seguetana alternative.

Non-Adopters

The case of non-adopters on the farm in Koulikoro yields different results than the other farms in the study. As in Segou, the price of cotton in Koulikoro stays the same, limiting the effect that the decrease in foodstuff prices have on the farm. However, the difference is that the price of rice in Koulikoro increases. Rice generates the second highest revenue on the Koulikoro farm and more than offsets the price decreases in other crops. One of the effects that these price changes have is a slight

Table 4.8. Implications of Introducing Improved Varieties of Sorghum on the Case Farm in Koulikoro, Assuming Low Adoption

	Base	N'Tenimissa	Seguetana
Probability of B/C >= 1.0[a] (%)	100	100	100
Probability of Survival[b] (%)	100	100	100
Probability of Economic Success[c] (%)	100	100	100
Probability of Lower Real Equity[d] (%)	0	0	0
Net Present Value,[e] 1000 fcfa			
Mean	3842.17	4064.29	4178.99
Std. Dev.	209.66	217.73	242.37
Present Value Ending Net Worth,[f] 1000 fcfa			
Mean	10650.01	11098.41	11281.60
Std. Dev.	479.56	487.68	557.49
Benefit Cost Ratio[g]			
Mean	11.44	12.05	12.36
Std. Dev.	0.57	0.59	0.66
Change in Real Net Worth[h] (%)			
Mean	6453.81	6729.75	6842.48
Std. Dev.	295.11	300.11	343.07
Average Annual Cash Receipts,[i] 1000 fcfa			
Mean	773.97	825.37	842.58
Std. Dev.	45.84	48.32	49.78
Average Annual Cash Expenses,[j] 1000 fcfa			
Mean	168.58	168.56	168.54
Std. Dev.	0.04	0.03	0.02
Average Annual Net Cash Farm Income,[k] 1000 fcfa			
Mean	605.39	656.81	674.04
Std. Dev.	45.84	48.32	49.78

[a]Probability of B/C >= 1.0 - Chance that the farm will generate a Benefit Cost ratio greater than or equal to one.

[b]Probability of Survival - Chance that the farm will not be declared insolvent, i.e., equity to asset ratio greater than the minimum of 0.19.

[c]Probability of Economic Success - Chance that the farm will earn a return on initial equity greater than 0.1260.

[d]Probability of Lower Real Equity - Chance that the farm will experience a decrease in net worth after adjusting for inflation.

[e]Net Present Value - After-tax net return to initial equity, assuming an after-tax discount rate of 0.1260

[f]Present Value Ending Net Worth - Discounted value of farm's net worth in the last year simulated.

[g]Benefit Cost Ratio - The ratio of present value for annual returns divided by the present value of annual costs.

[h]Change in Real Net Worth - Percentage change in real net worth over the simulation period, 1997-2006.

[i]Cash Receipts - Total cash receipts from crops and other farm related activities.

[j]Cash Expenses - Total cash costs for crop production, including interest and fixed cash costs; excludes depreciation.

[k]Annual Net Cash Income - Total cash receipts minus total cash expenses; excludes family living expenses, principal payments, and costs to replace capital assets.

increase in the farm's relative risk under the N'Tenimissa and Seguetana scenarios. Average annual net cash farm income increases by 1 percent and net present value increases by 2 percent in both the N'Tenimissa alternative and the Seguetana alternative (Table 4.9).

Full Adoption

In the full adoption scenario, the relative risk on the farm in Koulikoro increases slightly from the base for both the N'Tenimissa and Seguetana alternatives. The presence of cotton on the Koulikoro farm still limits the effect of the increases in the yield of sorghum and in the new price of rice. However, positive changes due to both the price and the yield effects combine to increase the financial health of the farm in full adoption. Average annual net cash farm income increases by 9 percent when there is full adoption of N'Tenimissa sorghum and by 11 percent when there is full adoption of Seguetana sorghum (Table 4.10). Net present value in full adoption for this farm increases by 7 percent under N'Tenimissa and by 9 percent under Seguetana.

