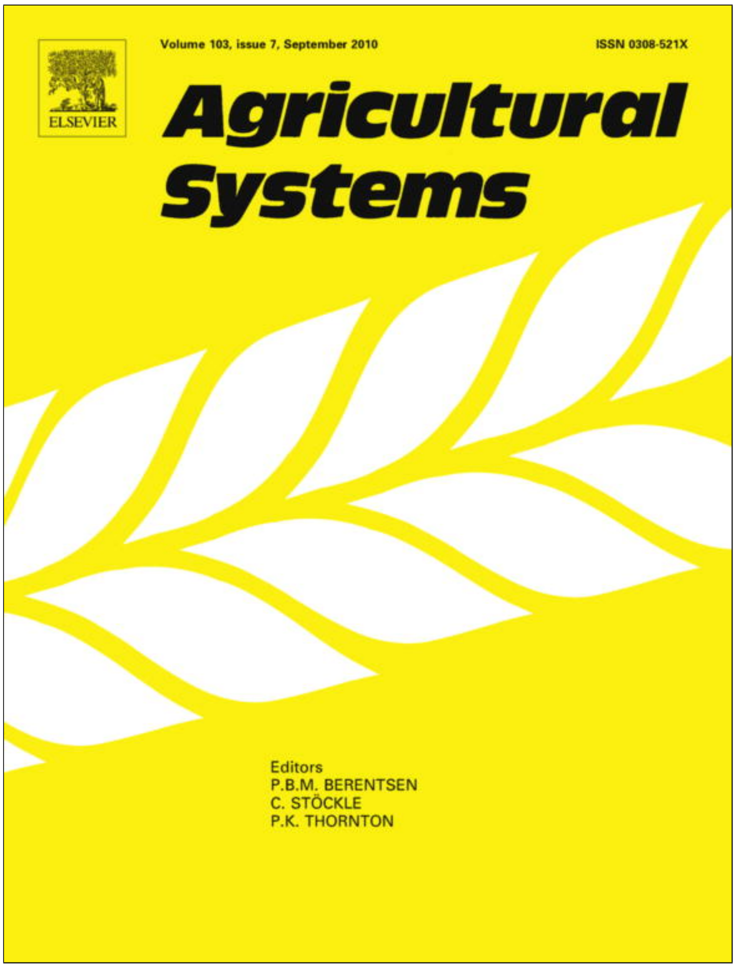
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Increasing incomes of Malian cotton farmers: Is elimination of US subsidies the only solution? ☆

Felix G. Baquedano [a,*], John H. Sanders [b,1], Jeffrey Vitale [c,2]

[a] Economics Research Service U.S. Department of Agriculture, 1800 M St., NW, Rm 5168, Washington, DC 20036, USA
[b] Department of Agricultural Economics, Purdue University, 403 W. State St., KRAN 609, West Lafayette, IN 47906, USA
[c] Department of Agricultural Economics, Oklahoma State University, 418 Ag Hall, Stillwater, OK 74078, USA

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ABSTRACT

In a WTO battle and the press the argument is often made that eliminating US cotton subsidies would have a large effect on the incomes and competitive position of farmers in developing countries. In Francophone West Africa cotton productivity has stagnated after rapid gains in the first two decades following independence (1960–1980). A farm model was constructed based on farmers' definition of their decision-making framework which they use to respond to income and weather risks. With this model the effects on farmers of eliminating US subsidies are compared with various productivity increasing measures for cotton and sorghum in Dioila, Mali. Dioila is located in a representative cotton region producing 16% of the cotton in Mali. We include sorghum due to its importance for consumption and the observation of Malian farmers substituting cereals (sorghum and maize) for cotton as the returns to cotton have fallen in the 21st Century. In the farm model, the elasticity of transmission of a change in the world cotton price to the farm gate price is taken into account. The gains from eliminating US subsides are small. In contrast, the various technological alternatives including Bt cotton introduction, the use of higher fertilization levels for cotton, and the introduction of improved sorghum cultivars and moderate fertilization along with a marketing package all have substantially higher returns Even with substantial improvement in the mechanisms enabling farmers to benefit from the higher prices resulting from elimination of US subsidies, there are still much higher returns resulting from the various types of productivity increases.

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1. Introduction

In Mali, cotton was the successful driver of agricultural development in the 20 years after independence in 1960. Cotton farmers were supported by research, extension services, and input credit resulting in substantially increased incomes and productivity. Yields of seed cotton for example increased from less than 0.4 Mt/Ha in the 1960's to over 1.3 Mt/Ha in the early 1980's. Farmers also had access to better schools and healthcare relative to non-cotton farmers. These services were partially financed by the cotton para-statal (SWAC-OECD, 2005).

Since the mid 1980's, farmers' incomes have declined as cotton yields fell (due to the dismantling of the support structure for cotton production including the research and extension systems) while production costs, especially fertilizer and insecticides, increased. Moreover, the terms of trade for cotton exports have deteriorated as world cotton prices fell. To respond to this situation, policymakers in Mali and elsewhere in West Africa have been pursuing two strategies: (1) introducing more competition and higher prices for farmers by expanding the number of gins and privatizing the para-statal gins;[3] and (2) lobbying for the removal of US subsidies to cotton in the WTO and other international forums (Goreux, 2005; Watkins and Sul, 2002; Alston et al., 2007).

However, little attention has been given to enhancing cotton productivity or the productivity of other crops in the production system. Mali has often linked the profitability of its cotton sector to US cotton policy. However, when US production of cotton

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* Corresponding author. Tel.: +1 202 694 5149.
E-mail addresses: fbaquedano@ers.usda.gov (F.G. Baquedano), jsander1@purdue.edu (J.H. Sanders), jeffrey.vitale@okstate.edu (J. Vitale).
[1] Tel.: +1 765 494 4221.
[2] Tel.: +1 405 744 6175.

[3] The pressure for market reform has been led by the multi-lateral and bilateral agencies that provide monetary support for the industry (Pursell, 1998; Badiane et al., 2002; Tschirvley et al., 2007). Reforms to the cotton industry structure have not yet taken place in Mali but there is a government plan to expand the number of gins and they will be privately held (Prime Minister's Office, 2006). As market reforms are introduced in Mali, it will be important to analyze the economic impact of these strategies in future comparisons.

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declined by 44% and exports by 26% from 2005 to 2008 Mali was not able to take advantage of this by increasing production and productivity (Meyer et al., 2008). Instead countries, which had invested heavily in Bt cotton and other productivity enhancing technologies on cotton (including India and China) benefited from the declining US world market share for cotton.

In this paper we focus on a third strategy: the renewal of the rapid technological progress in cotton that took place between 1950's and 1980's and the initiation of rapid productivity gains for sorghum. The benefits to cotton productivity improvements in West Africa, and Mali have been highlighted previously (Anderson and Valenzuela, 2006 and Vitale et al., 2007). However, for new technologies the primary focus has been on Bt cotton. Given the low productivity of cotton and its high cost of production, farmers have been diversifying recently into cereals such as sorghum and maize. With the continued improvement of cereal yields, the introduction of marketing strategies to respond to seasonal price variations and other price-depressing phenomena, and the development of new markets for processed cereals for food and feed, farmers are presently obtaining higher returns from cereals than cotton.

In this paper, we compare and contrast the farm level effects of: (1) an increase in world cotton prices by eliminating US subsidies; and (2) introducing technological change in cotton and sorghum. We focus on changes in expected household income and in the production of cotton and cereals. The farm level modeling incorporates farmers' observed decision making processes based on our fieldwork and previous modeling of low-income farmers (Vitale and Sanders, 2005; Abdoulaye and Sanders, 2006; Baquedano and Sanders, 2006).

The remainder of the paper proceeds as follows. In Section 2, we discuss the industry structure and the price mechanism setting farm gate prices. To evaluate the effects on household income of a change in world prices and of technology we discuss the farmers' decision-making mechanism and how it is incorporated into a linear programming model. In Section 4, we analyze the impact on household income of an increase in world cotton prices from the removal of US subsidies. We compare that with the technological alternatives of increasing the productivity of cotton and that of one of the cereals in the system, sorghum. In Section 5 we present our conclusions and policy implications.

2. The cotton industry, Malian farming systems and the farm gate price

Mali, located in the Sahelian zone of West Africa, is one of the major cotton producers in West Africa. In 2006/2007, Mali's output represented 18% of total seed cotton production in West Africa (Baquedano et al., 2008). Cotton export earnings in 2005 represented 6% of GDP and 30% of the value of total exports (Baffes, 2007). Nearly 300,000 farm households produce cotton in Mali in 2005 (Baffes, 2007).

In the last decade, cotton yields in Mali have declined. In 2008, national seed cotton yields averaged 900 kg/Ha, equaling the yields of the 1970's (Baquedano, 2009; Fok, 2007). In addition to yield declines there was also a downward trend in the area of cotton harvested in the last 5 years (Vitale and Park, 2007; Fok, 2007; Baquedano et al., 2008). The causes of the yield stagnation and decline in Mali have been attributed to poor soil fertility management, lack of varietal development, and the extension of cotton into marginal cotton zones (Fok, 2007). The recent rapid increases in fertilizer prices have discouraged the introduction of the higher fertilizer levels for cotton demonstrating good results already on the experiment stations.

The cotton sub-sector in Mali is composed of a single ginning company, the Malienne Company for Textiles, (CMDT in French). The CMDT is a vertically integrated para-statal providing farmers various support operations including input credit, research, extension, and transportation of seed cotton to the gins. The CMDT is the sole exporter of the Malian cotton lint to the world market. Evidentally the CMDT has monopsony power in the negotiation of seed cotton prices. The state holds a 60% interest in CMDT and the French multinational company Geocoton controls the remaining shares.

