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Cotton Price Policy and New Cereal Technology in the Malian Cotton Zone

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Abstract

During the last decade, cotton production and area have been declining as a result of depleting soil nutrients and low cotton prices in the cotton zone of Mali. This paper shows that the Malian government's 2011 policy to increase the farm gate cotton price as a response to world cotton price increase enhances farm income but has less impact on cotton than on maize production. A complementary policy of introducing new sorghum technologies would have an equal impact on farmers' incomes in the cotton zone of Mali.

Introduction

Agricultural technology introduction and marketing strategies are the main policies to stimulate agricultural growth in sub-Saharan countries. In these countries, agricultural development is constrained by low soil fertility, but water management techniques and improved cultivars are also critical (Sanders et al. 1996). Hence, it is not surprising that research programs have emphasized the diffusion of inorganic fertilizers, high yielding varieties, and water retention techniques.

In Southern Mali, diffusion of new varieties of sorghum cultivars combined with increasing use of fertilizer and water retention techniques have been growing during past decades to respond to soil fertility constraints (Ayele and Wield 2005). This diffusion process has also been accelerated recently with farmers' disillusion from declining world cotton prices¹ (Baquedano et al. 2010). The downward trend in the world cotton price is due to the cost reduction and output expansion effects of the introduction of transgenic cotton, Bt cotton in the major cotton producers, combined with the reduction of the system of guaranteed cotton price by the Malian parastatal company (Droy 2008) as well as the competition from synthetics. The declining cotton price has encouraged Malian farmers to move away from cotton to cereal technologies including sorghum. Farmers are diversifying away from cotton through an increase in area

¹ There has been a recovery of the world cotton price in 2009-2010 hence Mali announced a farm level price increase for the 2010-2011 crop season. In 2011, the price has been raised to 255 F CFA/kg from the 185 F CFA/kg in 2010. The exchange rate presently (May 2011) is 452 F CFA/kg.

and improved inputs allocated to the production of cereals. In the cotton zone, cotton production and area cultivated over the past decade has dramatically decreased by 80 percent (see Figure 1) while maize and sorghum areas have increased by 143 and 18 percent² (Malian Ministry of Agriculture 2010). Some of the fertilizer allocated as credit for cotton is presently being diverted to cereals especially maize but including sorghum.

However, limited access to financial resources and price collapses, have an impact on farmers' willingness to adopt new cereal technologies. Farmers operate in an environment characterized by variability in rainfall and volatility of grain market prices (Vitale and Sanders 2005). There are three types of price collapses faced by staples in developing countries. These three price collapses reduce the expected prices, hence the expected incomes. Hence, marketing strategies to moderate or eliminate the price collapses will increase the incentive to introduce new technologies.

This research evaluates the effects of improved sorghum technologies and marketing strategies on farm income levels comparing it with the 2011 cotton price increases. The next section presents the geographical setting and technologies options available to farmers. Then, the methodology and data are discussed. The results section considers validation of the model with traditional technologies. From there, the effects of new sorghum technologies and marketing strategies on farm income are evaluated. The paper closes with concluding remarks and policy implications.

Geographical Setting and Agricultural Technologies

Geographical Setting

The study takes place in the higher rainfall region of Mali specifically in the district of Koutiala in southern Mali. This district is an old cotton zone. Cotton, maize and sorghum are the principal crops. The rapid population growth has resulted in an extension of area cultivated in order to meet the increasing demand for food. In addition to those effects, the longtime practice of cotton culture has led to soil

² Millet area has even doubled during the last decade, which is a symptom here of soil fertility depletion.

depletion and a reduction in the traditional fallow systems (Kaya and Nair 2001). Land in the Koutiala district is a scarce resource. So, the resulting land scarcity combined with the poor quality of soils in the district make imperative the introduction and diffusion of intensive technologies.

The soils in Koutiala have a topographic variation of plateau, the slopes, and lowlands. The soil textures are predominantly clay, sandy loam and sandy soils. Sandy soils have very low organic matter and infiltration capacity. Due to their poor level of fertility and poor water retention capacity, sandy soils are mainly cropped to millet which tolerates better low soil fertility and water scarcity than the other crops and is concentrated on the plateau and slopes. Clay and loam sandy soils are of higher quality and crop yields respond better in these soils. They are used to cultivate cotton, maize and sorghum often grown in rotation.

Agricultural Technologies

During the past decades, much public attention has been focused on cotton and maize in southern Mali. Sorghum and millet received little notice. The increased yields for cotton and maize were led by the extension services of the *Compagnie Malienne du Developpement du Textile* (CMDT) which supplied improved varieties of cotton seeds, credit for fertilizers, insecticides, extension and finally purchased the cotton.

Recently, the IER-INTSORMIL program has introduced a combination of improved agricultural technologies and marketing strategies in order to increase sorghum productivity and enhance farmers' income. The use of high yielding varieties, moderate amounts of inorganic fertilizers, water management technologies, and improved agricultural practices such as thinning have all been introduced.

