**Gender, generation and cereal crop intensification in Mali**

Smale, Melinda[1]., Alpha Kergna[2], Véronique Thériault[1], Amidou. Assima[3], Naman Keita[2]

[1] Department of Agriculture, Food and Resource Economics, Michigan State University, East Lansing, MI, USA, 48824. msmale@msu.edu ; theriault13@msu.edu
[2] Economie de la Filière, Institut d'Economie Rural (IER), Bamako, Mali. akergna@yahoo.fr. namankeita2@yahoo.fr.
[3] Department of Agriculture, Food and Resource Economics, Michigan State University, East Lansing, MI, USA. Based in Bamako, Mali. amidou.assima@gmail.com;

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**Abstract**

In Mali, stagnating yields of dryland cereals—excepting maize—are often attributed to limited use of fertilizer and declining land quality. In the Sudanian Savanna of Mali, as elsewhere in the West African Sahel, dryland cereals are grown on fields managed collectively and individually by extended families that span multiple generations and several households, headed by a responsible elder. The roles of women and youth in farm production are changing. We contribute to the empirical literature on agricultural intensification in this region by exploring intra-household differences in fertilizer use. We test differences by: 1) plot management type (collective, individual); 2) gender of plot manager given plot management type; and 3) and plot manager status in the family (youth, relationship to head). We compare findings between major cereal crops (maize, sorghum). Fertilizer use is greater on individually managed plots, which is explained primarily by use on sorghum fields allocated to women, which are very small, frequently intercropped with groundnuts, and serve as "food security" reserves. Use rates in maize production are lower on individual plots managed by men who are not household heads. Further, use is lower on plots managed by youth under 25 years of age (specifically, maize plots) and sons (in particular, sorghum plots). On sorghum plots, wives of the head have higher intensity of fertilizer use on sorghum plots than other managers. Findings have implications for the design of extension programs to support inclusion of women and younger generations in the intensification of dryland cereals production.

## Introduction

Mali's economy relies on rainfed agriculture and the majority of rural Malians have long depended on sorghum and millet as their staple food. Sluggish rates of yield growth in these crops, estimated at only 3% since the 1990s (Staatz et al. 2011), have been attributed to multiple factors, including underuse of fertilizer on degraded, aging soils. The average use of nitrogen (N total nutrients) on arable and permanent crop area is about 14 kg per ha in Mali, compared to only 3 kg per ha for the West African region as a whole but almost twice that much (27 kg per ha) in Southern Africa (FAOSTAT 2015). The global food price crisis of 2008/09 heightened concern for low productivity and low rates of fertilizer use in Mali. The Government of Mali responded by establishing a fertilizer subsidy program that effectively reduces the price per unit of fertilizer used applied to cereal crops as well as cotton, the country's premier export crop.

A recent review of the structure and performance of the fertilizer value chain in Mali (Theriault et al. 2015) concludes that while total fertilizer use appears to have risen over the past decade, incentives for fertilizer use vary substantially among growers of the same crop and among crops. For example, there is considerable evidence that the institutional and technical relationship of maize to cotton has contributed to a surge in both the scale of maize area and maize productivity—at the expense of sorghum, in particular. From the mid-1970s to mid-1980s, the state-owned cotton ginnery, CMDT (Malian Company for Textile Development), engaged in the promotion of maize production to help support household food security among cotton growers (Theriault and Sterns, 2012; Coulibaly and Sissoko 2001). CMDT still allocates a part of its budget to fertilizers offered to farmers (more than 90 percent in the cotton zone) and also has a seed division that provides maize farmers with selected seed varieties (Diallo 2012; Tschirley et al. 2009), boosting maize production (Tefft 2010). Koulibaly et al. (2011) report that the CMDT recently began to  provide input loans for fertilizer and herbicides for maize as a diversification strategy and to prevent the continued decline in cotton yields.  With falling cotton prices, farmers decided to re-allocate fertilizers destined for cotton to maize, resulting in maize intensification of maize and hefty yield gains (Laris et al.2015; Foltz et al. 2012).

Stagnating productivity has also been attributed to the harsh, uncertain production environment and an impoverished population with high rates of population growth. One argument for the customary, collective organization of family farming in the drylands of Mali is that it has facilitated effective management of land and labor by pooling risk under the aegis of the family patriarch. Recent research by Guirkinger and Platteau (2014) explores how land scarcity has contributed to the individualization of plot management as a means of providing economic incentives within the collective farming structure. Guirkinger et al. (2015) then found higher yields on individual plots relative to collective plots when managed by men—for care-intensive (including maize)—but not for care-saving crops (including sorghum).