Cotton is produced in an annual rotation system with cereals including maize and sorghum. Cereals are the traditional food source for Malian farm households. Typically cotton is followed by maize and then sorghum before returning to cotton. In the more northern parts of the country with less rainfall and more variable rainfall cotton is followed by sorghum. These same farms produce some maize, millet, and cowpeas. Traditionally farmers have only used fertilizer and insecticide on the cotton but the cereals benefitted from the residual effects of fertilization. In the 21st Century with the decline of cotton more purchased inputs are being used directly on the cereals. Higher input use is encouraged by the increasing demand for maize and sorghum for their food use and for new alternative markets (food processing and feed rations). Even though cereals have become an important source of income diversification, cotton is still the main source of income.

CMDT also continues to encourage the cotton/cereal rotation for agronomic reasons, i.e. reducing the population of cotton pest, weeds and insects. Both the cereals and cotton will continue to be priority activities for farmers and policy makers. Even with the rapid growth of cotton productivity from 1960 to 1980 farmers maintained their cereal production and increased their maize productivity.

Cotton farm gate prices are set through negotiations[4] between the CMDT and the national farmers' groups in Mali. However, farmers' ability to negotiate product prices is limited by two factors: (1) the strength of negotiating power of their representatives; and (2) legislation that sets the floor and ceiling of farm gate prices (Nubkpo and Keita, 2005). Prices are either set prior to planting or no later than a month after planting and are pan-territorial. The ginner CMDT will sell that same cotton 4–5 months after harvest, which begins in December. If world market prices increase to a sufficient degree that the ginner has "excess profits", there is a legislated mechanism to distribute part of those profits back to farmers in the form of second payments.[5] The ginning sector adjusts farm gate prices to variations in the world cotton price with a lag (of a year) during their negotiations at the beginning of a new production season. The government of Mali has set the floor price for seed cotton at 0.32 US$/kg and its ceiling at 0.35 US$/kg during the last 3 years.

[4] In Benin and Burkina Faso there were attempts to increase the farm level prices and bargaining power of cotton farmers by increasing the number of gins. Burkina Faso now has three gins. Unfortunately, the predominant effect of the increased number of gins has been to establish regional purchase territories and price fixing between gins (Baquedano et al., 2008). One reason for this price fixing being encouraged by the public sector has been to avoid the phenomenon observed in East Africa of farmers obtaining credit from one gin and then selling to another and not repaying the credit. Mali has a program to enable an increased number of gins but with fairly onerous conditions that may well discourage buyers (Baquedano et al., 2008). In any event the previous experience in West African reform of increased competition by ginners has not led to noticeable increases in price competition. Monopsonies were converted to price fixing oligopsonies.

[5] From 1994 second payments occurred annually until 2001. After 2001, farmers received a second payment in 2004 and 2005. The highest second payment given to farmers was 21% of the farm gate price. The lowest second payment was 3% of the farm gate price (Cotton Data Set from Baffes, 2007). Cotton prices used in the modeling include the second payments.

3. The study region and farmer decision making

The CMDT has organized cotton production in Mali into seven regions. The Fana region is responsible for 16% of cotton production in Mali (Office of the Prime Minister of Mali, 2006). The Cercle of Dioila, which has one of the 17 gins operated by CMDT, produces 33% of the cotton production in the Fana region (Office of the Prime Minister of Mali, 2006). Dioila is representative of cotton production outside the main zone of best conditions for cotton, the Sikasso and Koutiala regions which have approximately half the production of cotton in the country. We expect the primary zone to focus more on cotton productivity and policy in the future and the secondary zone to increasingly focus on the cereals as a cash crop activity. We use farm household level data obtained through interviews with 66 farmers in 7 villages covering the 2006 and 2007 cotton production seasons in the Cercle of Dioila.

The major crops produced in Dioila are cotton, sorghum and maize. Although both sorghum and maize are produced, the former is much more important as both rainfall patterns and soils favor sorghum production over maize in Dioila.

In empirical studies in Sub-Saharan Africa (Vitale and Sanders, 2005; Baquedano and Sanders, 2006; Abdoulaye and Sanders, 2006), farmers state two primary objectives and there is implicitly a third objective: (1) a harvest income goal; (2) a subsistence consumption objective for the cereals, maize and sorghum in this case; and (3) income maximization once the above objectives are attained.

Farmers need money at harvest to pay for their purchased inputs and family[6] labor, finance out-migration of family members after the crop season, pay school fees, taxes, health costs, and finance weddings and other ceremonies. The financial obligations pressuring farmers to obtain income at harvest time are so pervasive that most developing countries experience staple price collapses at harvest time. For Malian cotton farmers, cotton is usually the primary crop they rely onto meet their harvest income goal. More recently though with cotton payments delayed up to 3 months after harvest, farmers have started to rely on cereal grain and small livestock sales for their post harvest cash requirement.

The second farmer objective is to put aside sufficient quantities of the main staple to assure subsistence consumption during the year. While many modelers in developing countries have put this as the first constraint, a series of empirical studies (Rain, 1999; Abdoulaye, 2002; Baquedano, 2005) have shown farmers consistently ranking the harvest income goal above the subsistence goal. This priority ranking is very obvious in bad rainfall years when most farmers are unable to set aside sufficient subsistence consumption for the year. Even though farmers must then rely on the market or private/public assistance[7] to obtain sufficient staples later in the year they attempt to achieve first their harvest income goal.

The third objective is to maximize income after the first two objectives have been met. This is the standard income maximization objective. Note that the first two objectives are the farmers' response to risk. Before being concerned with profit maximization farmers put aside cash for their after harvest time requirements and then sufficient cereals for home consumption all year. In our Malian farm household model, preferences are ordered lexicographically responding to the hierarchal ordering in which farmers satisfy their objectives. This behavioralist approach is based on farmer interviews and departs from the traditional tradeoff between expected income and some proxy for risk. While this traditional approach is mathematically elegant, it is hard to refute or confirm its ability to predict a meaningful risk aversion coefficient.[8]

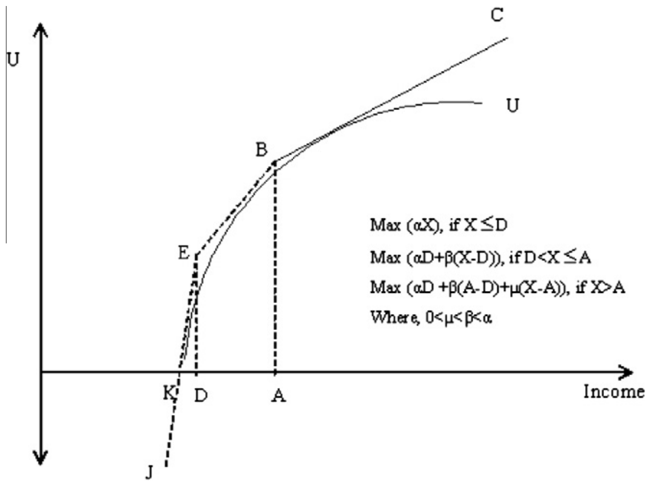

Fig. 1. the conceptual lexicographic utility problem in African households.

Our conceptual approach is illustrated in Fig. 1 below. The three components of the African farm-households' utility function (the harvest income requirement, subsistence consumption, and maximization of expected income) can be divided into three non-continuous segments. Up to income level (D) the farmer attempts to achieve his harvest income goal by maximizing his utility function along (JKE). Once obtaining the income level (D), the farmer stores grain for later consumption up to a money value of (DA). His utility function in this region can then be maximized along (EB). Once at (A) he then maximizes expected income along (BC).

The linear programming model that depicts the representative households' decision-making framework considers three states of nature with respect to yield: bad, normal, and good. Even though in Mali major crop production (such as cotton, maize, and sorghum) is concentrated in the Guinean zone, which receives on average between 800 mm and 1200 mm of rainfall annually, water is still a major concern given its distribution. Farmers yield function, which represents farmers productivity per area in a particular year can be defined as: $Y_t(W_t, SF_t, IU_t, FP_t)$, where Y_t is yield at year t, and W_t, SF_t, IU_t, FP_t, are water, soil fertility, input use, and farmers' practices in year t respectively. It is hard to identify or separate on an individual farm plot, the effects of rainfall, soil fertility, and farmers' practices on yields. Crop yields summarize the effect of all these variables. Additionally crop yields can be considered a suitable proxy for the stochastic risk that rainfall introduces into production systems in this Guinean zone (Anderson and Dillon, 1992). Therefore because of ease of measurability we define a state of nature with respect to yield rather than rainfall.

[6] Family labor is compensated by purchasing clothing or giving grain to other family members (besides the household head) to sell. These payments are made after the harvest when the household head is able to sell the cotton or the cereals. The household head is responsible for setting aside the cereal for subsistence from production and if necessary purchase. So this additional grain is a wage payment to the family member.

[7] Farmers' sell their grain in bad years despite its scarcity (Rain, 1999). This indicates the primacy of their income requirement at harvest over their subsistence grain storage goal. Complex social ties with family members working in other regions enable them to obtain emergency help. These social ties are a type of social insurance policy in which urban based family members are counted onto provide money and/or food primarily in bad rainfall years. In good rainfall years grain flows go from rural to urban relatives.

[8] To validate the traditional approach we would need to be able to determine a decision maker's risk aversion coefficient and then show that with this value we could predict better the choice of activities than with some other decision making system. In practice this risk aversion coefficient is hard to estimate even for developed country farmers. It is an especially difficult concept for farmers in developing countries to grasp.

Table 1
Probability of state of nature with respect to yield for four crops in Dioila, Mali.

	Bad	Normal	Good
	%		
Cotton	0.17	0.58	0.25
Maize	0.19	0.44	0.36
Sorghum	0.24	0.44	0.32
Average	0.20	0.49	0.31

Source: Authors calculations from survey data.