The recommended fertilizer levels on sorghum are 50 kg of Di-Ammonium Phosphate (DAP, 18-46-0) and 50 kg of Urea (44-0-0). The gains in production due to adoption of soil management practices and inorganic fertilizer are increased if they are accompanied by the diffusion of high-yielding cultivars. Currently, the sorghum cultivar introduced (Grinkan) is a cross between a Caudatum and a Guinea sorghum. It is an intermediate cycle variety as opposed to the local Guinea sorghums, which are

predominantly long cycle. Average crop yields in normal years is 1.4 tons to 1.9 tons with the best farmers reaching 2.5 tons to 3 tons per hectare (IER-INTSORMIL bulletin 2009). These high yield levels of best farmers require the rigorous implementation of agronomic practices at specific periods of the plant cycle as well as the above combined inputs.

Improved Grain Marketing Strategies

The development of marketing strategies is a main determinant of the adoption of agricultural technologies because they contribute to the profitability of the technologies introduced. Higher yields reduce costs of output. Unfortunately, technology introduction of staples is constrained by three types of price collapses. Prices plummet at harvest because most farmers are entering the market as sellers to satisfy the necessary harvest time expenditures. These expenditures are series of requirements due at harvest. Prices collapse during years of good or even normal rainfall because of the price inelasticity of demand. Once households with sufficient income to buy cereals have enough, there are few alternative markets to keep prices from collapsing. Lastly, during adverse years for crop production, the government often intervenes to prevent substantial increases in consumer prices.

So, new marketing strategies need to be implemented to assist farmers in dealing with the first two of these staple cereal price collapses. To respond to the post-harvest price collapse a strategy of storage, waiting for the price recovery, and wide contacts with potential buyers is implemented. Marketing responses to the price collapse during good rainfall years rely on the expansion of alternative markets to absorb the abundant supply of sorghum. Demand can expand by targeting the emerging and rapidly growing processing industry for human food and animal feed rations. Moreover, adding values to sorghum grains by producing clean and uniform grains give incentives to food processors to pay premium prices.

Specifically, the model is concerned with also incorporating the higher prices from the process of selling later after the post-harvest price recovery plus the development of new markets to respond to the

price inelasticity of demand. These practices are being implemented presently in the Mali INTSORMIL project.

Methodology

Justification of the methodology

Several methods have been described in the literature to measure the income effect of agricultural technologies and to evaluate farmers' decision making in an uncertain environment. Uncertainties are related to the stochastic events of rainfall distribution, plus input and output price variation. Programming techniques incorporating risk have included Mean-Variance models (EV) solved by quadratic programming, MOTAD (Hazell 1971) and safety-first models (Hazell and Norton 1986) employing linear programming. A lexicographic utility function in which farmers make their decisions in-order has been also used to capture farmers' behavior under risk (Abdoulaye and Sanders 1996). In this model, farmers' strategies to handle risk are to satisfy the harvest income requirement and consumption requirement before maximizing expected profit.

The models listed above were extensively used to capture stochastic events in agricultural production but two of their assumptions place some restrictions on their use. These models assume that all decisions are made at one point of time and all information regarding the probability of occurrence of the stochastic event is assumed to be known then. Therefore, these techniques do not permit farmers to make adaptive production and marketing decisions based on new information received over time.

Interviews with farmers in Mali revealed that producers make decisions at several points in time in order to cope with production and marketing uncertainties. Also, there is a growing recognition of the importance of sequential decision making in farmers' strategies to cope with uncertainty (Fafchamps 1993, Dorward 1996). A flexible modeling framework takes into account farmers' ability to adjust their decisions over time. Discrete Stochastic Programming (DSP) models analyze sequential farmers' decision making under uncertainty. Moreover this programming technique has the advantage to being able to handle conditional strategies allowing future decisions to be influenced by past decisions (Preckel 2008).

The implementation of a discrete stochastic programming model requires several steps: the specification of the random variables; the construction of the probability distribution; the identification of the decision variables; the constraints within each stage and the definition of the objective function for the planning horizon.

The specification of the DSP stochastic events requires first the definition of the random variables included in the model. The random variables of interest are crop yields and prices. The traditional crops are cotton, sorghum, maize and millet. The improved crop is the new variety of sorghum. Three stages are modeled and are represented by the agricultural season (beginning of the planting season up to the end of harvest), the price recovering period (from the end of harvest up to the next planting season) and the hungry season (from the second planting season up to the beginning of the next harvest). The outcomes of the stochastic events are observed at three main points in time. The first point is at the end of harvest in December when all outcomes of randomness in yields have occurred. The second one is at the end of the price recovering period in May, when prices have recovered from their harvest collapse. The third point is at the end of the hungry season, in September, just before the next harvest.

For the traditional technologies, the first stage of the model comprises 7 random variables including 4 crop yields and 3 grain prices. Cotton prices are not random because cotton prices are fixed by the CMDT parastatal company and announced at the beginning of the agricultural season. Thus, the only random prices observed at harvest are grain prices (sorghum, millet and maize). After harvest, variations of these three random prices are tracked throughout the other two stages of the model that means the recovering period and the hungry season. So, at the end of the price recovering period and the hungry season, the outcomes of the 3 random grain prices are known. While randomness of prices was defined for each of the three stages in the planning horizon, stochastic yields were only identified for the stage in which crops are harvested, which is at the end of the first stage or agricultural season.

