Do Women Benefit from New Technology and Higher Cotton Prices in the Malian Cotton System?

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Abstract

Development objectives are often concerned with the impact of agricultural technologies on women's welfare. The introduction of a new agricultural technology in the farming system creates additional demand of labor and often negotiation over the distribution of new income streams. It is therefore critical to identify the types of agricultural and policy change that can result in increased welfare for women farmers. This paper uses data from southern Mali to analyze the impact of the decisions to diversify or rejuvenate the cotton sector on intra-household labor allocation and women's income. Based on a household modeling approach, we compare and contrast the household and women incomes following changes in technologies and policies. Result showed that the most profitable economic opportunity for the household is not the most beneficial for women. Women are better off with adoption of less labor intensive agricultural technologies. These findings stressed out the importance of considering intra household bargaining power and promoting labor saving technologies to improve women's benefit in the agricultural system.

Keywords: Agricultural technology, cotton, sorghum, women, farming system, household decision making

JEL codes: D1, D13, C61, O13, O33

I. Introduction

In the Sahel as in numerous sub-Saharan countries, women participate in agricultural production activities and perform household chores resulting generally in very long daily hours of work. Women are also credited with higher expenditures on their own welfare and that of their children than men. So, development objectives are frequently focused on reducing their labor burdens and increasing their incomes. The traditional farming system divides landholding into communal and private plots. All adult family members work in the communal or family plots and the household head makes labor allocation decisions on their field contributions and their remuneration. The principal objective of the communal land is to provide subsistence consumption and major family expenditures.

When cash crops such as cotton are introduced, the subsistence pressures are generally reduced. There are new income streams for the household head to allocate. The concern here is with the share that women receive as technologies and economic policy shifts benefit the household. Unfortunately, in the last decade the returns to cotton have collapsed especially in the marginal cotton zones. So, there has been at least a partial return towards subsistence or the disappearance of the bonuses for women. At the same time there has been an increasing emphasis by farmers and public agencies on diversification. This paper is concerned with the impacts of the decision to diversify and/or to rejuvenate the cotton sector on women's welfare. Elsewhere we concentrated on the household effects (Coulibaly et al., 2015). Here we compare and contrast the household effects with the effects on women of these changes in technologies and policies. We subsequently suggest measures to increase the effect on women's incomes.

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The paper starts by discussing the theories underlying the household decision making process. Then, we discuss the rise and fall of the cotton sector and the increasing diversification into the cereals. Next, we illustrate the present choices of activities by women and the incomes received from them. Then we compare and contrast the impacts of various technologies and policies upon household incomes and the incomes received by women. Finally, some implications and recommendations are derived from the findings.

1.   Some Theories of Household Decision Making

Three predominant theories of household decision making have been applied to intra household decision making and resource allocation. These are the exploitative theory, derived from Marxian theory, the unitary approach often referred to as the neo-classical theory, and the bargaining approach associated with Sen and Nash (Sen, 1990, Bourguignon and Chiappori, 1992, Quisumbing and De la Brière, 2000).

In the exploitation theory, the household head is portrayed as a dictator who allocates resources within the family. Women are relegated to subordinate roles within the household. The division of labor and distribution of resources within the family is controlled by the male household head (Heath and Ciscel, 1988). The compensation received by women, when new income streams become available, are determined by social factors, customs or expectations about women's role in the family rather than economic factors such as productivity and opportunity costs (Folbre, 1986). Families struggling to produce enough food to eat may well be willing to defer to this centralized decision making.   However, given the general discrediting of the Marxian model for failing to provide incentives, resistance to this decision making system would be expected when new income streams become available.

In the unitary theory, the household head still makes all decisions but he satisfies a joint utility function. The joint utility function means that the household head is altruistic hence allocates resources within the family in the best interests of family members. So, incomes would be divided according to the jointly understood needs of the household. This does not mean equally divided as the family adults could and often do make substantial sacrifices for the children. It just means that there is joint or family agreement on the welfare maximization impact of the income division. This joint utility hypothesis has been challenged by empirical studies. Substantial informal evidence in developing countries indicates that household members have diverse preferences, particularly in the context of the extended family. With numerous wives, extended household systems it would be difficult for the household head to internalize these decisions even if he wanted to.   With new income streams from technology introduction there would be a large pent-up demand for many different goods and services varying by age and gender as the family emerged from an income level closer to subsistence (see for example Schultz, 1990, Thomas, 1997, and Hopkins et al., 1994).