Table 2
Traditional technology packages in the household model.

State of nature	Crop	Technology package (1) 150 kg/Ha of NPK + 50 kg/Ha of Urea	(2) 100 kg/Ha + 50kg/Ha of Urea	(3) No fertilizer
		(Yield, kg/Ha)		
Bad	Cotton	700		
	Maize		890	
	Sorghum			700
	Cowpea			200
Normal	Cotton	1200		
	Maize		1400	
	Sorghum			1100
	Cowpea			400
Good	Cotton	1800		
	Maize		2000	
	Sorghum			1500
	Cowpea			600

Source: Authors calculations from household survey data ($n = 66$).

To determine the probability of a state of nature, we elicited from farmers in Dioila their expectation of yields for a bad, normal, and good year for cotton, maize, and sorghum. Using the cumulative distribution of farmers yield expectations of the three main crops considered, we calculated the probability for each state of nature per crop. Given the similarities in cropping systems of cotton, maize, and sorghum and that the probabilities per state of nature did not differ significantly we use the average value across the three crops per state of nature. The probability of a bad year in our model is 20%, a normal year 49%, and a good year 31% (Table 1).

There are three traditional technology packages in the model (Table 2). The technological packages (TP) involve four crops[9]: cotton, maize, sorghum, and cowpeas. Maize and sorghum are the main food crops for the household, while cotton and cowpeas are the main cash crops. Nevertheless, in the model, food crops can also be sold to meet the household income goal. The first TP represents the current production technology used for cotton by farmers in Mali. It includes 150 kg/Ha of the complex fertilizer NPK and 50 kg/Ha of Urea, insecticides, and herbicides. The rate of fertilizer used in maize, is 100 kg/Ha of complex fertilizer NPK and 50 kg/Ha of Urea. The yields reported in Table 2 for the traditional practices are the averages of a farm household survey completed in 2008.

The objective function in the model, as stated in Eq. (1), maximizes the expected value of adjusted post harvest income, which is defined in Eq. (4), subject to the farmers' objectives of first meeting his harvest income goal (Eq. (2)) and then fulfilling his staple consumption objective (Eq. (3)).

$$\text{Max } E[I] = \sum_S \theta_S I_S \tag{1}$$

S.t.

$$\sum_c SH_{cs} P_{c1s} > HI_S \tag{2}$$

$$\sum_c C_{cs} + B_{cs} < Cr \tag{3}$$

$$I_S = \sum_c SPH_{cs} P_{c2s} + \sum_c SH_{cs} P_{c1s} + \sum_l RT_{ls} Z_l - STC_s - \sum_f \sum_i (ID_{fi} X_i) P_f - \lambda \sum_c PC_{cs} B_{cs} - \sum_b HLAB_b W_b - CF_s \tag{4}$$

The model requires that the harvest income goal (Eq. (2)) be met through sales of crops in every state of nature[10] at harvest prices in that particular state. When farmers sell crops (other than cotton) at the harvest price they are forgoing additional income by not selling later in the year at a higher price. If we algebraically rearrange Eq. (8), which defines the use of production, to give us the definition of sales after harvest (SPH_{cs}) and substitute it into Eq. (4) above, which results in (4.a), and differentiate with respect to sales at harvest (SH_{cs}) we see in Eq. (4.b) that the cost in loss of income to farmers from selling one unit of cereals to meet their harvest income goal is equal to the price differential between prices 7 months after harvest and the harvest price.

$$I_s = \sum_c (Q_{cs} - C_{cs} - SH_{cs}) P_{c2s} + \sum_c SH_{cs} P_{c1s} + \sum_l RT_{ls} Z_l - STC_s - \sum_f \sum_i (ID_{fi} X_i) P_f - \sum_c \sum_t PC_{cts} B_{cs} - \sum_b HLAB_b W_b - CF_s \tag{4.a}$$

$$\frac{d_{ls}}{dSH_{cs}} = P_{c1s} - Pc2s \tag{4.b}$$

If the price at harvest were the same as the price 7 months later, defined in Eq. (4.b), there would be no cost for farmers to bear from selling at harvest. In that scenario, our harvest income goal constraint would not be binding and farmers would face the more common income maximization problem with a subsistence constraint. Given that in the Sahel prices for staples have substantial seasonal variation, farmers pay the cost in forgone income to meet their harvest income goal. Therefore, the opportunity cost of storage for farmers is equal to the revenue forgone of the price difference between the price at harvest and the price 7 months later times the amount of cereal crops sold at harvest to meet their income goal.

In our model the consumption requirement[11] (Eq. (3)) can be met from consumption of stored grain and/or purchases from local markets.

Only after these harvest income and subsistence consumption objectives have been met, does the household maximize income. Eq. (4) is maximized in the objective function and is defined as "adjusted net income" from grain sales and income from other activities. Relevant costs for grain storage, production inputs, labor and financing cost have been deducted to obtain the net value. Note that the income maximization in Eq. (4) – after assuring the two priority objectives of harvest income and subsistence consumption

[9] In regards to land quality our model does not adjust for differences in land across the modeled crops. Substitution of one crop for the other is assumed to be done on the same quality of land. More detailed modeling would include the variations in land quality adjusting for sandier lower fertility soils. Fertilizing these soils requires more organic fertilizer to improve structure and biological activity than is required on the heavier often alluvial soils where cotton and the main cereals, sorghum and maize are predominantly grown.

[10] Using farm-household interviews, we estimated the harvest income goal for the three states of nature in the model.

[11] The consumption requirement of 8500 kg/annum/household of cereal grain was obtained in farm-household interviews and is the same across states of nature. The consumption requirement estimate takes into account the differences in consumption between adults and infants as well as males and females. We chose to take the observed consumption as the base requirement over statistics such as the FAO nutritional requirements. If we were to use statistics such as the FAO's Codex Alimentaris, we would be assuming that farmers in Mali have perfect information about their nutritional requirements.

– also enables the farmer to buy the amount of his subsistence requirement not achieved by his own production.

Eq. (5) returns the income definition in Eq. (4) back to a more standard income definition by adding back the value of food purchases multiplied by λ (to be explained below). Eq. (6) defines total expected household income, which is the sum of income in Eq. (5) plus the estimated value of home consumption.

$$I_s^* = I_s + \lambda \sum_c PC_{cs} B_{cs} \tag{5}$$

$$THI = \sum_s \theta \left(I_s^* + \sum_c PC_{cs} C_{cs} \right) \tag{6}$$

As stated previously, the household can choose to meet its consumption requirement from production or through purchases from the market. In the model this tradeoff is balanced by the own production premium lambda (λ) in Eq. (4). This parameter (λ) enables an decreased shadow price of production of cereal below the expected price 7 months after harvest to compensate for the desire of farmers to assure much of their own grain for consumption and to reduce their dependence on cereal markets (Abdoulaye and Sanders, 2006). When $\lambda = 1$, the farmer produces cereals until the value of his marginal product is equal to the expected purchase price of cereals 7 months later (Baquedano and Sanders, 2006). At $\lambda = 1$ in our model, there was a difference between our predictions and farmers' observations. Farmers relied more on the market for their consumption of cereals than the model predicted. Even in the boom period of high cotton productivity and prices farmers still preferred to produce more cereals than the model predicted for a unitary value of lambda.[12] A lambda value of 1.4 gave the best predictions of actual behavior.[13] At this value for lambda, the farmer produces cereals at a cost 40% higher than the expected purchase price 7 months after harvest. This translates into an expected price for cereals of 0.39 US\$/kg (195 Fcfa/kg). Note that this price is closer to the price in bad years, 0.40 US\$/kg (200 Fcfa/kg) than to the expected price across years of 0.28 US\$/kg (139 Fcfa/kg). So adjustments in this lambda value are another method of incorporating risk aversion into the model from actual observed behavior. Eq. (7) defines production as the area planted under the technologies available in the model times their respective yields. Eq. (8) defines how grain from own production in the household can either be consumed, sold at harvest, or sold 7 months after harvest. Eqs. (9) and (10) define land and labor constraints respectively.

$$Q_{cs} = \sum_i YLD_{cis} X_i \tag{7}$$

$$Q_{cs} = C_{cs} + SH_{cs} + SPH_{cs} \tag{8}$$

$$\sum_i X_i \leqslant Ha \tag{9}$$

$$\sum_i X_i LR_{ib} < FLAB_b + HLAB_b \tag{10}$$

Eq. (11) defines the liquidity constraint in our model, this constraint is based on the capital available to the household and sales of livestock by the household. Capital (*CAP*) is exogenous in the model, and drives the model results since the new technologies raise the capital requirements. The initial capital available[14] to the household in the model is the average sum of investments incurred by the household in agricultural and non-agricultural activities observed in the 2006 and 2007 production seasons. Except for cotton this capital is internally generated by cashing in the farmers' own assets. Recently, there has been a rapid multiplication of micro-finance institutions in the cotton zone increasingly making credit available for both agricultural and non-agricultural activities.

Households own various assets that they can and do cash in on the market such as grain stocks, chickens, sheep, and goats. The capital available in the model reflects observed investment levels of farmers from selling off these assets during the 2006/2007 agricultural season. Bigger livestock such as cattle, which are common in Dioila and in other cotton[15] areas of Mali, are predominantly used as a savings instrument or animal traction and only sold in extremely bad years. In the model we do not consider this type of capital as a source of liquidity. For cotton the ginning sector provides fertilizer, seed and pesticides on credit and deducts their value from the cotton sold by farmers to them. For maize and sorghum the CMDT occasionally provides fertilizer on credit, although farmers have reported using some of the cotton fertilizer on the cereals.

Table 3
Subscripts, variables, and parameters in the model.