Using the Gaussian Quadrature approach³, 15 states of nature for yields were defined with the sum of the probability of occurrence of the 15 events equal to 1. Observations for prices are only available for 10 years so an empirical distribution is used to define the states of nature and their associated probabilities. So, 10 possible states of nature were defined with a probability of occurrence equal to 1/10. Those price states of nature and their associated probabilities were applied for harvest time, price recovering period and hungry season. At the end of the year, the total number of states of nature is the product of the events that were obtained in each decision period. This product is equal to 15,000 that is $15 \times 10 \times 10 \times 10$. The probability of the end period states of nature is also obtained by multiplying the probabilities of the outcomes that unfold in each time period. As we can notice, the size of the DSP increases exponentially with the number of stages and states of nature but the modeling of number of states of nature achieved with the traditional technology is feasible with current computer capacity.

Decision Variables and Empirical Modeling

The representative farm household strategies to handle uncertainties in yields and prices are to make discrete decisions within a specific planning horizon. The planning horizon in which output sales, production, consumption and grain purchases decisions are made has been divided into three time periods.

The first time period starts at the first planting season and ends at the first harvest. At the beginning of the time period, farmers make decisions about the amount of land to devote to the different crop technologies and the quantities of inputs (fertilizer, insecticides, and seeds) to purchase. Throughout this first period, farmers make other decisions regarding the amount of grain to purchase for home consumption in case the initial stock is not enough to meet the household's consumption requirements.

The second time period extends from the end of the first harvest up to the end of the price recovering period. At the end of harvest, some pressing household expenditures need to be met. These

³ The Gaussian Quadrature is a technique that uses moments to construct distributions. It is based on selecting points among random variables and their corresponding weights in such a way that the moments of the discrete approximation match the moments of the true distribution (De Vyust and Preckel 2007). The points can be interpreted as states of nature and the weights as the probabilities associated to the states of nature.

are expenditures for taxes payment, debt repayment, school fees, wages for migrant labor (family members working on farm in cropping season), hired labor and expenses for social ceremonies such as naming ceremonies. To achieve this goal, part of the output harvested will be sold at the market. Output at harvest is variable and depends on the state of nature. This latter one reflects a combination of farmers' practices, rainfall, soil fertility and input use on crop yields. Depending on the state of nature, decisions concerning grain sales, purchase and inventories will be made.

The third time period begins at the end of the price recovering season and goes up to the end of the hungry season or “soudure” period. At the beginning of stage 3, farmers have full knowledge of the post-harvest grain prices that prevailed in the recovering period. Recovering prices have been determined conditionally on harvest prices. Thus, the set of activities selected at the start of the hungry season takes into account realization of prices during the recovering period and harvest season. The decisions made by farmers include grain sales, grain purchases and home consumption. At the end of stage 3, the outcome of price uncertainty in the hungry season is known and influences the end period wealth.

The empirical formulation of the model requires specification of material and cash balances in each time period. Then, the expected profit across time periods is maximized.

Material balance at first planting up to first harvest:

$$C_{1k} + S_{1k} + I_{1k} \leq Q_{1k} + B_{1k} \quad (1.1)$$

In equation (1.1), the starting inventory of output k (Q_{1k}) is used for consumption (C_{1k}), sales (S_{1k}) and the remainder (I_{1k}) is kept in the form of inventory stock. This constraint allows cereals to be purchased (B_{1k}) in the event that the starting stock is not enough to meet the household grain consumption needs. Minimum subsistence requirements for the grains are defined in this period as well as in the subsequent periods as households need to guarantee a food security level before satisfying any other objective.

Material balance from first harvest up to the hungry season

$$C_{2ks} + S_{2ks} + I_{2ks} \leq I_{1k} + \sum_j b_{kjs} y_j + B_{2ks} \quad (1.2)$$

Equation (1.2) specifies that consumption (C_{2ks}), sales (S_{2ks}) and inventory of output k for a given state of nature s in the second period (I_{2ks}) cannot be greater than the inventory of output k (I_{1k}) carried over from the first period plus output k produced in state of nature s using different combinations of crop technologies ($b_{kjs} y_j$) plus the amount of grain k purchased (B_{2ks}) in the corresponding state of nature s during the second period.

Production of output k harvested in the second period is subject to the resource constraints as follows:

$$\sum_j y_j \leq K \quad (1.3)$$

Equation (1.3) defines the land constraint. The sum of areas allocated to the different crop technologies (y_j) must be less or equal to the total land availability (K).

$$\sum_j a_{ij} y_j \leq x_i \quad (1.4)$$

Equation (1.4) is the constraint on total purchased input availability. Input i used (a_{ij}) for the different crop production systems j is (y_j) set to not exceed the amount of input i available (x_i).

$$x_l + l^o \leq L^h + H \quad (1.5)$$

In equation (1.5) labor allocated to crop production system j and (x_l) to off-farm employment (l^o) must be less or equal to the total family labor available (L^h) and the amount of hired labor (H).