In the Sudanian Savanna of Mali, cereals are grown on fields managed collectively and individually within complex households with both vertical (unmarried sons, married sons and their families) and horizontal (brothers; multiple wives) dimensions. The farm enterprise of the extended family is headed by an elder patriarch, or a designated team leader, who is responsible for guiding the organization of land and labor with the goal of meeting the staple food needs of the family on plots managed and worked collectively. Traditionally, sorghum was the main staple food grown on collective plot in the Sudanian Savanna, followed by millet. In recent years, maize has occupied an important place as a cash crop but also as a contributor to food needs. Aside from the fields that are managed collectively on behalf of the household as a whole, individual fields are allocated to household members.

The cultural stereotype in the Sudanian Savanna is that married women cultivate the crops that contribute to the stews that accompany the staple food, such as legumes, groundnuts, and vegetables, rather than the staple food itself. On the plots allocated to them by the patriarch and managed on their own, women decide which crop to grow, also controlling the harvest from their plots. Their harvests provide them with income to buy the ingredients for their food (spices, salt, sugar and oil), pay school fees, buy clothes for themselves and their children, gifts, and items for their daughter's dowry.

Recently, case studies  have challenged this stereotype by revealing that women in the Sudanian Savanna are producing sorghum on their individual fields (Some 2011; Donovan 2010; Siart 2008; Van den Broek 2009). Women respondents explained that due to factors such as declining soil fertility, harvests on the collective fields have often been insufficient to feed the extended family. Women have begun to grow cereals on their individual fields in order to help ensure family food security.

We have not found rigorous analyses of farm-level or intrahousehold demand for fertilizer on either sorghum or maize in Mali, and nor have we found research that considers the evolving role of younger men in addition to women within the household unit, other than that of Guirkinger et al. (2015). Young people have specific characteristics that distinguish them demographically and socially (Bennell, 2010), such as lack of full economic independence and autonomy in decision-making. The African continent has the largest proportion of youths (UNECA and UNPY, 2011), and the number of young people is expected to reach 42.5 million in sub-Saharan Africa alone by 2020 (Proctor and Lucchesi 2012). Most young people in sub-Saharan Africa are self-employed in the informal and agricultural sectors (ILO 2007), but they are also heavily represented among the unemployed (60%, according to the World Bank in

2009). Social norms and traditions affect the ability of young people to participate in farm decision-making, and thus choose agricultural employment as a viable future. In many African societies, generational hierarchy often determines access to labor and to other productive resources, such as land (Abeles and Collard, 1985).

Here, we seek to better understand evolving roles and incentives for agricultural intensification within complex households in the process of social and demographic change. We contribute to the literature on intra-household decision-making and agricultural intensification by testing several hypotheses empirically. First, we test whether adoption probabilities and intensity of fertilizer use differ by plot management type (collective, individual). Second, we are able to differentiate individual plots managed by men and women who are not heads of household, testing the role of gender while controlling for plot management type. Third, we test the effects of youth (which we refer to as "generation") and the status of the plot manager in the household (relationship to head, including wife or son). This third focus, and our interest in input use (rather than yields) differs from that of Guirkinger et al. (2015). Finally, we test the robustness of our findings by comparing two major cereals (maize and sorghum). As noted above, maize has features of both a staple food and a cash crop.

Our analysis begins an important inquiry into the process of cereal crop intensification in Mali. First, understanding adoption patterns within as well as among households, highlighting the changing roles of women and youth, can assist in the design of programs to raise productivity and support the future of farming in Mali. Second, examining maize and sorghum plots together sheds some light on the changing priorities among farmers, and possible substitution effects or complementarity between the two crops in terms of fertilizer use. This is important for understanding how fertilizer policies that influence one crop may affect the other.

## Methods

We draw on detailed farm-level data from 628 households and 1305 maize and sorghum plots in the Sudanian Savannah, a drylands area with relatively high productivity potential for both sorghum and maize, and also for cotton, the primary cash crop among farmers surveyed. Applying nonlinear econometric models to handle the large concentration of zeros in fertilizer use, we test whether the likelihood, intensity, and determinants of use differ in three sets of regressions based on the same general adoption model and set of regressors. The data and econometric approach are described below.