Item	Definition
Subscripts	
B	Labor period
C	Crop
I	Technology package
F	Factor input
L	Livestock
S	State of nature
1, 2	1: Sales at harvest; 2: sales 7 months after harvest
Variables	
B_{cs}	Amount of crop *c* in state of nature *s* purchased for consumption
C_{cs}	Amount of own production of crop *c* in state of nature *s* destined for consumption
CF_s	Finance cost in state *s*
$HLAB_b$	Hired labor used in labor period *b*
I_s	Adjusted post harvest income in state of nature *s*
SH_{cs}	Amount of crop *c* in state of nature *s* sold at harvest
SPH_{cs}	Amount of crop *c* in state of nature *s* sold 7 months after harvest
ST_{cs}	Amount of crop *c* in state *s* to store for sales 7 months after harvest
STC_s	Storage costs in state of nature *s*
X_i	Amount of area under technology package *i*
Z_l	Amount of livestock activity *l* undertaken in model
Parameters	
θ_S	Probability of a state of nature *s*
CR	Consumption goal
$FLAB_b$	Amount of family labor available in labor period *b*
HA	Amount of hectares of land available
HI_s	Harvest income goal in state of nature *s*
I_s^*	Post harvest income in state of nature *s* plus the value of food purchases
ID_{fi}	Demand of input factor *f* by technology package
LR_{ib}	Labor requirement of technology package *i* in labor period *b*
P_{c1s}, P_{c2s}	Sale price of crop *c* in period 1 or 2 in state of nature *s*
PC_{cs}	Consumption price of crop *c* in state of nature *s*
P_f	Price of input factor *f*
RT_{ls}	Return of livestock activity *l* in state of nature *s*
W_b	Wage rate in labor period *b*
YLD_{cis}	Yield of crop *c* under technology package *i* in state of nature *s*

[12] When new technologies are introduced, especially Bt Cotton, according to our model with lambda equal to 1 farmers in Mali would be become net buyers of food and dedicate themselves to the production of cotton to finance their food purchases and other expenditures. But even during the cotton boom in the 1980's, when cotton productivity was at its highest, farmers never stopped producing their own food. There is a strong farmer aversion to depending on the market for own cereal consumption. So we expect that even with the successful introduction of Bt cotton and more fertilizer on cotton farmers would still have a high preference for producing their own staples.

[13] The own food premium in our model quantifies how much a farmer is willing to pay to avoid relying on the market for his subsistence consumption by increasing the quantity of his own production of staple cereals.

[14] The total initial capital available to the household in the model for all activities is US\$1988 of which US\$ 1282 was the average expenditure on cotton and maize inputs. The remaining, US\$706, was the observed average investment on livestock, veterinary costs of livestock, and entrepreneurial investments made by the household.

[15] Relative to farmers who only produce cereals, cotton farmers are generally richer and are able to afford more cattle which they use primarily as a savings instrument (SWAC-OECD, 2005). This was observed in Dioila and other cotton areas of Mali.

We allow the model to sell small livestock (chickens, goats, and sheep) to increase liquidity for input purchases when new technologies are introduced. Farmers traditionally use the revenue of sales of small livestock to cover short term consumption and ceremony expenditures. But it has been observed that on occasion farmers use this revenue to invest in income generating activities such as funding small shops and buying agricultural inputs. Moreover, with the introduction of microfinance banks in Dioila, and elsewhere in the cotton zone of Mali, sheep's and goats are being used regularly as collateral to obtain loans for investment in agricultural and non-agricultural activities. Therefore assuming that sales of small livestock can be destined to increase liquidity for input purchases is consistent with field observations.

In the future, we would expect the connection of farmers' associations and regional savings and loan associations to provide more of these credits. As more credit is obtained from these sources taking into account the interaction of farmers with these savings and loans associations and their general access to capital will be a useful improvement to our model.

$$\sum_{f}\sum_{i}(ID_{fi}X_i)P_f + \sum_{b} HLAB_b W_b \leqslant \sum_{l} RT_{ls}Z_l + CAP \quad (11)$$

The model is solved using linear programming and a detailed description of all the variables is given in Table 3.

4. Effects on household income of changes in the world cotton price and enhancing cotton and sorghum productivity

4.1. Income and production effects of increased world cotton price

What happens to Malian farmers' prices and incomes when US cotton subsidies are removed? Many studies have evaluated the effects of eliminating these subsidies on the world cotton price and supply (Sumner, 2003, 2006). Alston and Brunke (2006) go beyond this to evaluate the changes in farm gate prices and farmers' incomes in Benin from a removal of US cotton subsidies. Their analysis does not consider the farmer response to a higher-priced activity. Our analysis includes the farm level supply response to the incentive of a higher price and the effects of this price increase on farmer's income and consumption.

For world prices, we use the Cotton A index price (1970–2007), which is the world reference cotton price (Cotlook, 2008). The farm gate price is the lint equivalent price reported by the Malian cotton para-statal, CMDT. This price is obtained by dividing the farm gate price, denominated in seed cotton, by the ginning ratio of 42%.

From 1970 to 1993, the lint equivalent farm gate price averaged 159 Fcfa/kg (Table 4) while the world cotton price averaged 502 Fcfa/kg. After devaluation, over the period 1994–2007, farmers' average lint equivalent farm gate prices increased to 409 Fcfa/kg and the average world price to 935 Fcfa/kg (Table 4). This represents an increase of 433 Fcfa/kg in the world price that the CMDT received and a 250 Fcfa/kg increase in the price received by farmers between the two periods. Therefore, of the world cotton price increases from the 1970–1993 period to the 1994–2007 period 58%[16] was transmitted back to farmers. In Benin where the structural reforms to the cotton sector are more advanced than in Mali, Alston and Brunke (2006) found that the transmission of world cotton price changes to farmers prices was 80%. So we use these two values of transmission elasticity in our modeling.[17] The first is an average of the recent historic transmission in Mali and the second is an estimate of what the transmission could be if Mali moves as quickly as Benin in reforming the sector and increasing the price level effect for farmers.

In a summary of nine studies, FAO (2004) found an average increase of world cotton prices of 15% with a minimum of 2% and a maximum of 30%. Sumner (2006), in his brief for Brazil's case against US subsidies in the WTO, found that with the removal of all subsidy programs in the US, world cotton prices would have increased almost 14%.

At a compromise value of a 15% increase in the world cotton price from the removal of US subsidies, the ginners' cotton lint price would increase by 0.20 US$/kg (Table 5). To obtain the increase in farmers' seed cotton price we multiply the ginner's price increase from the removal of US subsidies by the transmission coefficient and the ginning ratio. Then the farm level seed cotton price increases by 0.05 US$/kg or 14% (Table 5). If after the reforms of the Malienne cotton sector, farmers can obtain the same level of price transmission as in Benin, this would mean that with a 15% world cotton price increase farmers seed cotton prices could increase by 0.07 US$/kg or 19% (Table 5).

According to our model results, a 58% transmission of a 15% increase in the world cotton price, resulted in a $135 (5%) increase in farmers' expected household income (Table 6). If the transmission of a world cotton price change were to rise to the 80% found in Benin, farmers increase their expected household income by $252 (9%).

The income increase, from the removal of US subsidies, comes from higher crop sales, with expected crop sales at harvest increas-

Table 4
Increases in world cotton prices and farm gate prices in Mali.

	1970–1993	1994–2007	Absolute change
	Fcfa/kg of cotton lint		
World price	502	935	433
Farm gate price	159	409	250

Source: Authors calculations from CMDT, Cotlook, USDA price data.

Table 5
Changes in the gins export price and farm gate cotton lint equivalent price from the removal of US subsidies.

World cotton price change from removal of us subsidies	Increase in Mali Gin gate lint price (Base = 1.33 US$/kg)	Farm gate seed cotton price			
		58% Transmission		80% Transmission	
		(Base = 0.36 US$/kg)			
(1) (% Change)	(2)	(3) Change in US$/kg	(4) (% Change)	(5) Change in US$/kg	(6) (% Change)
15	0.20	0.05	14	0.07	19

Source: Authors calculations. 1. Source of world price change FAO (2004). 2. Base gin gate lint price is the gin gate price in Mali calculated from Cotlook (2008) and taking into account CIF to FOB costs and ginning cost for the 2007/2008 cotton production season. 3. Base farm gate seed cotton price is the seed cotton farm gate price in Mali for the 2007/2008 production season. Exchange rate: 1 US$ = 498 FCFA (Oanda Corporation, 2008).

[16] The transmission of the price increase received by farmers was calculated as the percent ratio of the increase in farmers lint equivalent price from 1970–1993 to 1994–2007 to the increase in the world price received by CMDT from 1970–1993 to 1994–2007. Mathematically this is represented as $\Delta P_f/\Delta P_w * 100$, where ΔP_f is the change in the farm gate price from 1970–1993 to 1994–2007; ΔP_w is the change in the gin gate price from 1970–1993 to 1994–2007. This methodology was also used by Alston et al., (2007).

[17] An alternative approach to estimating an elasticity of world price transmission to Malian producer prices would require a spatial or general equilibrium framework that would have to take into account supply and consumption trends of the major players in world cotton markets. This analysis of transmission would also need to consider the potential changes in costs of transportation and transactions.

Table 6
Changes in expected household income given a 15% increase in world cotton prices and two levels of price transmission.