Material balance from the hungry season up to the next harvest

$$C_{3kst} + S_{3kst} + I_{3kst} \leq I_{2ks} + B_{3kst} \quad (1.6)$$

In this equation (1.6) another state of nature t is added to reflect the price dynamic that occurred during the second period. Indeed, from the first harvest to the price recovery period (hungry season) prices of the

main grain commodities that are millet, sorghum, peanut, maize increase across time and covary positively. The state of nature t is conditional on the state of nature s that occurred in the first period. We assume that at the beginning of the third time period, producers have full knowledge of the state of nature of yields and prices realized in the past periods. Hence, in the third period, the sum of consumption (C_{3kst}), sales (S_{3kst}) and inventory of output k in state of natures s and t (I_{3kst}) are restricted to not be more than the amount of cereal k purchased in period 3 in state of nature s and t (B_{3kst}) and the transfer of inventory of output k received from the second period in state of nature s (I_{2ks}).

The cash balances corresponding to each set of material balance are defined below:

Cash balance in the first period

$$E_1 + \sum_{i \neq K} c_i x_i + \sum_k p_{1k}^b B_{1k} + R_1 \leq F + \sum_k p_{1k}^s S_{1k} \quad (1.7)$$

Equation (1.7) represents the cash constraint for the first period. The cash and any liquid asset (F) plus the value of output sold in the first period ($p_{1k}^s S_{1k}$) is used to satisfy household expenditures (E_1), input purchases except labor and land (x_i), expenses on grain for home consumption ($p_{1k}^b B_{1k}$). Remained cash (R_1) is carried over the next period. Cash and liquidity assets include any sales of livestock that occur to finance some emergency expenditure such as health expenses and/or food purchases mainly during a bad state of nature.

Cash balance in the second period

$$E_2 + \sum_k p_{2ks}^b B_{2ks} + R_{2s} + H \leq \sum_k p_{2ks}^s S_{2ks} + R_1 \quad (1.8)$$

Equation (1.8) states that the cash generated from the second period output sales ($p_{2ks}^s S_{2ks}$) in a given state of nature s and the retained cash from the first period is allocated to the necessary household expenditures (E_2) (school fees, debt and taxes repayment, wages for migrant labor, health expenses, social

ceremonies), to hire labor (H), and to grain purchases ($p_{2k}^b B_{2ks}$). Again, retained cash from the second period in state of nature s (R_{2s}) is transferred to the subsequent time period.

Cash balance in the third period

$$E_3 + \sum_k p_{3kst}^b B_{3kst} + R_{3st} \leq \sum_k p_{3kst}^s S_{3kst} + R_{2s} \quad (1.9)$$

In equation (1.9), the cash revenue from the sales of output in state of nature s in the third period ($p_{3kst}^s S_{3kst}$) and the retained cash from the second period in the identical state of nature s must at least covered household expenditures (E_3), grain purchases needed in the third period ($p_{3kst}^b B_{3kst}$). Any excess of liquidity will be in the form of retained cash (R_{3st}).

Expected profit objective to be maximized

$$\sum_s \sum_t \sum_r \rho(s) \cdot \rho(t|s) \rho(r|t|s) |\Psi_{str}| \quad (1.10)$$

$$\begin{aligned} \Psi_{str} = & \sum_k \left[(p_{1k}^s S_{1k} - p_{1k}^b B_{1k}) + (p_{2ks}^s S_{2ks} - p_{2ks}^b B_{2ks}) + (p_{3kst}^s S_{3kst} - p_{3kst}^b B_{3kst}) + w^s l^o + p_{kstr}^s I_{3kst} \right] \\ & - \left[\sum_{i \in K} c_i x_i + w^s H + E_1 + E_2 + E_3 \right] \end{aligned} \quad (1.11)$$

The objective function is the expected profit maximized in equation (1.10). It is a function of the profit across the planning horizon and the joint probabilities of states of nature s , t and r . r is the probability of the price state of nature for the end of the hungry season. Yield and prices are both random variables with yield and prices at harvest having a probability distribution of $\rho(s)$, post-harvest recovering price carrying a probability distribution of $\rho(t)$ and post-harvest price in the hungry season having a probability of $\rho(r)$. The sum of the probabilities of states of nature s , t and r is equal to 1. Equation (1.11) details the profit maximized in equation (1.10) as the difference between the sum of the net revenue earned in each period from the cropping activities, non-farm work and the value of the grain stock remaining at the end of hungry season, and the sum of the expenditures on non-labor and non-land inputs, hired labor and household expenditures.

We can derive the household income by adding back the value of home grain consumption.

Estimation of this farm household model using only the present traditional technologies gives the optimal crop mix, quantities of grain purchased, inventories of stock over the planning horizon and household's profit prior to the introduction of new cereal agricultural practices. This first model is the base case scenario.

We will use it to measure the impact of the use of intensive level of inputs (fertilizer, urea, improved seeds) and government policies on the decision variables and the farm income.