Stochastic Dominance Rankings

STODOM was used to rank the empirical probability distributions of net present value in the full adoption scenario for the three technology alternatives at each case farm location. TIES generated the distributions of net present value in the stochastic simulation of each scenario. To represent a risk averse decision maker risk aversion coefficients (RAC) were set with an upper bound of five divided by the average standard deviation of net present value for the farm across all scenarios. The lower

Table 4.9. Implications of Introducing Improved Varieties of Sorghum on the Case Farm in Koulikoro, Assuming Non-Adopters

	Base	N'Tenimissa	Seguetana
Probability of B/C >= 1.0[a] (%)	100	100	100
Probability of Survival[b] (%)	100	100	100
Probability of Economic Success[c] (%)	100	100	100
Probability of Lower Real Equity[d] (%)	0	0	0
Net Present Value,[e] 1000 fcfa			
Mean	3842.17	3901.56	3902.42
Std. Dev.	209.66	234.83	234.98
Present Value Ending Net Worth,[f] 1000 fcfa			
Mean	10650.01	10728.13	10729.60
Std. Dev.	479.56	550.09	550.42
Benefit Cost Ratio[g]			
Mean	11.44	11.61	11.61
Std. Dev.	0.57	0.64	0.64
Change in Real Net Worth[h] (%)			
Mean	6453.81	6501.89	6502.79
Std. Dev.	295.11	338.52	338.72
Average Annual Cash Receipts,[i] 1000 fcfa			
Mean	773.97	778.01	778.14
Std. Dev.	45.84	47.14	47.15
Average Annual Cash Expenses,[j] 1000 fcfa			
Mean	168.58	168.58	168.58
Std. Dev.	0.04	0.03	0.03
Average Annual Net Cash Farm Income,[k] 1000 fcfa			
Mean	605.39	609.43	609.56
Std. Dev.	45.84	47.15	47.16

[a]Probability of B/C >= 1.0 - Chance that the farm will generate a Benefit Cost ratio greater than or equal to one.

[b]Probability of Survival - Chance that the farm will not be declared insolvent, i.e., equity to asset ratio greater than the minimum of 0.19.

[c]Probability of Economic Success - Chance that the farm will earn a return on initial equity greater than 0.1260.

[d]Probability of Lower Real Equity - Chance that the farm will experience a decrease in net worth after adjusting for inflation.

[e]Net Present Value - After-tax net return to initial equity, assuming an after-tax discount rate of 0.1260

[f]Present Value Ending Net Worth - Discounted value of farm's net worth in the last year simulated.

[g]Benefit Cost Ratio - The ratio of present value for annual returns divided by the present value of annual costs.

[h]Change in Real Net Worth - Percentage change in real net worth over the simulation period, 1997-2006.

[i]Cash Receipts - Total cash receipts from crops and other farm related activities.

[j]Cash Expenses - Total cash costs for crop production, including interest and fixed cash costs; excludes depreciation.

[k]Annual Net Cash Income - Total cash receipts minus total cash expenses; excludes family living expenses, principal payments, and costs to replace capital assets.

Table 4.10. Implications of Introducing Improved Varieties of Sorghum on the Case Farm in Koulikoro, Assuming Full Adoption

	Base	N'Tenimissa	Seguetana
Probability of B/C >= 1.0[a] (%)	100	100	100
Probability of Survival[b] (%)	100	100	100
Probability of Economic Success[c] (%)	100	100	100
Probability of Lower Real Equity[d] (%)	0	0	0
Net Present Value,[e] 1000 fcfa			
Mean	3842.17	4109.70	4178.99
Std. Dev.	209.66	240.41	242.37
Present Value Ending Net Worth,[f] 1000 fcfa			
Mean	10650.01	11148.32	11281.60
Std. Dev.	479.56	555.16	557.49
Benefit Cost Ratio[g]			
Mean	11.44	12.17	12.36
Std. Dev.	0.57	0.65	0.66
Change in Real Net Worth[h] (%)			
Mean	6453.81	6760.46	6842.48
Std. Dev.	295.11	341.64	343.07
Average Annual Cash Receipts,[i] 1000 fcfa			
Mean	773.97	826.16	842.58
Std. Dev.	45.84	49.16	49.78
Average Annual Cash Expenses,[j] 1000 fcfa			
Mean	168.58	168.55	168.54
Std. Dev.	0.04	0.03	0.02
Average Annual Net Cash Farm Income,[k] 1000 fcfa			
Mean	605.39	657.61	674.04
Std. Dev.	45.84	49.17	49.78

[a]Probability of B/C >= 1.0 - Chance that the farm will generate a Benefit Cost ratio greater than or equal to one.

[b]Probability of Survival - Chance that the farm will not be declared insolvent, i.e., equity to asset ratio greater than the minimum of 0.19.

[c]Probability of Economic Success - Chance that the farm will earn a return on initial equity greater than 0.1260.

[d]Probability of Lower Real Equity - Chance that the farm will experience a decrease in net worth after adjusting for inflation.

[e]Net Present Value - After-tax net return to initial equity, assuming an after-tax discount rate of 0.1260

[f]Present Value Ending Net Worth - Discounted value of farm's net worth in the last year simulated.