To handle these new income streams, we would expect a bargaining process in which the decision outcomes on incomes and resource allocation depend upon the relative bargaining power of the family members. The decision making process with the bargaining theory in the household is analogous to that of the firm where conflicts are resolved through negotiation. Both the owner and the workers want to increase their income shares but each knows that they are dependent upon the other. So there needs to be cooperation to produce but there is also conflict over the share of the income stream to be received by each side.   Each has a threat point at which he (they) will close the factory or go out on strike respectively.

Analogously, bargaining theories have been developed based on the cooperation-conflict relationship in the household. The outcome of negotiation is determined by the relative bargaining power which is derived from the parties' best alternative to cooperation, the "threat point". The relevance of the exit option between bargaining parties depends not only on the alternative options but also on how credible the threat point is in the bargaining process.

Numerous studies in developing countries point out some bargaining in the process of household resource allocation and income distribution within the household (Alderman et al. 1995; Bobonis 2009;Quisumbing and Maluccio 2003;Bourguignon and Chiappori.1992;Manser and Brown,1980; and Mc Elroy and Horney,1981; Doss, 2013).So, an important policy initiative for women is to increase their bargaining power to make sure that they get higher shares from the new activities increasing incomes. Here, we will consider the incomes women obtain from different sources presently and with the different policy-technology options being proposed.

2.   The Rise and fall of Cotton: A Recovery?

Cotton is the most valuable cash crop in Mali. From 1968-1998 the cotton sector experienced a "White Revolution with production increasing from 41,000 to 523,000 tons (Figure1). The cotton golden age was accompanied by an increase in cereal production, food security and the development of the southern zone infrastructure (Serra, 2012).

Farmers benefited from subsidized input prices, breeding of new varieties, facilitation of access to fertilizer and pesticides, and investment in animal traction.

In 2001-03 cotton represented 30% of exports earnings and accounted for 6 % of the Malian GDP. The number of households employed in the cotton sector was estimated at more than 300,000 which represented almost one third of Mali's work force (Baffes, 2007). The years of cotton prosperity resulted in significant increase in household income and the share of income distributed to the family members including women in the cotton producing regions. During that time in the Koukiala sub-region of Sikasso cotton region, women were often compensated in cash, grain or presents as wage payment for the work on the cotton field (Lilja and Sanders, 1998).
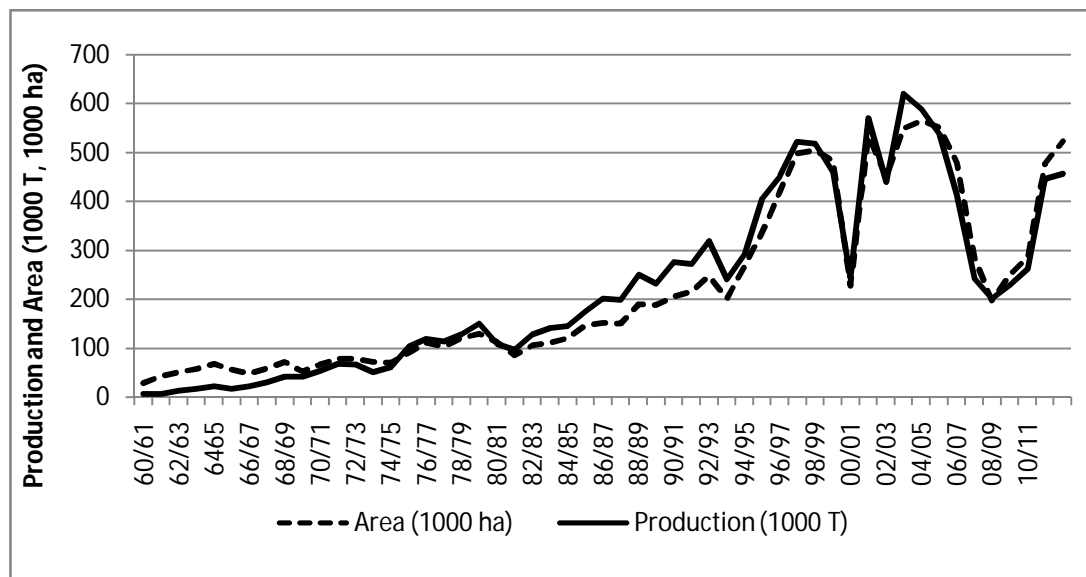