Variable definitions

j = combination of crop and technology

i = inputs used (fertilizer, urea, pesticides, herbicides, insecticides, seed)

y_j = area devoted to production system j

a_{ij} = use of input i by production system j

b_{kjs} = yield per unit of area for output k

$T = 1, 2, 3$: plant period, harvest and up to the next harvest

s = state of nature of yield and prices

t = state of nature of price between harvest and second planting

C_{Tk} = Consumption during period T for output k

S_{Tk} = Sales during period T for output k

I_{Tk} = Output k inventory for period T

Q_{1k} = Starting inventory for output k

B_{Tk} = Quantity of output k purchased in period T

E_T = Expenditures in period T

p_{Tk}^s = Selling price of output k in period T

p_{Tk}^b = Buying price of output k in period T

R_T = retained cash in period T

K = Total area of land available

x_i = Total quantity of input i available

x_l = Labor allocated for crop activities

c_i = Cost of input i per unit of hectare

l_j = labor allocated to the production system j

l^o = labor allocated to off-farm activities

L^h = Total amount of family labor available

H = Total amount of hired labor

ρ_s = Probability of state of nature s

ρ_t = Probability of state of nature t

Ψ_{st} = Profit maximized in state of nature s and t

Data

Information on yields for traditional and improved technologies are a combination of primary and secondary observations. The traditional technologies include sorghum, millet, maize and cotton while the improved technology concerns sorghum variety. Primary data have been collected from a field survey conducted in 2008 and in the months of June and July 2010 in the village of Garasso which is part of the district of Koutiala. Secondary data are aggregate information in Koutiala from 1998 to 2008, gathered from the Ministry of Agriculture in Mali and the “Compagnie Malienne pour le Développement du Textile” (CMDT). Prices data for the crops mentioned above are monthly observations covering the time frame 1998 to 2008 and were obtained from the National Market Watch in Mali. Those prices have been deflated using a GDP index for the same time period obtained from the International Monetary Fund (IMF). Rainfall observations in Koutiala for the time span 1980 to 2009 have been collected with the State Department of Meteorology.

The labor coefficients used in the model were developed from the household survey and confirmed by field observations from Coulibaly (1995).

Model Results for the Traditional Technology

This section will validate with empirical observations the model consistency in predicting farmers' decision making. First, the model prediction will be compared with other recent studies. Second, the ability of the model to predict farmers' recently observed behavior of moving the cotton fertilizer on to the cereals will be evaluated.

Validity of the Model with Existing Cropping Strategies and Farming System

The traditional technologies included in the model are cotton, maize, sorghum and millet. The representative farm household⁴ in the study region is composed of 27 people and cultivates on average 15 hectares (ha) land.

Running the model for the cotton price of 2008, the model allocates 1.1 ha to cotton, 0.7 ha to maize, 9.8 ha to sorghum and 3 ha to millet. The higher share of sorghum in the crop mix is supported by the use of sorghum as the most preferred staple in grain consumption. In addition, sorghum has a comparative advantage over maize in this region because sorghum is more flood and drought tolerant than maize.

The model results for the traditional technologies are compared with some other empirical studies in the Sudano-Guinean region of Mali. Baquedano et al. (2009) analyzed the impact of the removal of US cotton subsidies on farm household income in Mali. Under traditional technologies, they found that farmers allocate 3.6 ha to cotton, 5.8 ha and 1.0 ha respectively to sorghum and maize. Coulibaly et al. (1998) studied the impact of devaluation on new technology adoption. They estimated that on average farmers grow 3.0 ha of cotton, 6 ha on sorghum and 0.5 ha on maize and 2 ha on millet⁵. As in our study, sorghum is the principal cereal activity. But the lower cotton area in our study is supported by the sharply decreasing area in cotton (Figure 1).

Consistency of the Model with Farmers' Behavior

The two main cash crops are generally grown intensively with the inputs financed by CMDT credits. There is a standard application of fertilizer on cotton and maize recommended by the CMDT. The recommended fertilizer levels supplied to cotton are 150 kg/ha of NPK and 50 kg/ha of Urea, while 100

⁴ The information on the average farm comes from a survey of 67 households in the village of Garasso located in the district of Koutiala (Sikasso region).

⁵ These results are for moderate risk averse farmers. We also handle risk aversion by including constraints to satisfy subsistence consumption and the harvest income goal. Both constraints are expressed as priorities by farmers in their decision making.

kg/ha of NPK and 100 kg/ha of Urea are specified for maize. Sorghum is rotated with the cotton and maize and receives the residual fertilizer effect. In this rotation system, sorghum yields are around 1 ton/ha compared to unrotated sorghum of 600 kg/ha to 800 kg/ha. Millet is usually planted on the lower soil fertility areas (plateau or sloping area) with the cotton, maize, and sorghum on the better low-lying soils.

Various simulations were performed with the cotton price to evaluate how farmers will respond to a change in the price of their main cash crop with their traditional technologies (see results in Table 1). Generally, as cotton price rises, farmers shift to cotton and maize reducing their areas in the subsistence crops of sorghum and millet. Meeting the subsistence objective⁶ with either grain production or grain purchases takes precedence over the income maximization goal at low cotton prices.

At a cotton price, below 200 F CFA/kg (0.44 \$/kg), small areas of cash crops are raised to satisfy pressing household expenditures. The low cotton price constrains the amount of fertilizer that will be obtained on credit to grow maize and cotton. Thus, little area is put into these crops. Farmers are more oriented to the production of subsistence crops, sorghum and millet for home consumption and sales. But they also purchase maize to meet their subsistence goal.