[g]Benefit Cost Ratio - The ratio of present value for annual returns divided by the present value of annual costs.

[h]Change in Real Net Worth - Percentage change in real net worth over the simulation period, 1997-2006.

[i]Cash Receipts - Total cash receipts from crops and other farm related activities.

[j]Cash Expenses - Total cash costs for crop production, including interest and fixed cash costs; excludes depreciation.

[k]Annual Net Cash Income - Total cash receipts minus total cash expenses; excludes family living expenses, principal payments, and costs to replace capital assets.

bound RAC was set at zero for each farm. Ordering the RAC's in this manner allows for the determination of the most preferred technology alternative on each farm given the assumption of a risk averse decision maker.

Mopti

Table 4.11 summarizes the STODOM results on the case farm in Mopti for the base scenario, the full adoption of N'Tenimissa scenario, and the full adoption of Seguetana scenario. The lower bound RAC was set at 0.00000000 and the upper bound was set at 0.00008703 to represent a risk averse decision maker. The most preferred technology alternative was the introduction of Seguetana sorghum. The adoption of N'Tenimissa sorghum was also preferred over the base situation.

Confidence premiums show how much more net present value is required by the decision maker over the ten year planning horizon to select a lesser preferred scenario. The minimum risk premium that a risk averse decision maker would accept to move from the Seguetana scenario to the N'Tenimissa scenario is 24,579 fcfa. This means that in a random sample of decision makers at least one would select the N'Tenimissa given they received an additional 24,579 fcfa. The maximum risk premium require for a risk averse decision maker to select N'Tenimissa over Seguetana is 32,618 fcfa. These confidence premiums are between 24.68 percent and 32.75 percent of the net present value of the Seguetana alternative.

Segou

The most preferred technology alternative for the case farm in Segou is the introduction of Seguetana sorghum (Table 4.12). The next most preferred alternative is

Table 4.11. Stochastic Dominance Rankings of the Base, N'Tenimissa, and Seguetana Alternatives for the Case Farm in Mopti, Assuming Full Adoption

Technology Alternative	Mean Net Present Value	Standard Deviation	Skewness	Coefficient of Variation	Minimum Net Present Value
Base Scenario	37635	62934.87	0.90	167.22	-79580
N'Tenimissa Scenario	69867	55085.91	-0.12	78.84	-51546
Seguetana Scenario	99586	54337.45	-0.21	54.56	-19281

Risk Aversion Interval (Pratt Coefficients)	
Lower Bound	0.00000000
Upper Bound	0.00008703

Ranking of Technology Alternatives

The Most Preferred Efficient Set Contains:

The Introduction of Seguetana Sorghum

2nd Most Preferred Efficient Set Contains:

The Introduction of N'Tenimissa Sorghum

The Least Preferred Efficient Set Contains:

The Current Baseline Conditions

Confidence Premiums for Specified Probability Distribution Functions*

Dominant PDF	Challenger PDF	As Absolute Monetary Amounts		As a Percentage of The Dominant Mean	
		Lower	Upper	Lower	Upper
		——(fcfa)——		——(%)——	
The Most Dominant PDF					
Seguetana Scenario	N'Tenimissa Scenario	24579	32618	24.68	32.75
Seguetana Scenario	Base Scenario	75236	102760	75.55	103.19
The Next Most Dominant PDF					
N'Tenimissa Scenario	Base Scenario	17991	39573	25.75	56.64

Note: The confidence premiums represent the minimum and maximum amounts of money a decision maker in the risk aversion interval would have to be paid to shift from the dominate distribution to the challanger distribution.

Table 4.12. Stochastic Dominance Rankings of the Base, N'Tenimissa, and Seguetana Alternatives for the Case Farm in Segou, Assuming Full Adoption

Technology Alternative	Mean Net Present Value	Standard Deviation	Skewness	Coefficient of Variation	Minimum Net Present Value
Base Scenario	12413390	1056578.88	0.04	8.51	9726738
N'Tenimissa Scenario	12595506	1053822.25	-0.02	8.37	9875515
Seguetana Scenario	12820269	1056343.00	-0.02	8.24	10097740

Risk Aversion Interval (Pratt Coefficients)	
Lower Bound	0.00000000
Upper Bound	0.00000047

Ranking of Technology Alternatives

The Most Preferred Efficient Set Contains:

The Introduction of Seguetana Sorghum

2nd Most Preferred Efficient Set Contains:

The Introduction of N'Tenimissa Sorghum

The Least Preferred Efficient Set Contains:

The Current Baseline Conditions

Confidence Premiums for Specified Probability Distribution Functions*

Dominant PDF	Challenger PDF	As Absolute Monetary Amounts		As a Percentage of The Dominant Mean	
		Lower	Upper	Lower	Upper
		—(fcfa)—		—(%)—	
The Most Dominant PDF					
Seguetana Scenario	N'Tenimissa Scenario	224757	225757	1.75	1.76
Seguetana Scenario	Base Scenario	632635	633635	4.93	4.94
The Next Most Dominant PDF					
N'Tenimissa Scenario	Base Scenario	182120	183120	1.45	1.45

Note: The confidence premiums represent the minimum and maximum amounts of money a decision maker in the risk aversion interval would have to be paid to shift from the dominate distribution to the challanger distribution.

the introduction of N'Tenimissa sorghum with the base scenario ranked last. The RAC's used to determine the rankings were a lower bound of 0.00000000 and an upper bound of 0.00000047.

A risk averse decision maker would require a minimum risk premium of 224,757 fcfa to select the N'Tenimissa alternative over the Seguetana alternative. The maximum risk premium required to move a decision maker to the N'Tenimissa sorghum from the Seguetana sorghum is 225,757 fcfa. This equates to a range between 1.75 percent and 1.76 percent of the net present value under the Seguetana scenario to switch to the N'Tenimissa scenario.

Koulikoro

Table 4.13 shows that a lower bound RAC of 0.00000000 and an upper bound RAC of 0.00000217 was used to determine the STODOM ranking of alternatives for Koulikoro. The most preferred efficient set for the case farm in Koulikoro is the Seguetana alternative. The second most preferred set is the N'Tenimissa alternative. The base is also ranked last for the Koulikoro farm.

The confidence premium for a decision maker to move from the Seguetana alternative to the N'Tenimissa alternative is between 1.64 percent and 1.65 percent of the net present value of the Seguetana scenario. The lower bound of the confidence premium for the case farm in Koulikoro is a 68,351 fcfa risk premium. The upper bound risk premium is 69,101 for a risk averse decision maker.

Table 4.13. Stochastic Dominance Rankings of the Base, N'Tenimissa, and Seguetana Alternatives for the Case Farm in Koulikoro, Assuming Full Adoption

Technology Alternative	Mean Net Present Value	Standard Deviation	Skewness	Coefficient of Variation	Minimum Net Present Value
Base Scenario	3842169	209661.91	-0.22	5.46	3205638
N'Tenimissa Scenario	4109705	240410.25	-0.29	5.85	3350617
Seguetana Scenario	4178987	242365.36	-0.28	5.80	3418301

Risk Aversion Interval (Pratt Coefficients)

Lower Bound	0.00000000
Upper Bound	0.00000217

Ranking of Technology Alternatives

The Most Preferred Efficient Set Contains:

The Introduction of Seguetana Sorghum

2nd Most Preferred Efficient Set Contains:

The Introduction of N'Tenimissa Sorghum

The Least Preferred Efficient Set Contains:

The Current Baseline Conditions

Confidence Premiums for Specified Probability Distribution Functions*

Dominant PDF	Challenger PDF	As Absolute Monetary Amounts		As a Percentage of The Dominant Mean	
		Lower	Upper	Lower	Upper
		----(fcfa)----		----(%)----	
The Most Dominant PDF					
Seguetana Scenario	N'Tenimissa Scenario	68351	69101	1.64	1.65
Seguetana Scenario	Base Scenario	388227	405977	9.29	9.71
The Next Most Dominant PDF					
N'Tenimissa Scenario	Base Scenario	250776	267526	6.10	6.51

Note: The confidence premiums represent the minimum and maximum amounts of money a decision maker in the risk aversion interval would have to be paid to shift from the dominate distribution to the challanger distribution.

Sensitivity Analysis

A sensitivity analysis was performed on the upper bound of the RAC's for the STODOM rankings to determine how sensitive the technology adoption decision was to the level of risk neutrality held by the decision maker. The full adoption scenario for each of the three farms was analyzed using a RAC upper bound that had been increased by 10 percent and a RAC that had been decreased by 10 percent. The STODOM rankings for the empirical distributions of net present value for each farm did not change when the adjusted RAC's were used. Because the STODOM rankings did not change the upper bound RAC for each farm was increased and decreased by 20 percent and 30 percent. Again, the rankings of the technology alternatives did not change. These results suggest that the rankings are robust with respect to the RAC upper bound for the full adoption scenario of each farm.