Figure 1. Malian Cotton Production and Area from 1960 to 2011

Source: Malian Ministry of Agriculture, 2010 and USDA data accessed on July 18, 2013

In the last two decades the volatility of cotton production and harvested area has substantially increased. The CMDT was confronted with a sharp financial crisis triggered by the fall in the world cotton price in the 21st Century and with pressures from international financial institutions reducing their support of the public functions of the agency. Transgenic Bt cotton was rapidly introduced in major trading nations. This innovation lowers production costs by reducing the spraying required. This introduction of Bt in many of the principal cotton exporters make it more difficult for countries resisting this innovation, such as Mali, to compete internationally especially with the declining world prices in the 21th Century (J.Vitale et al., 2007;J. Baffes, 2011).

Outside of the prime cotton areas, those having the best rainfall and soils, the decline of cotton in the last decade have been especially rapid (Figure 2).As a result there has been increasing diversification with a reduction of cotton area and an increase in cereal area. Even input credits taken for cotton, especially fertilization, have partially ended up on maize and sorghum. In the Koutiala area, cotton area declined by 80% from 1998-2008 (Coulibaly, 2011). Making a virtue out of a necessity the CMDT now proclaims a policy goal of diversification. As new cereal cultivars come out of the research system and farmers apply more fertilizer to them, farmers especially in these marginal areas for cotton are increasingly interested in diversification.
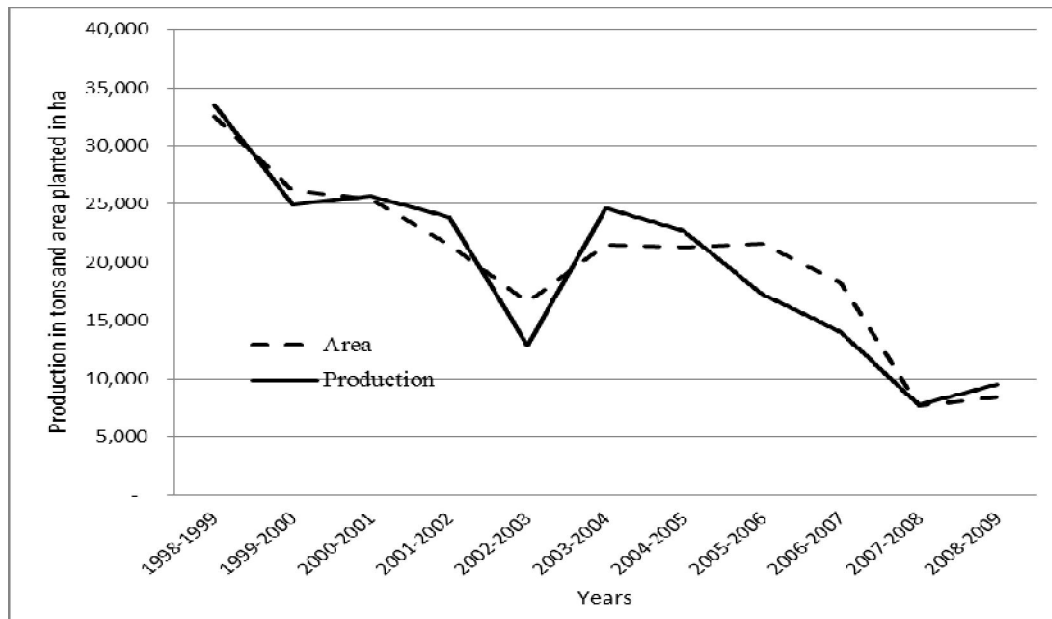
Figure 2: Cotton Area and Production in Koutiala (Mali), from 1998 to 2008.

Source: Ministry of Agriculture, Mali

Despite the growing interest in the cereal crops, cotton continues to be a priority for the Malian government. Following the jump in prices of cotton in the world market in 2010 (80% increase), the Malian government raised the domestic cotton price to a historical level of 255 F CFA/kg for two consecutive agricultural seasons 2011 and 2012, That was an increase of 38% relative to 2010. The expected impact of this price policy was to renew farmers' interest in cotton, doubling their production and area compared to the base year of 2010 (Coulibaly et al., 2015).