With the increases in cotton prices above 200 F CFA/kg, there is more incentive to produce the intensive crops of cotton and maize.⁷ Surprisingly, there is a greater response from expansion of maize area than that of cotton. Why? Marginal returns from increasing maize production are greater than those from increasing cotton production. The marginal return of producing more maize here is the difference between the purchasing price of maize on the market when farmers would buy it and the shadow price of

⁶ During field interviews, farmers revealed that guaranteeing a threshold level for grain consumption for the whole year was a main goal for them before maximizing profit. So, in the programming model, minimum subsistence requirements have been defined for each grain based on farm level observations. Farmer observations indicated that presently at least 32 percent of their grain consumption was of sorghum, 23 percent and 20 percent for millet and maize respectively. So we put these in as lower boundaries for a cereal consumption goal of 25 kg/day for a household of 27 people.

⁷ In the study region, the CMDT provides credit for inputs (fertilizer, seed, insecticides, herbicides) for cotton. More recently, they also provide input loans (fertilizer and herbicides) for maize but insist it be repaid after harvest in cotton valued at the prearranged cotton price. Before that change farmers were increasingly observed putting the cotton fertilizer on their maize.

producing their own maize. The need of meeting the subsistence requirement and the high purchasing price for maize for home consumption as compared to the cost of own production leads farmers to grow maize for home consumption at the expense of using more resources on cotton. As long as this return is greater than that for cotton farmers respond more to the higher price of cotton, which means greater access to fertilizer, by increasing the maize area faster than that of cotton. Cotton area stays in the crop mix because the fertilizer credit must be repaid in cotton. If it was not for the necessity to repay the loan even during a bad year of production, cotton area allocated to cotton would have even been lower. See Figure 2 where the cost of inputs overlaps with the revenue of cotton in adverse rainfall years until the cotton gets to the very high price of 290 CFA/kg. The falling prices of cotton in the last decade have resulted in a vicious cycle for cotton as increasingly farmers put the cotton fertilizer on to the cereals.

These results are consistent with recent experience of the CMDT in the study region. They have been frustrated with the increasing use of fertilizer loans for cotton that were put on the cereals, maize and sorghum. Hence, they designated loans for cereals as a diversification strategy and it became legal to get fertilizer for maize but farmers still had to repay the credit in cotton. So, the model predicts fairly well a phenomenon that CMDT has been struggling with: why in recent years have there been shifts of CMDT fertilizer credit for cotton onto the cereals?

Results for the Improved Technologies

In this section the new technology introduction for sorghum will be compared with the income effect of the 2011 price increase for cotton. First, the income and area effects of the 2011 cotton price increase are presented. Then they are compared with the adoption of a higher yielding cultivar of sorghum with associated technologies. Also, the 2011 extension of the fertilizer subsidy to sorghum is then added in to evaluate the total income effect.

Effect of an Increase in Cotton Price on Crop Portfolio Mix and Farm Profit.

In 2010, the farm gate cotton price was in real term 172 F CFA/kg⁸ (0.38 US\$/kg). For 2011, the Malian Government increased the guaranteed price to 231 F CFA/kg (255 F CFA/kg in nominal terms which is 0.51 US\$/kg) in response to the higher world price. This increase in the cotton price enables an increase in cotton area by 34 percent while maize area more than quadruples. We have already discussed this preference for increasing maize production when the cotton price increases. This 36 percent increase in farm level price increases farm profits by 64 percent (Table 3).

Effect of the Introduction of Improved Sorghum Technology on Land Allocation and Farm Profit.

When the improved sorghum technology⁹ is introduced, farm profit is increased by 60 percent. The new sorghum substitutes principally for traditional sorghum and to a lesser extent for cotton and maize. The area cultivated for the traditional sorghum variety is reduced by 45 percent while the areas for cotton and maize are each reduced by 26 percent. These substitutions allow 4.5 ha to be raised for the improved sorghum (Table 3).

The farmers operate in farmers' associations to obtain the lower price of credit of 12 percent from the BNDA (National Bank for Agricultural Development) and we have put a credit ceiling of 150,000 CFA(\$332 at 452 CFA/\$). An elastic supply of credit at this interest cost would have allowed an area of 9.5 ha in the new sorghum thereby increasing farm profits by 118 percent. These income increases for sorghum technology also include the improved marketing practices of selling later¹⁰ in the season (Table 4).

⁸ This price is 185 F CFA/kg (\$0.41/kg) in nominal term. The base year used to deflate prices in this study is 2008.

⁹ The new technology introduced in the model is composed of 50 kg of DAP, 50 kg of Urea and 10 kg of the improved sorghum variety. These are the doses recommended by the Institute of Rural Economy (IER) in Mali.

¹⁰ The expected price increase from harvest to four months later in the recovery period was 26% for sorghum.

Effect of Change in Cotton Prices and Adoption of Improved Sorghum

With the combined introduction of the sorghum technology package and the increase in the cotton price the traditional sorghum variety area decreases substantially (46 percent) while the area cultivated in the new sorghum stays constant with the credit limitation (Table 3). Areas used under cotton and maize increase respectively by 34 percent and more than 400 percent. The combined effect of adoption of improved sorghum and cotton price increase leads to a rise in the expected profit by 110 percent (Table 3).