Summary

The results of both the TIES analysis and the STODOM analysis indicate that the most preferred technology is the adoption of Seguetana sorghum on all of the case farms. If the case farms chose to be early adopters of the technology they would see the results from the low adoption scenario. As more farms adopted Seguetana sorghum, the early adopters would experience a situation that would move from the results for the low adoption scenario to the results for the full adoption scenario. The case farm in Mopti would benefit the most from changing technologies due to the harsh conditions and crop limitations on this farm. Both Segou and Koulikoro offset the effects of price

reductions to foodstuffs through the production of cotton. Koulikoro is further aided by the price increase seen in rice.

CHAPTER V

CONCLUSION

Problem Statement

In the past, agricultural research in Sub-Saharan agriculture has produced technologies that have been only marginally successful when implemented at the farm level. It has been a challenge to develop technologies that will achieve their desired goals in the complex systems of subsistence agriculture in the Sub-Sahara. Part of the reason for the lack of results from agricultural research has been the high level of risk that is associated with farming in the Sub-Sahara. This study examined the effects of farm level risk on the implementation of new technologies in the Sub-Saharan nation of Mali.

Objectives

The objective of this research was to evaluate the farm level economic impacts of implementing new technologies in Sub-Saharan Africa explicitly incorporating risk into the future outcomes of alternative technology assumptions. To meet the objective, this study developed case farms in Mali for the TIES simulation model as a case study for exploring the effects of implementing new technologies on small holder farms. The technologies that were analyzed are improved varieties of sorghum, N'Tenimissa sorghum and Seguetana sorghum. This model was able to quantify the risk that each

case farm faces and generate probabilistic predictions to determine the most preferred strategy for implementing the new technology.

Procedures

The Sub-Saharan nation of Mali was used in this study to analyze the farm level impact of introducing improved varieties of sorghum onto small holder farms. Three regions of Mali (Mopti, Segou, and Koulikoro) were identified based on the diversity of their farming condition. Specialists familiar with agriculture in Mali selected a case farm for each region, based on their representativeness, and collected farm level data for each of the farms.

Each farm was simulated over a ten year planning horizon using TIES. Three technology alternatives (base technology, N'Tenimissa sorghum, and Seguetana sorghum) and three adoption scenarios (low adoption, non-adopter, full adoption) were simulated for each of the three case farms. Stochastic results were assimilated and placed into tables for analysis.

The empirical distributions of net present value generated by TIES for each farm under conditions of equilibrium were analyzed using STODOM. Technology alternatives for each farm were ranked in STODOM for risk averse decision makers. A pairwise comparison of each alternative was made using STODOM for each farm to obtain the confidence premiums required to move a decision maker to a lower ranked alternative. A sensitivity analysis was performed on the upper bound RAC for each

farm moving the upper bound by plus or minus 10 percent, 20 percent, and 30 percent for each alternative.

Results

The results from the TIES and SODOM analyses show that the most preferred technology alternative in each region is the introduction of Seguetana sorghum. The dynamic nature of technology adoption indicates that farmers who implement Seguetana sorghum early will benefit the most initially and see incremental declines as more producers adopt the technology and prices adjust downward for most foodstuffs. On the case farm in Mopti the benefit from adopting Seguetana sorghum was the most pronounced. Poor farming conditions magnified the effect of improved yields in Mopti. In both the case farms in Segou and Koulikoro the ability to produce cotton limited the farm level economic effect of the Seguetana sorghum. Prices for cotton stayed the same as prices for foodstuffs declined with increased sorghum production. Koulikoro was able to benefit not only from the increased yield, but also from the positive movement of rice prices.

The confidence premiums generated in the STODOM analysis indicated that the amount of net present value required to shift from the Seguetana alternative to the N'Tenimissa alternative is small relative to the mean net present values on the farms. The exception to this is the Mopti farm, which had a confidence premium with a wider range due to the increased risk on that farm. The sensitivity analysis indicated that the upper limit of the RAC's were robust.

Conclusion

The results indicate that the early adopters of this new technology will be the farms that benefit the most. In its early stages the number of farms that typically adopt a new technology is small. Therefore the increase in production caused by the initial introduction of Seguetana sorghum will be limited at the sector level. The farm level impact of this for early adopters is higher production at the same price. As more producers adopt the Seguetana sorghum the market will adjust prices. In most case the prices of foodstuffs will decrease and the benefits of introducing Seguetana will decrease as the market moves to equilibrium.

Additional Research

Further research needs to be done on how the farm family's consumption patterns change with changes in production. Decision criteria needs to be made in the model to distribute the production of agricultural commodities according to the historical and predicted consumption patterns of the farm family.

Another area of future research is the use of external models to supplement the limited information that is available in developing countries. Models such as the Environmental Policy Integrated Climate (EPIC) model can be used to generate yield variabilities that are statistically representative of the historical variability that the farm observes.

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VITA

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