The year 2010 was an unusual year for world cotton trade due principally to the Chinese floods so world cotton prices have already declined. Mali is still studying the bio-technology issue while Burkina Faso has been rapidly introducing Bt cotton. It will become increasingly difficult for Mali to be competitive in cotton internationally without the introduction of Bt cotton.

So further adjustments and even rapid changes are still expected with cotton (falling price and removal of fertilizer subsidies) and diversification (new sorghum technology).We have already taken a systematic look at these shifts on the household incomes and farm activities(Coulibaly et al., 2015)?How are women affected as Mali shifts between promoting cotton and diversification?

3. Female Labor Allocation and Incomes in the Cotton-Cereal System before the Cotton Recovery of 2011.

In this section we review the components of women's' incomes. First we consider the main income component, the earnings from the private plots. In the sample of 30 women interviewed in the village of Garasso, 73 % of women had access to a private plot. Income from the private plot producers is the most important cash generating activity for these women in spite of the low productivity of these plots (Table 1). These plots generally are far from the village, on poorer soils and the women complain about the lack of access to the manure and the carts to take the organic fertilizer to the fields.

Table 1: Income Earning Activities and Labor Allocation across the Main Activities

Activities	Private Plot Owners			Non Private Plot Owners		
	Average Return	Number	Total Income	Average Return	Number	Total Income
	F CFA/day	days/year	F CFA	F CFA/day	days/year	F CFA
Private Plot	1,042	35	36,461	0	0	0
	($2)		($81)			
Off Farm	431	20	8,617	952	43	40,813
	($1)		($19)	($2)		($90)
Work Group	275	4.0	1,087	419	3.3	1,363
	(<$1)		($2)	($1)		($3)
Communal Plot	25	108	2,667	8	108	900
	(<$1)		($6)	(<1$)		($2)
Total	1,773	167	48,832	1,379	154	43,075
	($3.92)		($108)	($3.05)		($95)

Source: Household Survey Data, adapted from J. Coulibaly, 2013

Sample: 30 women with 73 percent having a private plot.

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

The average area of land cultivated by women with a private plot in the sample is 0.56 ha. The value of women's production on the 0.56 ha of land cultivated is on average 36,461 F CFA ($US 81). From the private plot earnings, women often invest in assets including the purchase of small ruminants (goats and sheep) for fattening.

Older women in the household, the retired cooking wives, have priority in access to private plots over younger active cooking wives. Retired cooking wives in the household are women who no longer participate in the household chores and are not obligated to work on the communal plot during the agricultural season. A woman achieves this social status when at least one of her sons get married and brings his wife to live with the extended family in the compound. Her daughter in law represents an additional worker in the household. This latter then substitutes for her mother's in-law labor with respect to household duties and the labor obligation on the communal plot. The average age of women having access to a private plot is 47 whereas those who do not have access to a private plot 37 years old.

In families with limited land resources to meet household food consumption, no private plots were granted to women. For these women, one fourth of the sample, off-farm income (principally petty commerce) 40,813 FCFA ($US 90) was the main source of income earnings. The payments for family labor on the common fields are variable across years depending upon the state of nature. For bad weather years there is little payment for the communal labor. During good years of crop production, these payments can be up to 77 percent greater than the value for normal years (unpublished field interview data).

In 2010 after almost a decade of decline in the earnings from cotton it is not surprising that the earnings of women from the communal plots had practically disappeared. In the '90s the income received from both the communal plots and the work groups were substantially higher (Lilja and Sanders, 1998).Women's compensation for the communal work is much lower than the daily returns to either the private plot or the off farm labor. It would not have been rational for a woman to allocate a substantial amount of time to the communal plot if it were not for the need to provide for the household subsistence and living expenses. The increase in the household income generated on the family plot is controlled by the household head. With new activities and new income streams the share of the additional income accruing to women or income compensation for women's increased labor is the outcome of negotiation between spouses and is expected to depend upon their relative bargaining power.

Previously (Lilja and Sanders, 1998) had indicated that one type of institutional change was occurring to enable women to claim higher income shares when new technologies were increasing the income flows available to the household. This was the evolution of gender work teams responding to increased seasonal labor demand. In Garasso, 63 percent of women interviewed were members of a farm work team. The purpose of these work teams was to assist the husbands of group members in performing agricultural tasks during peak labor seasons. These work groups historically functioned as a type of labor exchange with minimum income compensation for service rendered.