Effect of Access to Subsidized Fertilizer for the Improved Sorghum on Farm Profit and Crop Mix

Adding in the subsidized fertilizer for sorghum as the Malian government did in 2011 to the package above of increased cotton price and the sorghum technology, raises the farm profit by 124 percent over the base case. The new sorghum technology is now introduced on 5.3 ha of land with a very large reduction in area planted for the traditional sorghum variety. Also in this combination farmers increase their cotton and maize areas respectively by 34 percent and above 400 percent over the base case.

Concluding Remarks, Policy Implications and Direction for Further Research

The discrete stochastic model helped explain the dilemma of farmers diverting inorganic fertilizer from cotton onto cereals at the lower cotton prices. This understanding of the competition between maize and cotton for the use of fertilizer is important as Mali plans to recover the foreign exchange revenue lost from falling cotton exports.

The Malian government's 2011 policy to increase the farm gate price for cotton is an important strategy that improves household income by 60 percent and thus enables farmers also to benefit from the recent world price increases for cotton. The above results also indicated the difficulty of cotton in competing with maize for the additional credit resources. To increase cotton productivity and revenues will probably also require new technology for cotton including Bt cotton and improved fertilization

techniques. A principal emphasis should probably be on continuing diversification in the cotton zone and on increasing cotton productivity sufficiently to compete with the other world cotton producers that have already successfully reduced their cotton production costs with the introduction of Bt cotton.

This research will be continued with further field work in Mali including the investigation of the distribution of the income gains within the household for women.

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Table 1. Crop Mix and Cotton Prices

Price (FCFA/kg)	200	231	255	290
Cotton (ha)	1.121	1.667	2.057	2.876
		49%	23%	40%
Maize (ha)	0.709	1.722	2.762	2.934
		143%	60%	6%
Sorghum (ha)	9.822	8.611	7.181	6.19
		-12%	-17%	-14%
Millet (ha)	3	3	3	3
Farm Profit (F CFA)	900,953	1,011,049	1,092,998	1,173,493

Table 2. Changes in Revenue for Cotton in a Bad Year and Input Costs for Maize and Cotton

Cotton Price (F CFA/kg)	172	184	200	222	231	255	290
	767	767	767	767	767	767	767
Cotton area (ha)	1.241	1.11	1.121	1.693	1.667	2.057	2.876
Revenue from Cotton (F CFA)	163,718	156,652	171,961	288,274	295,354	402,318	639,709
% Change		-4%	10%	68%	2%	36%	59%
Maize Area (ha)	0.336	0.472	0.709	1.551	1.722	2.762	2.934
Fertilizer Cost for Area of Maize	19,950	28,025	42,098	92,092	102,245	163,997	174,209
% Change		40%	50%	119%	11%	60%	6%
Input Cost for Area of Cotton (F CFA)	143,787	128,609	129,884	196,158	193,145	238,332	333,225
Total inputs Cost (F CFA)	163,738	156,635	171,981	288,250	295,391	402,329	507,434

Exchange rate: 1 \$ US =452.61 F CFA on April 18, 2011 at www.oanda.com

Table 3. Impact of Different Policy Scenarios on Crop Portfolio Mix and Farm Profit

Crop Mix Areas (ha)	Traditional Technologies		Adoption of Improved Sorghum		New Sorghum+ Fertilizer Subsidy	
	at 2010 Cotton Price	at 2011 Cotton Price	at 2010 Cotton Price	at 2011 Cotton Price	at 2010 Cotton Price	at 2011 Cotton Price
Cotton	1.241	1.667	0.912	1.667	0.349	1.667
Maize	0.336	1.722	0.247	1.722	0.09	1.722
Local Sorghum	7.517	8.611	4.139	4.093	5.487	3.254
Millet	3	3	3	3	3	3
New Sorghum	-	-	4.518	4.518	5.357	5.357
Total Area	12.094	15	12.816	15	14.287	15
Farm Profit (FCFA)	617,763	1,011,049	989,575	1,295,759	1,239,950	1,382,198
% Change in Profit with base case		64%	60%	110%	101%	124%

Exchange rate: 1 \$ US =452.61 F CFA on April 18, 2011 at www.oanda.com.