Technology package	Harvest sales State of nature				Value of cereal grain purchases State of nature				Value of cereal grain consumption State of nature				Total household income State of nature			
	Bad (1)	Normal (2)	Good (3)	Expected (4)	Bad (5)	Normal (6)	Good (7)	Expected (8)	Bad (9)	Normal (10)	Good (11)	Expected (12)	Bad (13)	Normal (14)	Good (15)	Expected (16)
	US$															
Traditional technology	1204.8	1455.8	2257.2	1643.5	2736.5	805.7	–	969.5	522.8	1718.0	2154.3	1597.9	2696.9	3055.9	2743.7	2886.8
15% World cotton price increase																
58% Price transmission	1204.8	1850.1	2848.6	2014.1	2139.7	836.0		859.0	964.4	1706.8	2183.7	1693.9	2321.0	3248.4	3143.8	3022.3
(% change from traditional technology)				22.5				−11.4				6.0				4.7
80% Price transmission	1204.8	1986.8	2980.2	2120.6	1977.2	910.7		861.5	1077.0	1651.0	2222.8	1702.0	2271.0	3404.1	3314.4	3139.3
(% change from traditional technology)				29.0				−11.1				6.5				8.7

Source: Model Results.

Table 7
Changes in Cotton and Sorghum Production Given a 15% Increase in World Cotton Price.

State of nature	Traditional practices	15% Increase in world price with traditional practices	
		58% Price transmission	80% Price transmission
	(1)	(2)	(3)
(kg of seed cotton)			
Bad	2350	2635	2710
Normal	4028	4516	4645
Good	6042	6775	6968
Expected	4280	4799	4935
(% change from traditional)		12	15
(kg of cereals)			
Bad	3899	3846	3718
Normal	6129	6047	5846
Good	8500	8500	8200
Expected (% change from traditional)	6372	6321	6105
		−0.8	−4.2

Source: Model results.

ing $371 (23%) and $477 (29%) at the 58% and 80% price transmission levels respectively (Table 6). Additionally the household increases the value of own cereal grain consumption and decreases the value of purchases from the market at both lower and higher level of price transmission respectively (Table 6).

Our model also suggests that famers' cotton production is expected to increase by 519 kg (12%) in response to a 15% increase in world prices and 58% transmission (Table 7). At an 80% price transmission level, production increases by 655 kg (15%). Conversely, cereal production decreases at the 58% and 80% level of price transmission respectively (Table 7) due to the increased area planted to cotton (Annex 1 columns 2 and 3).

4.2. Income and production effect of increased cotton productivity

Field trials in Mali found that by increasing the dosage of the complex fertilizer NPK by 50 kg/Ha or one third, cotton yields can be increased by 18% (IER, 2006). However, the largest potential yield-increasing technology for cotton is Bt cotton. In 2007 Bt Cotton was used in half of the cotton growing areas in the world (ICAC, 2008). Furthermore, in 2008, Burkina Faso became the first country in West Africa to use Bt cotton on farmers' fields (ICAC, 2008). In 2009 Burkina Faso plans to cultivate at least 100,000 Ha of Bt cotton (personal communication, Jeffrey Vitale). The attitude in Mali towards Bt cotton is becoming more receptive in spite of active resistance from NGOs and others to GMO's.

The advantage of Bt cotton is the improved protection it offers against the bollworm complex.[18] The gene of the bacteria *Bacillus thurengensis* that controls the bollworm complex is already in the cotton plant. The traditional control method for the bollworm complex in Mali involves spraying the insecticide Endosulfan. The efficiency of a spray-based protection method depends on various factors including the environmental conditions at the moment of treatment and the ability of the person spraying the product. The better delivery of protection that Bt cotton offers has the potential to increase yields and reduce cost by saving up to four applications per growing season of insecticide in Mali. Moreover, there is the human health benefit of eliminating the handling of Endosulfan, a very toxic chemical.

[18] The bollworm is *Lepidoptera* spp., a worm that can attack both the leaf and cotton boll, causing defoliation to abortion of the cotton fruit.

Annex 1
Crop area given a 15% increase in world cotton price and introduction of Bt cotton.

Crop	Traditional practices	15% Increase in world cotton price with traditional practices		Increased fertilization cotton	Bt cotton	Bt cotton with increased fertilization	Bt cotton with increased fertilization and a 15% increase in world cotton price	
		58% Price transmission	80% Price transmission				58% Price transmission	80% Price transmission
	(1) Ha	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1. Cotton	3.36	3.76	3.87	3.59	–	–	–	–
2. Bt cotton	–	–	–	–	3.84	3.60	4.48	4.69
3. Sorghum	3.57	1.95	2.12	2.64	2.00	2.60	–	–
4. Maize	1.57	2.79	2.51	2.27	2.67	2.30	4.13	3.81
5. Cowpea	0.50	0.50	0.50	0.50	0.50	0.50	0.39	0.50
Total	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00

Source: Model results.

Table 8
Traditional and new technology packages for cotton and sorghum in the model.

	Technology package	Bad		Normal		Good		Expected yield	
		Cotton	Sorghum	Cotton	Sorghum	Cotton	Sorghum	Cotton	Sorghum
		(Yield, kg/Ha)							
	Traditional								
1	150 kg/Ha of NPK + 50 kg/Ha of Urea	700		1200		1800		1275	
2	100Kg/Ha + 50Kg/Haof Urea								
3	No fertilizer		700		1100		1500		1136
	New technologies								
4	Higher fertilized cotton (200 kg/Ha of NPK + 50 kg/Ha of Urea)	826		1416		2124		1505 18	
5	BT cotton seed + 150 kg/Ha of NPK + 50 kg/Ha of Urea (% increase in expected yield from traditional practice)	847		1452		2178		1543 21	
6	BT cotton seed + 200 kg/Ha of NPK + 50 kg/Ha of Urea (% increase in expected yield from traditional practice)	973		1668		2502		1772 39	
7	Improved sorghum + 100 kg/Ha + 50 kg/Ha of Urea (% increase in expected yield from traditional practice)		1120		1600		2000		1619 43

Source: Traditional packages 1–3: authors calculations from survey data ($n = 66$); New technologies: Technology Package 4: estimated from PASE (2006) and Vitale and Park (2007); and Technology Package 6: estimated from INTSORMIL (2007–2008).

Bt cotton can be made available rapidly in Mali as it has been under field experiments in Burkina Faso[19] since 2003. Vitale and Park (2007) in an evaluation of these trials, projected that on average under different levels of bollworm infestation, cotton yields increase by 21%[20] in farmers fields with Bt cotton.

To evaluate the impact of increased fertilization, cotton yields were increased by 18% in our model (Table 8). For Bt cotton's impact, farmers' yields were increased 21% as reported by Vitale and Park (2007) for Burkina Faso. We then evaluate the joint effect of Bt cotton and increased fertilization by increasing farmers' traditional yields by 39% (Table 8). Finally we also include the effect of increased world prices with better productivity.

According to our model results, increasing current fertilizer levels for cotton by 50 kg/Ha or one third, increases expected household income by almost $115 (4%) (Table 10 column 16). This increase is similar to the expected income increase obtained from a 15% world cotton price increase and 58% price transmission.

Table 9
Probability of state of nature and prices of sorghum and cotton under traditional and improved technologies and marketing strategies.

State of nature	Probability of a state of nature	Traditional sorghum		Improved sorghum with improved marketing strategy	
		Price at harvest	Price 7 months later	Price at harvest	Price 7 months later
(1)	(2)	(3)	(4)	(5)	(6)
	(%)		US$/kg		
Bad	0.21	0.15	0.28	0.18	0.33
Normal	0.49	0.13	0.25	0.15	0.29
Good	0.30	0.11	0.22	0.13	0.26

Source: Probabilities: authors calculations; sorghum prices: farm household surveys. Exchange rate: 498 FCFA/US$ (*Source*: Oanda Corporation, 2008). Prices in column 5 are the prices in column 3 increased by a 17% price premium for cleaner sorghum grain. Similarly prices in column 6 are the prices in column 4 increased by 17% reflecting the same price premium.

[19] In 2008 farmers in Burkina Faso planted 10,000 Ha of Bt cotton on farmers fields (ICAC, 2008) and they were expected to plant 100,000 Ha in 2009.

[20] Vitale and Park (2007) found experiment station yields increased by 25%. They expanded their analysis to project yield increases in farmers' fields in three regions given that farmers production conditions are less favorable than at the experiment station. The 21% yield increase is the average of the projected yields for the three different regions (Vitale and Park, 2007).

Table 10
Changes in expected household income given better cotton fertilization, Bt cotton, and a 15% increase in world cotton prices and two levels of price transmission.

Technology package	Harvest sales State of nature				Value of cereal grain purchases State of nature				Value of cereal grain consumption State of nature				Total household income State of nature			
	Bad (1)	Normal (2)	Good (3)	Expected (4)	Bad (5)	Normal (6)	Good (7)	Expected (8)	Bad (9)	Normal (10)	Good (11)	Expected (12)	Bad (13)	Normal (14)	Good (15)	Expected (16)
Traditional technology	1204.8	1455.8	2257.2	1643.5	2736.5	805.7	–	969.5	522.8	1718.0	2154.3	1597.9	2696.9	3055.9	2743.7	2886.8
15% World cotton price increase																
58% Price transmission	1204.8	1850.1	2848.6	2014.1	2139.7	836.0	–	859.0	964.4	1706.8	2183.7	1693.9	2321.0	3143.8	3143.8	3022.3
(% change from traditional technology)				22.5				−11.4				6.0				4.7
80% Price transmission	1204.8	1986.8	2980.2	2120.6	1977.2	910.7	–	861.5	1077.0	1651.0	2222.8	1702.0	2271.0	3404.1	3314.4	3139.3
(% change from traditional technology)				29.0				−11.1				6.5				8.7
Increased fertilizer cotton	1204.82	1836.88	2828.82	2001.73	2151.23	822.99	–	855.0	949.3	1711.6	2171.1	1689.4	2317.7	3227.1	3111.4	3001.1
(% change from traditional technology)				21.8				−14.1				5.7				4.0
Bt cotton	1204.8	2013.1	3051.4	2154.8	1914.1	879.2	–	832.8	1124.0	1674.8	2206.7	1718.7	2255.0	3422.7	3369.6	3161.5
(% change from traditional technology)				31.1				−14.1				7.6				9.5
Bt cotton and increased fertilization	1265.7	2169.8	3328.3	2327.5	1835.0	823.8	–	789.0	1187.102	1711.311	2171.82	1739.4	2299.9	3560.5	3611.5	3311.1
(% change from traditional technology)				41.6				−18.6				8.9				14.7
15% World cotton price increase and Bt cotton with increased fertilization																
58% Price transmission	1784.8	3059.7	4589.5	3250.9	1920.3	949.1	–	868.3	1146.7	1631.1	2251.6	1715.5	2863.8	4644.7	5101.7	4407.8
(% change from traditional technology)				97.8				−10.4				7.4				52.7
80% Price transmission	1950.6	3343.9	5015.9	3552.9	2026.8	1099.2	200.2	1024.3	1069.1	1527.4	2111.1	1606.3	3058.5	4975.2	5587.8	4756.4
(% change from traditional technology)				116.2				5.7				0.5				64.8

Source: Model Results.