Moreover, the cash earned was spent in organizing some social activities and village parties (purchase of clothes for wedding, funerals, naming ceremonies, musical entertainment). But with the boom in the cotton economy (Lilja and Sanders, 1998), these groups shifted from mutual assistance and community service to be more profit oriented. They were hired by farmers for some agricultural tasks and with their collective bargaining power, the gender work groups demanded to be paid at a fixed cash rate upon completion of their work or at harvest. Furthermore, these groups were evolving into associations and helping members obtain small loans for private investments. However, in 2010 the returns to these work groups had become very low though still higher than the returns to communal labor.

In summary women's incomes are very low whether they specialize in the private plots or off-farm work. Those with private plots do slightly better in total income than those without. Communal returns (besides subsistence and normal living costs paid by the household head) are very low. So, female low returns from communal activity are influenced by the push back towards subsistence as cotton profitability declines. At these lower household income levels the implicit value of the assured grain consumption for the household becomes more important for household and female decision making. Otherwise it would certainly be irrational for women to work on the communal plot.

The public sector is trying to revive the cotton sector and there are technologies available for cereal diversification. So, which strategy or combination of strategies benefits women the most and what is the tradeoff between the benefits to the household and to women's' private earnings. The next two sections are concerned with these questions.
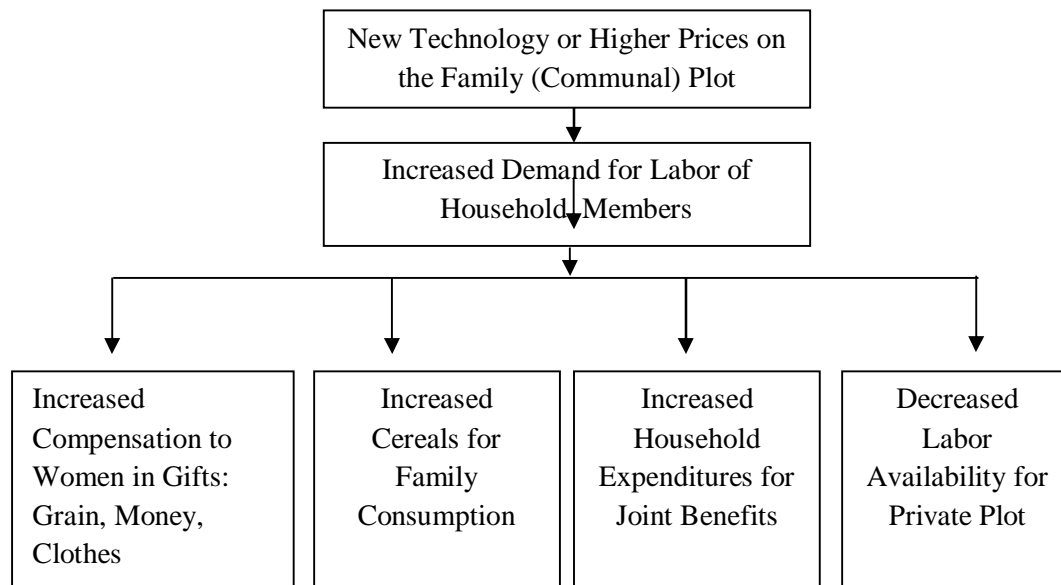
4.   Costs and Benefits to Women of New Technology Introduction on the Farm

With the 2011 spike in the Malian cotton price and the return of more cotton area, sizable income increase for households are expected. In the traditional system the household head provides subsistence consumption partially as compensation for the household labor on the communal plots. Increased incomes lead to additional grain for the family; undoubtedly the family will eat better and have more security with more grain in the storage bins.

With the increased returns on the communal plot, farmers make household investments some for the collective good of their families. Household investment expenditures benefiting women include housing improvements, new farm equipment, and motorcycle purchase. They can also include another wife and the expenditures associated with that. Given the amount of labor for women related to the household and to the farm, some women may consider this additional wife of benefit to them. Even though such investments undoubtedly improve women's welfare, it is difficult to measure quantitatively the effect of those shared household goods on women's welfare. This is illustrated by asking how much a motorcycle purchase, housing improvement, or an additional wife benefits present wives.

Once subsistence goals are achieved, we would expect some family struggle over the increased returns from cotton and the sale of cereals. There would be some bargaining process with the women and other adult family members. With bargaining we would expect increased labor demands on women to be compensated in various ways. Household women are paid with various types of gifts predominantly clothing. But these payments for the additional labor can also include cash and grain, which they can convert to cash on market days. The amount of these after harvest payments for women, are also expected to increase with the recovery of the cotton price.