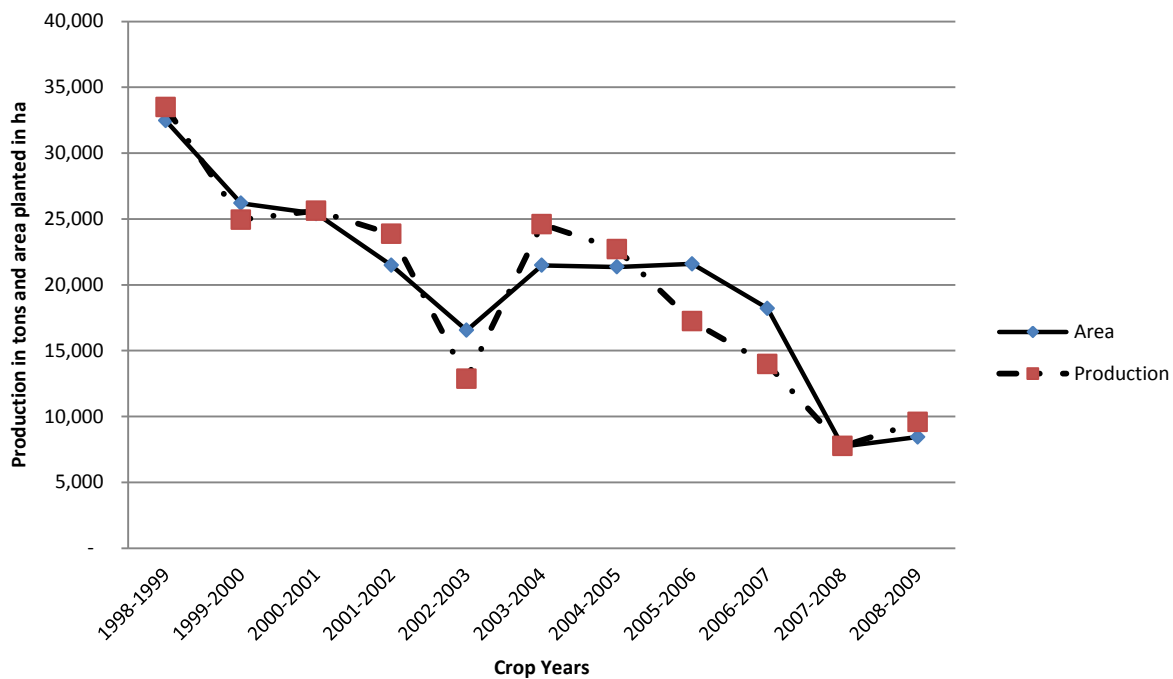
Table 4. Share of Grains Sold from Production at the different Marketing Periods

Grains	Traditional Technologies				Adoption of Improved Sorghum				New Sorghum+ Fertilizer Subsidy			
	2010 Cotton Price		2011 Cotton Price		2010 Cotton Price		2011 Cotton Price		2010 Cotton Price		2011 Cotton Price	
	Period 2 ^a	Period 3 ^b	Period 2	Period 3	Period 2	Period 3	Period 2	Period 3	Period 2	Period 3	Period 2	Period 3
Sorghum	0.30%	31.00%	0.40% 19.00	34%	0.3%	44%	0.20%	43%	1.70%	45%	0.10%	42%
Millet	10%	13.00%	%	12%	19%	10%	16%	15%	0.43	0%	15%	15%
Maize	0%	0%	0%	8%	0%	0%	0.20%	11%	0%	0.70%	0%	11%

^aPeriod 2 corresponds to the harvest Season

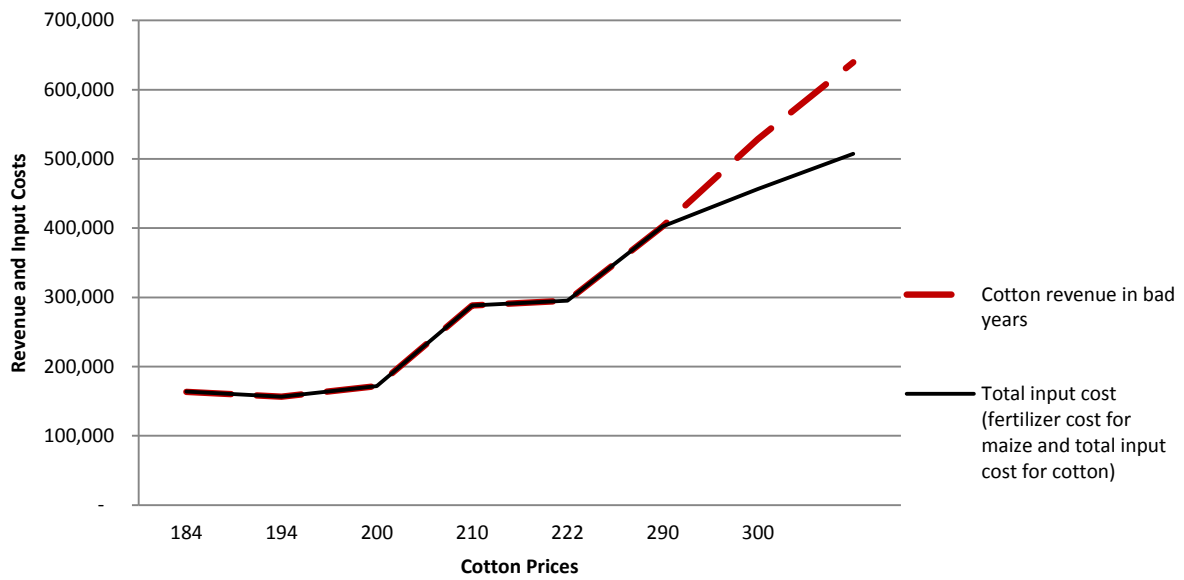
^bPeriod 3 corresponds to the Price Recovery Season

Figure 1. Cotton Production and Area Planted from 1998 to 2009 in the Cotton Zone of Mali.



Source: Malian Ministry of Agriculture, 2010.

Figure 2. Change in Cotton Revenue and Total Input Cost (Maize and Cotton)



Source: Model's results