Table 11
Changes in cotton and cereal production given better cotton fertilization, Bt cotton, and a 15% increase in world cotton prices and two levels of price transmission.

State of nature	Traditional practices	15% Increase in world price with practices traditional		Increased fertilization cotton	Bt cotton	Bt cotton and increased fertilization	Bt cotton with increased fertilization and a 15% increase in world cotton	
		58% Price transmission	80% Price transmission				58% Price transmission	80% Price transmission
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(kg of seed cotton)								
Bad	2350	2635	2710	2965	3249	3502	4357.072	4560.607
Normal	4028	4516	4645	5082	5570	6003	7469.266	7818.183
Good	6042	6775	6968	7623	8354	9005	11203.9	11727.275
Expected (% change from traditional)	4280	4799	4935	5400	5918	6378	7936	8307
		12	15	26	38	49	85	94
(kg of cereals)								
Bad	3899	3846	3718	3868	3772	3867	3679	3393
Normal	6129	6047	5846	6082	5931	6080	5338	5338
Good	8500	8500	8200	8500	8330	8500	8267	7626
Expected (% change from traditional)	6372	6321	6105	6343	6197	6341	6088	5616
		−0.8	−4.2	−0.5	−3	−0.5	−4.5	−11.9

Source: Model results.

Annex 2
Crop area given the introduction of Bt cotton and improved sorghum with better marketing.

Crop	Traditional practices	Bt cotton with increased fertilization	Improved sorghum	Improved sorghum with better marketing	Improved sorghum with better marketing and Bt cotton with increased fertilization	Bt cotton with increased fertilization, a 15% increase in world cotton price , and improved sorghum with better marketing	
						58% Price transmission	80% Price transmission
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Ha						
1. Cotton	3.36	–	3.36	3.24	–	–	–
2. Bt cotton	–	3.60	–	–	3.69	4.67	4.68
3. sorghum	3.57	2.00	–	–	–	–	–
4. Improved sorghum	–	–	5.14	5.31	5.31	4.25	4.22
5. Maize	1.57	2.67	–	–	–	–	–
6. Cowpea	0.50	0.50	0.50	0.44	–	0.09	0.09
Total	9.00	8.76	9.00	9.00	9.00	9.00	9.00

Source: Model results.

A critical factor[21] in the adoption of Bt cotton is the cost of the annual technology licensing fee. In 2009, it was announced that farmers' technology fee[22] would be 45 US$/Ha in Burkina Faso (Personal Communication Jeffrey Vitale). In Mali, this fee would represent an increase of farmers annual seed cost[23] of 72%. However, using Bt cotton can save Malian farmers approximately 80% (or from 46 to 9 US$/Ha) in their costs of insecticide application by reducing applications from 5 to 1 application. The one application is for the insect pests unaffected by the Bt gene.

When Bt cotton without improved fertilization is introduced into the model, the increase in expected household income is more than double than that of increasing fertilization in cotton. With Bt cotton, farmers expected household income increases by almost $275 (10%) (Table 10 column 16). The income increase from Bt cotton alone is $22 (9%) higher than a 15% increase in the world price for cotton with 80% price transmission.

When combining the effect of Bt cotton with higher fertilizer use, farmers expected household income increases of $424 (15%) (Table 10 column 16). This is almost $172 (68%) higher than a 15% increase in the world price for cotton and 80% price transmission. With Bt cotton and higher fertilization, expected harvest sales increase by $684 (42%) (Table 10 column 4). We also observed significant changes in the value of own consumption of cereals and cereal purchases from the market (Table 10 columns 8 and 12). The adoption of Bt cotton along with higher fertilizer use in our model is driven by the cost savings generated from using less pesticides. The model results indicate the potential for farmers to reinvest the savings from using less pesticide into fertilizer and thereby substantially increasing productivity and income.

When cotton farmers in the Sahel were first provided credit for fertilizers and pesticides in the late 1960's to the early 1980's, they quickly adopted these inputs and invested heavily in their use, because of their higher returns and increased productivity. Given that both Bt cotton and higher fertilization promise higher returns and productivity, we expect a similar reaction of high adoption rates and willingness to invest in these inputs as in the first cotton revolution. While capital to adopt these technologies will always be a critical input, in the cotton zone this is less of an issue as the ginning sector provides short term financing for farmers to acquire these inputs. In Burkina Faso there has been rapid acceptance by farmers of the Bt cotton and associated technologies.

[21] Determining the licensing cost of Bt cotton seed has been one of the major sticking points of its commercial release in West Africa. Monsanto, has a monopsony position and the potential to charge a high price for the right to use this seed.

[22] Vitale and Park (2007) using a programming model found that the profitability of adoption for Bt cotton decreased at seed licensing costs greater than 75 US$/Ha. At higher price levels adoption by farmers steadily declines.

[23] For the crop year 2007/2008 farmers in our surveys reported a total cost of seed of 2.08 US$/kg at an annual average exchange rate of 498 FCFA/US$

With a 15% world price increase and Bt cotton with increased fertilization, expected household income increases by $1521 (53%) at the lowest transmission level and by $1870 (65%) at the highest transmission level (Table 10 column 16).

When we compare and contrast the income and production effects of a 15% world cotton price increase and 80% price transmission (Table 10 column 16 and Table 11 column 3) with that of Bt cotton with increased fertilization (Table 10 column 16 and Table 11 column 6), the increase in expected household income from the latter is not only $172 (68%) higher than the former, but cotton production is substantially higher as well. With Bt cotton and increased fertilization, cotton production increases 49% overall (Table 11 column 6). This is 1.4 mt (29%) more cotton production when using Bt technology with higher fertilizer than increasing the world cotton price by 15% and an 80% price transmission.

In regards to cereal production, cotton displaces some cereal area as cotton prices increase and cotton productivity improves (Annex 1). The largest drop in cereal production occurs with the combination of Bt cotton with higher fertilization and a 15% world cotton price increase with 80% price transmission (Table 11 column 8). Nevertheless, as in the boom period of cotton productivity expansion cereals retain an important component of the farm system even with the combined new technologies in cotton. In the model even when assuming the highest prices transmission and cotton productivity cereals represent 42% of the total crop area planted (Annex 1 column 8) (Annex 2).

4.3. Income and production effects of improved sorghum technology and marketing on household income and production

The sorghum technology package (TP 6) is based on the work carried out by IER (the National Agricultural Research Institute of Mali) with the International Sorghum and Millet Research Program or INTSORMIL in Dioila, Mali. The technology package consists of the improved sorghum variety, Soumba, combined with moderate fertilization. This variety is more responsive to fertilization than the traditional Guinean sorghums used in Mali. Besides the new cultivar, the technology package includes 100 kg/Ha of the complex fertilizer NPK and 50 kg/Ha of the nitrogen based fertilizer Urea. With the improved sorghum package, farmers have to invest 87 US$/Ha in fertilizer.[24] Baquedano (2009), in evaluating the IER-INTSORMIL program found that expected sorghum yields using the program variety and fertilizer increased yields up to 43% over farmers' traditional technology package. Repeated trials all over Mali in the cotton zone have demonstrated the profitability of this fertilized sorghum activity in good and normal years (Abdoulaye et al., 2008; Baquedano et al., 2009, Coulibaly, 2010). Even adding in the poor rainfall years the expected profits have been substantial. In 2010 these farm level activities of sorghum will be scaled up to 2500 ha with bank financing support.

The IER-INTSORMIL program is also aiding farmers in marketing their sorghum. Two of the marketing concepts promoted focus on encouraging farmers to delay their sales until prices recover from the harvest price collapse and secondly to sell a higher quality product by getting threshing off the ground.

By selling later in the year, farmers can take advantage of the seasonal price increase. To do this farmers need access to storage facilities and to loans to cover their harvest income requirements. In Mali several of the farmers' groups have been able to secure inventory credit from financial institutions to meet their harvest income goals. Inventory credit programs permit farmers to sell their grain 6–10 months after the harvest and then repay the storage agency for the costs of storage and interest. The program provides credit at harvest time based upon the value of the grain during this period. Farmers then repay the loan plus interest, which currently is at a 15% annual percentage rate, and storage costs. By delaying sales into the season farmers rather than merchants capture the price variation for their staple crop between harvest and later in the year. In the model we incorporate the terms of these loans of a 10 month maturity and 15% annual interest rate.