Increase labor demands on women have a cost side as they reduce their labor time on the private plot (figure 3). This decreases their productivity on the plots from which they control all the benefits (Savadogo et.al., 1989). According to our field interviews women spend at least 4 hours/day in domestic work (child care, preparing meals, bringing water, gathering firewood). They do not have time for income earning self-employment activities during the crop season. So the labor time increases on the communal plot result here in equal time reductions on the private plot. These private plots are generally marginal lands and the women have access to few inputs so the household head may need to compensate the women for these private losses.

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│   New Technology or Higher Prices on │
│      the Family (Communal) Plot      │
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│     Increased Demand for Labor of    │
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Increased Compensation to Women in Gifts: Grain, Money, Clothes	Increased Cereals for Family Consumption	Increased Household Expenditures for Joint Benefits	Decreased Labor Availability for Private Plot

Figure 3: Diagram of the Welfare Impact on Women of a Labor Intensive Economic Opportunity

Source: Author's Own Design

Now let's consider what happens to household and female incomes during this period of changes in technologies and prices after 2010. First, we estimated household and women's' incomes at the end of a long period of cotton yield stagnation and income decline in 2010 (Table 2). Then there was a reversal following the world price increase of cotton of 80% in 2010 resulting principally from the Chinese floods. In 2011 Mali increased cotton prices by 38%. This is a golden age or at least a few golden years for the cotton sector because not only is the price of cotton very high but also there are fertilizer subsidies for cotton and cereals.

Then we compared both household and female incomes for 2011 with 2010 utilizing a farm model (Coulibaly et al., 2015; also see Appendix A for description of the model). So the rebound from the 38% increase in the cotton price in 2011 almost doubles cotton area (3.8 to 5.5 ha). This combination of cotton price increase and fertilizer subsidies increases household incomes by 76% (second column of Table 2). However, the income for women is reduced by 12% even with increased payments for their communal labor since their returns from their private plots are reduced by 50%.

In the third scenario we consider a return to normal as the bubble in world cotton prices disappears and the government again finds fertilizer subsidies too expensive to continue. Fertilizer subsidies are expensive and disliked by many major donors. Moreover, their main intellectual support is to provide a learning by doing effect and ultimately farmers will be able to see the benefits. The cotton price is expected to come down again here and to continue to decline with the increasing use of B$_t$ cotton and synthetics in the world (Baffes, 2011). The cotton price as the average of the price in the five years up to 2011 is still higher than the 2010 cotton price and results in a household income increase of 49% (Column 4 in Table 2). The increased area requirement for cotton is only a hectare so a woman's income is only reduced by 14%. The household income increase is $692. So, note in both of these cases with cotton prosperity again occurring for the household that the household head could afford to pay more to family workers to maintain incentives.

Finally the forth scenario adds the cereal diversification to the long run normal cotton price of 212 cfa/kg. Household wealth only increases by $88 so diversification is clearly a supplementary activity to the cotton. So even with the new cereal technology (an improved cultivar, moderate inorganic fertilizer, improved agronomy and an improved marketing strategy), the changes in cotton still remain the principal mover with the diversification a complementary activity.

Table 2.Household and Woman's Incomes with Cotton Recovery, Back to Normal and Diversification of More Focus on Cereals

	Cotton Price Collapse 2010 Price cotton=185	Cotton Boom conditions Price cotton=231 Also fertilizer subsidy	Normal Cotton Price=212 Without fertilizer subsidy	Diversification Strategy Price cotton=212 No fertilizer subsidy
Household Wealth (US$)	1,403	2,470	2,007	2,095
Increase in household wealth		76%	43%	49%
Change in Communal Labor		48%	13%	20%
Income paid to women for work on communal plota ($US)	5.6	34.6	28.10	29.33
Number of days in private plot	35	18	30	28
Women Income from Private Plot ($US)b	80.58	41.54	69.75	64.77
Private Plot Income Gain or Loss ($US)		(39.03)	(10.83)	(15.81)
Total incomec Received ($US)	86	76	98	94
Change in total Income		-11.68%	13.53%	9.18%

Source: Author's Calculations

Exchange rate: 1 $ US =452.61 F CFA on April 18, 2011 at www.oanda.com. The average return to the private plot was $2.30/day with an average plot size of 0.56 ha.