To evaluate the effects[25] on farmers' household income and production, (of improving sorghum productivity), traditional sorghum yields are increased by 43% (Baquedano, 2009). To evaluate the effects of the two marketing improvements we first consider the gains from storing and selling later in the year. According to farmers' price expectations storing and selling later can double the harvest price (column 4 of Table 9) during the hungry season. In regards to selling a higher quality grain a survey of food processors in Mali, carried out by Aminata et al. (2007), found that food processors had an 13% impurities in their grain. By threshing on plastic tarps these impurities are largely eliminated. In Dioila in 2008 farmers received a price premium of 17% for selling cleaner grain. This price premium reflected the value of fewer impurities in the grain and the opportunity costs to the food processors of not contracting a woman to clean the grain as is normally done. In the model farmers' expected harvest price for improved grain quality was increased by a 17% premium as observed in Dioila (compare columns 3 and 5 in Table 9). Farmers' prices 7 months after harvest were also increased by 17% to reflect the gains from storage and selling a higher quality grain (Table 9 column 4). Finally we also compare the joint effect of Bt cotton, improved sorghum with better marketing and a 15% world cotton price increase.

According to our model, when improved sorghum seed is introduced with higher fertilization farmers' expected household income increases by $93 (2%) (Table 12 column 20). The change in expected income can be traced to an expected increase in total crop sales (the sum of expected harvest and expected post harvest crop sales) of $103 (6%), an increase in the value of own consumption of $364 (23%), and a decrease in purchases of grain of $540 (56%) (Table 12 columns 8, 12, and 16). The increase in expected household income from improved sorghum is very similar to increasing the world cotton price by 15% with 58% price transmission. Under that scenario, expected household income increases by $135 or only $42 more than with the improved sorghum seed and increased fertilization. But one important difference between an increase in the world cotton price by 15% and improved sorghum is that with the latter the expected value of own consumption is much higher and the value of expected grain market purchases is much lower (Table 12 columns 12 and 16). This result implies that with improved sorghum, food security is much higher than when increasing the world cotton price as the household produces more of its own food supply.

When we add better marketing to the improved sorghum technology, expected household income increases by $308 (11%) (Table 12 column 20). This increase in expected household income comes from an expected increase in total crop sales (the sum of expected harvest and expected post harvest crop sales) of $147 (9%) (Table 12 columns 8). Additionally the value of expected own consumption increases by $382 (24%) and the value of expected grain purchases from the market decreases by $585 (60%) (Table 12 columns 12 and 16).

[24] Now fertilizer costs have been reduced by substituting one bag of DAP for two bags of the complex (higher inert material fertilizer plus the urea.

[25] We only consider the benefits from these policies of increasing world cotton prices or new technologies for cotton and sorghum with marketing strategies. A benefit cost analysis of these policies would also need to be concerned with the diffusion and extension cost of the proposed alternatives to estimate the costs of public polices supporting marketing and extension.

Table 12
Changes in expected household income given Bt cotton and improved sorghum with better marketing.

Technology package	Harvest sales State of nature				Post harvest sales State of nature				Value of cereal grain purchases State of nature				Value of cereal grain consumption State of nature				Total house hold income State of nature			
	Bad (1)	Normal (2)	Good (3)	Expected (4)	Bad (5)	Normal (6)	Good (7)	Expected (8)	Bad (9)	Normal (10)	Good (11)	Expected (12)	Bad (13)	Normal (14)	Good (15)	Expected (16)	Bad (17)	Normal (18)	Good (19)	Expected (20)
	US$																			
Traditional technology	1204.8	1455.8	2257.2	1643.5	–	–	–	–	2736.5	805.7	–	969.5	522.8	1718.0	2154.3	1597.9	2696.9	3055.9	2743.7	2886.8
15% World cotton price increase																				
58% Price transmission (% change from traditional technology)	1204.8	1850.1	2848.6	2014.1	–	–	–	–	2139.7	836.0	–	859.0	964.4	1706.8	2183.7	1693.9	2321.0	3248.4	3143.8	3022.3
				22.5								−11.4				6.0				4.7
80% Price transmission (% change from traditional technology)	1204.8	1986.8	2980.2	2120.6	–	–	–	–	1977.2	910.7	–	861.5	1077.0	1651.0	2222.8	1702.0	2271.0	3404.1	3310.4	3139.3
				29.0								−11.1				6.5				8.7
Bt cotton with increased fertilization (% change from traditional technology)	1265.7	2169.8	3328.3	2327.5	–	–	–	–	1835.0	823.8	–	789.0	1187.1	1711.3	2171.8	1739.4	2299.9	3560.5	3611.5	3311.1
				41.6								−18.6				8.9				14.7
Improved sorghum and increased fertilization (% change from traditional technology)	1204.8	1455.8	2257.2	1643.5	–	–	341.6	102.5	1982.7	26.1	–	429.2	1041.628	2261.669	2116.466	1961.9	2546.753	3053.897	3163.683	2980.3
												−55.7				22.8				3.2
Improved sorghum, increased fertilization, and better marketing (% change from traditional technology)	1204.819	1455.823	2175.719	1619.1	–	–	571.8	171.5	1831.9	–	–	384.7	1149.3	2253.0	2116.5	1980.3	2650.629	3215.774	3542.353	3195.1
				−1.5								−60.3				23.9				10.7

(*continued on next page*)

Table 12 (*continued*)

Technology package	Harvest sales State of nature				Post harvest sales State of nature				Value of cereal grain purchases State of nature				Value of cereal grain consumption State of nature				Total house hold income State of nature			
	Bad (1)	Normal (2)	Good (3)	Expected (4)	Bad (5)	Normal (6)	Good (7)	Expected (8)	Bad (9)	Normal (10)	Good (11)	Expected (12)	Bad (13)	Normal (14)	Good (15)	Expected (16)	Bad (17)	Normal (18)	Good (19)	Expected (20)
Improved sorghum, increased fertilization, and better marketing and Bt cotton with increased fertilization (% change from traditional technology)	1296.845	2223.163	3334.744	2362.1	–	–	–	–	1032.289	0	0	216.8	1720.482	2253.012	2116.466	2100.2	2205.057	3673.986	4392.25	3581.0
				43.7								−77.6				31.4				24.0
Improved sorghum, increased fertilization, and better marketing and Bt cotton with increased fertilization and a 15% world cotton price increase 58% Price transmission (% change from traditional technology)	1859.494	3187.704	4794.003	3390.7	–	–	–	–	1507.2	618.3	–	619.5	1383.2	1816.0	2116.5	1815.3	2761.897	4676.408	5220.71	4437.7
				106.3								−36.1				13.6				53.7
80% Price transmission (% change from traditional technology)	1949.288	3341.636	5012.454	3550.5	–	–	–	–	1519.2	633.6	–	629.5	1374.8	1805.6	2125.1	1811.0	2855.4	4835.3	5447.8	4603.2
				116 0								−35.1				13.3				59.5

Source: Model results.

Table 13
changes in cotton and cereal production given Bt cotton and improved sorghum with better marketing.

State of nature	Traditional practices	Bt cotton and increased fertilization	15% Increase in world cotton price with traditional practices		Improved sorghum	Improved sorghum with better marketing	Improved sorghum with better marketing and Bt cotton with increased fertilization	Bt cotton with increased fertilization, a 15% increase in world cotton price, and improved sorghum with better marketing	
			58% Price Transmission	80% Price Transmission				58% Price transmission	80% Price transmission
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(kg of seed cotton)									
Bad	2350	3502	2635	2710	2350	2271	3588	4539	4557
Normal	4028	6003	4516	4645	4028	3893	6151	7782	7813
Good	6042	9005	6775	6968	6042	5839	9226	11,673	11,719
Expected (% change from traditional)	4280	6378	4700	4935	4280	4136	6535	8268	8301
		49	12	15	0	−3	53	93	94
(kg of cereals)									
Bad	3899	3867	3846	3718	5761	5950	5950	4760	4728
Normal	6129	6080	6047	5846	8230	8500	8500	6800	6755
Good	8500	8500	8500	8200	10,287	10,625	10,625	8500	8443
Expected (% change from traditional)	6372	6341	6321	6105	8328	8602	8602	6882	6836
		−0.5	−0.8	−4.2	31	35	35	8	7

Source: Model results.

The increase in expected income from improved sorghum and marketing is also $56 (22%) higher than an increase in the world cotton price by 15% and 80% price transmission (Table 12 column 20). But the increase in expected household income from improved sorghum and better marketing is $116 (38%) lower than introducing Bt cotton with higher fertilization. When combining Bt cotton with higher fertilization with the improved sorghum and marketing, expected household income increases by $694 (24%) (Table 12 column 20). The increases in expected household income comes from a $719 (44%) increase in expected harvest sales, an increase of $502 (31%) in the expected value of own consumption, and a decrease of $753 (78%) in the expected value of cereal grain purchases (Table 12 columns 4, 12 and 16). The combined effect on expected household income is $270 (64%) higher than when introducing Bt cotton alone and $442 (175%) higher than increasing the world cotton price by 15% with 80% price transmission.

The largest effect on expected household income is obtained from combining all three effects (i.e. improved sorghum with marketing, Bt cotton with higher fertilization, and higher world cotton prices). At the lowest level of price transmission expected household income increases by $1551 (54%) from combining all three strategies, and at the highest level of price transmission it increases by $1716 (60%).

When introducing only improved sorghum, cotton output remains the same but cereal production increases by almost 2 mt (31%) (Table 13 columns 5). When marketing is combined with improved sorghum, cotton production decreases by 3% and cereal production increases by 2.2 mt (35%) (Table 13 columns 6). The decrease in cotton production when improved sorghum with better marketing is introduced reflects the higher returns to sorghum relative to present cotton production techniques.

When combining Bt cotton with increased fertilization and improved sorghum with better marketing cotton production increases by 2.3 mt (53%) and cereal production by 2.2 mt (35%) (Table 13 columns 6). The increase in cotton production from the combination of Bt cotton with improved sorghum and marketing is higher than just introducing Bt cotton and 1.6 mt (32%) greater than increasing the world cotton price by 15% with 80% price transmission (Table 13 columns 2, 4, and 7). Cereal production is 2.3 mt (36%) higher with Bt cotton and improved sorghum and marketing than only introducing Bt cotton and 2.5 mt (41%) higher than with a 15% world cotton price increase and 80% price transmission (Table 13 columns 2, 4, and 7).

5. Conclusions

Using a household model based on farmers' decision-making framework we find that the farm income effect of Bt cotton is greater than that resulting from increasing world cotton prices. The effect on production is also significantly larger with Bt cotton than with increasing world cotton prices. The impact on farmers' incomes with Bt cotton when fertilization is also increased is more than double, than that of a 15% increase in world cotton prices.

When introducing an improved sorghum technology package with better marketing, we find similar income effects to those of the introduction of Bt cotton. The income effect of improved sorghum with better marketing is also higher than that of increasing the world cotton price under high price transmission. The largest impact on farmers' income is obtained from combining Bt cotton with improved sorghum and better marketing. Introducing improved sorghum technology and better marketing also substantially increases the food security of Malian households as more production is destined for own consumption and less is purchased from local markets.

The highest income and production effects are obtained when combining the price increases with better agricultural productivity for both cotton and sorghum with better marketing. For Mali to take advantage of the declines of US participation in world cotton exports Mali will need to increase cotton productivity.

For the welfare of the population and to anticipate the big jump in feed grain demand in the near future as consumption habits change to higher quality diets Mali also needs to be more concerned with increasing cereal productivity. So no matter what happens in the agricultural trade negotiations in the Doha round, Mali has some clear alternatives to begin increasing production, productivity and incomes in the cotton zone now.

Since the CMDT with governmental support made impressive gains in the 1960–1980 period, they appear to be the appropriate agency to push ahead with Bt cotton and fertilizer. For sorghum the combination of IER, the Malian national agricultural research agency, with DRA, the national extension agency, and/or various NGOs involved in extension would seem the most appropriate for pushing the combined technology-marketing innovations. Bank financing would be needed for both the cotton and the sorghum activities. Our paper has only focused on the initial effects of adoption by early adopters. Further analysis would need to consider the public cost of introducing these technologies and also of supporting continued technological change. Widespread adoption of technology in cereals will affect prices. Therefore, a continuing effort on developing the demand for processed food and feed use of the cereals will be very important.

References

Abdoulaye, T., 2002. Farm Level Analysis of Agricultural Technological Change: Inorganic Fertilizer Use on Dry Land in Western Niger. Ph.D. Dissertation. Purdue University, Department of Agricultural Economics, West Lafayette, IN.

Abdoulaye, T., Sanders, J.H., 2006. New technologies, marketing strategies, and public policy for traditional food crops: millet in Niger. Agricultural Systems 90, 272–292.

Abdoulaye, T., Sanders, J.H., Ouendeba, B., 2008. Evaluation of Sorghum and Millet Technology and Marketing Strategy Introduction: 2006–07 Crop Year, INTSORMIL Bulletin No. 8. Department of Agricultural Economics, Purdue University, West Lafayette, IN, 23 p.

Alston, J. Brunke, H., 2006. Impacts of Reductions in US Cotton Subsidies on the World Price of Cotton, and Implications for West Africa Cotton Producers. Report Prepared for Oxfam, Washington, DC.

Alston, J., Sumner, D., Henrich, B., 2007. Impacts of the Reductions in US Cotton Subsidies on West African Cotton Producers. Oxfam America, Boston, MA.

Aminata, T., Abdoulaye, T., Sanders, J., Ouendeba, B., 2007. Transformation commerciale du Mil et du Sorgho au Mali. Projet Production-Marketing. INTSORMIL Bulletin No. 7. Lincoln, Nebraska.

Anderson, J., Dillon, J., 1992. Risk Analysis in Dryland Farming Systems. FAO, Rome.

Anderson, K., Valenzuela, E., 2006. WTO's Doha Cotton Initiative: A Tale of Two Issues. Development Research Group, The World Bank, Washington, DC.

Badiane, O., Gura, D., Goreux, L., Masson, P., 2002. Cotton Sector Strategies in West and Central Africa. Policy Research Working Paper No. 2867. World Bank, Washington, DC.

Baffes, J., 2007. Distortions to cotton sector incentives in west and central Africa. World Bank. In: Paper Presented at the CSAE Conference Economic Development in Africa, 19–20 March, 2007, Oxford, UK.

Baquedano, F., 2005. The Economics of Inventory Credit in Western Niger. M.S. Thesis, Purdue University, Department of Agricultural Economics, West Lafayette, IN.

Baquedano, F., Sanders, J., 2006. Introducing inventory credit into Nigerian agriculture: improving technology diffusion. Agricultural Finance Review 66 (2), 297–314.

Baquedano, F., Abbott, P., Sanders, J., 2008. The West African Cotton Reform Process: What Needs to Be Done? Working Paper. Purdue University, Department of Agricultural Economics, West Lafayette, Indiana.

Baquedano, F., 2009. Increasing Incomes of Cotton Farmers in Mali: Effects of Price Increases, Productivity Gains, and Alternative Crops. Ph.D. Dissertation. Purdue University, Department of Agricultural Economics, West Lafayette, Indiana.

Baquedano, F., Diarra, Mamoutou, Ahmoutou, Aly, 2009. Economic Analysis of the 2007 Crop Year. INTSORMIL Bulletin No. 9. Department of Agricultural Economics, Purdue University, West Lafayette, IN, 34 p.

Cotlook, 2008. Cotton Outlook. Cotlook Limited, Merseyside, United Kingdom. <http://www.cotlook.com>.

Coulibaly, J., 2010. Evaluation of Sorghum and Millet Technology and Marketing Strategy Introduction: 2008–09 Crop Year. INTSORMIL Bulletin No. 10. Department of Agricultural Economics, Purdue University, West Lafayette, IN, forthcoming.

FAO, 2004. Cotton: Impact of Support Policies on Developing Countries – Why do the Numbers Vary? FAO Trade Policy Briefs, No. 1. Rome, Italy.

Fok, M., 2007. Analyse Multifactorielle de la Baisse du Rendement Coton en Zone CMDT: De la Physiologie a la Idéologie. Juin, 2007. CIRAD, Montpelier, France.

Goreux, L., 2005. Cut subsidies, beware diversionary tactics and don't miss the Hong Kong window of opportunity. In: Hazzard, Eric, (Ed.), International Trade Negotiations and Poverty Reduction: The White Paper on Cotton. Occasional Paper Number 249. Dakar, Senegal. <http://www.ictsd.org/ministerial/hongkong/docs/cotton_book_en.pdf>.

ICAC, 2008. Statement of the 67th Plenary Meeting: Technologies for Cotton Development. International Cotton Advisory Committee. Washington, DC.

Institut d'Economie Rurale, 2006. Capitalisation des acquis de la Recherche dans la zone cotonnière du Mali. Programme d'Amélioration des Systèmes d'Exploitation en Zones Cotonnières, Ministère de l'Agriculture, Bamako, Mali.

Meyer, L., MacDonald, S., Kiawu, J., 2008. Cotton and Wool Situation and Outlook Yearbook. November, 2008. Economic Research Service, United States Department of Agriculture, Washington, DC.

Nubkpo, K., et Keita, M., 2005. L'Impact sur L'économie Malienne du Nouveau Mécanisme du Fixation du Prix du Coton Graine. Etude Commande pour Oxfam. Oxafam, Dakar, Senegal.

Primature: Mission de Restructuration du Secteur Coton, 2006. Etude pour l'Elaboration du Schéma Opérationnel de Privatisation de la CMDT. Bamako, Mali.

Pursell, G., 1998. Cotton Policies in Francophone Africa. The World Bank, Washington, DC.

Rain, D., 1999. Eaters of the Dry Season: Circular Labor Migration in the West African Sahel. Westview Press, Boulder, CO.

Sumner, D., 2003. A Quantitative Simulation Analysis of the Impacts of US Cotton Subsidies on Cotton Prices and Quantities. Presented to the WTO Cotton Panel.

Sumner, D., 2006. Effects of US Upland Cotton Subsidies on Upland Cotton Prices and Quantities. Annex I to First Written Submission of Brazil to the Panel in the United States Subsidies on Upland Cotton (DS 267) Recourse by Brazil to Article 21.5 of the DSU. WTO, Geneva.

Vitale, J., Sanders, J., 2005. New markets and technological change for the traditional cereals in semi-Arid sub-Saharan Africa: the Malian case. Agricultural Economics 32, 111–129.

Vitale, J., Boyer, T., Uaiene, R., Sanders, J., 2007. The economic impacts of introducing Bt technology in smallholder cotton production systems of west africa: a case study from mali. AgBioForum 10 (2), 71–84.

Vitale, J., Park, P., 2007. Institutional and Technological Innovations in the Cotton Sector of West Africa. Report Submitted to the West Africa Cotton Improvement Program. Department of Agricultural Economics, Oklahoma State University, Stillwater, Oklahoma.

SWAC-OECD, 2005. Importance and Social Importance of Cotton in West Africa: Role of Cotton in Regional Development, Trade and Livelihoods. Nov. 2005. SAH/D (2005) 556. Sahel and West Africa Club Secretariat/OECD, Paris, France.

Tschirley, D., Poulton, C., Gergely, N., Labaste, P., Baffes, J., Boughton, D., Estur, G., 2007. Comparative Analysis of Organization and Performance of African Cotton Sectors: Learning from Experience of Cotton Sector Reform in Africa. Draft Report. The World Bank, Washington, DC.

Watkins, K., Sul, J.L., 2002. Cultivating Poverty: The Impact of US Cotton Subsidies on Africa. Oxfam Briefing Paper No. 30. Oxfam International, Washington, DC.