a. Finally, women's total income across the traditional system and each of the new economic opportunities is defined as the sum of the communal income and the private plot earnings. The welfare impact on women of the new technologies and policy change is defined as the percentage change in women's total income from the traditional system to the other economic opportunity. From the household surveys, a woman's proportion of household income is estimated on average at 0.4 percent of the household income with the collapse of the cotton sector. This proportion is the value of the gifts (grains, clothes and cash) women declared receiving at harvest divided by the total household expenditures in the period of cotton decline (544,978 F CFA or $1,204). Under a new economic opportunity, this proportion increases to 1.4 percent. This percentage is obtained by dividing the value of gifts women reported receiving during a good crop year or with the adoption of the new sorghum technology.

b. The private plot earnings result from the average return to labor multiplied by the change in labor time from the traditional system to the new technology or policy.

c. Women do have off farm income but this is minimal compared to what they earn from their private plot and much of the labor allocation occurs between the communal and private plots.

The contrast of the three options between the household benefits and the benefits to women highlight the within family potential for conflict as higher income streams become available. The household head needs more labor time from women to increase production on the communal plot and to earn higher profits. But women's productive priority is on the private plot because more labor time spent on the private plot leads to higher returns controlled by her.

5.   Conclusions and Policy Suggestions

The incidence of benefits to woman presently for their communal labor outside of the joint benefits from family expenditures and subsistence are very low. As new technologies and economic policies changed the returns to women in income streams they control increased but are still very low. But we have not measured the impact on women of a series of household expenditures and need to figure out how to do that. This research has demonstrated that the most profitable economic opportunity for the household is not the most beneficial for women. Women are better off with the adoption of less labor intensive technologies on the communal plot but to date the improvements in the cotton sector raise household incomes much more than the diversification example here.

One mechanism for women to get increased compensation is to increase their bargaining power over new income streams, which demand greater labor inputs from them. Women joining work groups or increasing their returns from off-farm activities thereby increase their opportunity costs and ultimately their bargaining power. Then, there will be increasing pressure on the household head to raise the share of the income surplus paid to women.

Increasing women's incomes through greater time on their private plots is constrained by the lack of access of women to quality land near the household as well as to inputs especially credit and fertilizer but even access to available manure and the carts to haul the organic fertilizer.

Another strategy to increase women's welfare is to reduce women's labor burden from unpaid household chores. This could be achieved through access to household labor saving technologies to increase the efficiency of performing household tasks and thereby release time for self-employment or income generating activities (Lawrence et al. 1999). Improved stoves to reduce the time spent gathering firewood is an obvious example.

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Appendix A. The household model

A linear programming model evaluates the impact of new technologies, price and policy changes at the household level and on women. This linear programming model is a discrete stochastic programming model in three stages that captures the harvest and post-harvest household decision making under rainfall and price uncertainty (Coulibaly et al. 2015). The objective of the programming model is to maximize the end period wealth in the household subject to a number of constraints including harvest income constraint, labor time, land availability, resources and a cash constraint. The model is presented below in algebraic notation:

$$\text{Max} \quad E[W] = \sum_s \sum_t \sum_r \rho_{str} W_{str} \quad (1)$$

Subject to:

$$-A_1 X_1 + B_{1s} X_{2s} \le b_1 \quad (2)$$

$$-A_{2s} X_{2s} + B_{2st} X_{3st} \le b_2 \quad (3)$$

$$-A_{3st} X_{3st} + B_{3str} W_{str} \le b_3 \quad (4)$$

$$X_1, X_{2s}, X_{3st}, W_{str} \ge 0 \quad (5)$$

where:

s, t, and r = the states of nature in stage 1, 2 and 3, respectively;

ϱ_{str} = the joint probability of states s, t, and r occurring in stages 1, 2, and 3, respectively;

A_1 = a matrix of coefficients for stage 1 accounting relationships (sources for grains, factors of production, variable inputs, and cash);

B_{1s} = a matrix of coefficients for stage 1accounting relationships, conditional on the realized state of nature (s) in stage 1 (uses for inventories of grains, factors of production, variable inputs, and cash, and consumption);

b_1 = a vector of endowments in stage 1 (initial stocks of grains, factors of production, cash, and minimum consumption quantities);

X_1 = stage 1 decision variables (land allocation, purchases of inputs, grain sales and purchases);

A_{2s} = a matrix of coefficients accounting relationships conditional on realization of state of nature s for stage 1 (sources for grains and cash);

B_{2st}= a matrix of coefficients for stage 2accounting relationships, conditional on the realized states of nature (s and t) in stages 1 and 2 (uses for inventories of grains and cash);

b_2 = a vector of endowments in stage 2 (cash obligations and minimum consumption quantities);

X_{2s} = decision variables conditional on realization of state of nature s for stage 2 (grain sales, purchases, and storage);

A_{3st}= a matrix of coefficients accounting relationships conditional on realization of state of nature s for stage 2 (sources for inventories of grains and cash);

B_{3str}= a matrix of coefficients for stage 1accounting relationships, conditional on the realized states of nature (s and t) in stages 1 and 2 (uses for inventories of grains and cash);

X_{3st} = decision variables conditional on realization of state of nature s and t for stage 1 and 2, respectively (grain sales, purchases, and storage);

b_3 = a vector of endowments in stage 3 (minimum consumption quantities); and

W_{str} = end period wealth conditional on realization of states of nature s, t, and r in stages 1, 2, and 3, respectively.

To estimate the household income for each of the specific technology, price and policy scenarios(traditional, new cotton economy, return to normal and diversification strategies), the model is run for each of these four scenarios and the household income (expected wealth) is generated (refer to Coulibaly et al, 2015 for detailed explanation). Women's labor allocated to the communal plot under each policy alternative is directly derived from the family labor constraint equation after every run. Then, the change in women's communal labor time triggered by the new policies is calculated as the percentage change in women's labor under each policy alternative relative to the traditional technology. Finally, a unit of labor increased on the communal land is equivalent to a unit of labor reduced from the private plot. Finally, we calculate the effect of this reduced labor on the production of the womens' plot with a linear production function.

Appendix B. Measuring the Impact of Technology and Policy on Women's Incomes

The welfare impact of technological change or economic policy on women (ΔW) depends upon the income gains received by women for their increased labor supply on the communal plot (Δy_c^f) plus their expected income losses from the private plot (Δy_p^f) due to the reduction in time there.This is expressed as follows:

$$\Delta W = \Delta y_c^f - \Delta y_p^f \quad (6)$$

The gain to women for their increased activity on the communal plot (Δy_c^f)represents their compensation for communal field work following technological, price or policy shift. It is measured by the change in women's communal income affected by both the shift and their bargaining power. .Mathematically, this expression can be written as:

$$\Delta y_c^f = \frac{\partial y_c^f}{\partial \beta} * \frac{\partial \beta}{\partial T} \quad (7)$$

Where ($\partial y_c^f / \partial \beta$) is the change in women's communal income with respect to their bargaining power and ($\partial \beta / \partial T$) is the change in bargaining power from the shift to the new technology, price or policy.

With increased household income we would expect women to bargain in order to be compensated for their communal work by receiving a higher compensation compared with the traditional technology. However, we cannot measure bargaining power since it is unobservable (Doss, 2013). We expect that the household decision making is characterized by bargaining or altruism, as opposed to an exploitative decision making. The higher women's ability to negotiate the bigger the change in their income from the communal land. Women's compensation for their work on the communal plot is calculated by valuing at the market price the gifts (grains, money, and clothing) received at harvest under both traditional and new technology.

The second component of the equation (Δy_p^f) is estimated by taking into account the change in labor allocated to the private plot as a result of technological change ($\partial l_p^f / \partial T$) and the average return to women's labor on the private plot (y_p^f / l_p^f)as written below:

$$\Delta y_p^f = \frac{\partial l_p^f}{\partial T} \left(\frac{y_p^f}{l_p^f}\right) \qquad (8)$$

Because of the lack of leisure time for women, they have to reallocate their labor across activities instead of reducing their leisure time. Women leisure time is often included in the time spent to do the household chores and child care (von Braun and Webb, 1989). The additional labor supplied to the communal land is equal to the amount of labor withdrawn from the private plot .

$$-\Delta L_p = +\Delta L_c \qquad (9)$$

Women's labor supply on the communal plot for each technology or policy scenario is derived directly from the farm programming results. The resulting income losses from the private plot is found by multiplying the reduced labor time supplied to the private plot under each economic opportunity by the average return to the private plot (y_p^f / l_p^f).