### *Data*

The sample was drawn from a baseline census of all sorghum-growing households in 58 villages located in the Sudanian Savanna within the 800 mm isohyet. Villages surveyed included all those listed as sites where the national research program (Institut d'Economie Rurale-IER) and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) have conducted testing activities via a network of farmer associations since 2009. Our findings are therefore representative of areas with at least some engagement by the national sorghum program as well as in some cases, the cotton program. Only villages with fewer than 1000 persons were included. The multi-visit survey was conducted in four rounds from August 2014 through June 2015, with a combination of paper questionnaires and computer-assisted personal interviews, by a team of experienced enumerators employed by IER.

The enumeration unit in the survey is the Entreprise Agricole Familiale (EAF, or family farm enterprise), which is the base unit most frequently used to analyze farm production systems in Mali. According to the national agricultural policy act (Loi d'Orientation Agricole), the EAF is a production unit composed of several members who are related and who collectively use production factors to generate resources under the supervision of one the members designated as head of the household. The head who can be a female or male member. The primary economic activity of the head is to ensure the optimal use of production factors. He also represents the EAF in all civil acts, including representation and participation in government programs, such as the fertilizer subsidy program.

Collective plots belonging to the whole EAF are managed by the household head or a designated team leader (*chef de travaux*) on behalf of the EAF. Individual plots belong to the EAF but are planted and managed by individual members, males or females for their own account. Production on individual fields is not managed collectively, although there are clearly interactions among managers regarding use of equipment and inputs belonging to the EAF as a whole, and potentially, other negotiations for sharing labor and resources. At each cropping season, the head distributes these plots based on the needs of the family.

The sample of EAFs was drawn with simple random sampling from a census of all sorghum-growing households in the 58 villages. The sample augmented by five percent to account for possible non-responses, leading to a total of 623 EAFs and an overall sampling fraction of 25%. Enumerators listed all plots operated by each sampled EAF, grouping them by crop (sorghum, maize) and plot management type (collective, individually managed by men or women who are not heads). One plot was randomly sampled per group per EAF. The number of plots per household in dataset depends on the type of plots found in the EAF and the two crops of interest (sorghum and maize). While our full plot inventory showed that 15% of a total of 4609 listed plots were managed by men who were not household heads, most of these were designated team leaders who have the same status as the household head or plots planted to other crops, such as cotton or groundnuts. We identified few (only 16) individual plots managed by male household members where the main crop was either sorghum or maize. Only 4 heads in 623 EAFs were female, and only two of these managed sorghum or maize plots. The plots managed by female household members who are not heads were most often planted to sorghum intercropped with groundnuts. The total analytical sample of sorghum and maize plots, including collectively and individually-managed fields, is 1305.

*Conceptual approach*

Our underlying perspective is that of a complex, agricultural family-firm (EAF) that maximizes utility over the consumption of farm-produced and purchased goods, and leisure. Although the farm has a common technology, production occurs over multiple plots managed by various family members. Virtually all production depends on family labor and there is no market for land is as yet discernible (as confirmed in our data). The senior decision-maker (head, or designated team leader) is vested with authority to allocate pooled land and fertilizer inputs among plots depending on the family status of members and crop. Individuals can negotiate, but social norms dictate certain rules of allocation, including, for example, rights of access to land by all married women and all able-bodied men above a certain age. In any single season, we view the land allocation as already predetermined when fertilizer decisions are made (Guirkinger and Platteau, 2014; Authors' interviews). A priori, we know little about how fertilizer allocations are decided, although we have reason to believe, based on previous research in the region (Udry 1996; Kazianga and Wahhaj 2014; Guirkinger and Platteau 2014), that this is the outcome of a household bargaining process in which the welfare of individuals and the family as a whole are interwoven.

As family-firms operating with imperfect markets, economic incentives for those who manage plots, whether collective or individual plots, are shaped in part by household endowments that affect transactions costs. Such endowments include human capital (ability to read and write; adult labor supply), wealth in livestock, land or other assets, and access to financial assets such as village cooperatives, which supply subsidized fertilizers to members. Physical characteristics of plots affect optimal decisions regarding fertilizer allocation. Response rates, and subsidies, differ between sorghum and maize. Moreover, the family status of plot managers affect the allocation of fertilizer within the extended family. For example, wives and sons of the head have different roles, rewards, and responsibilities. We can express our empirical model simply as:

$$(1)\ Z_{ij}^{*}=f(\mathbf{r}, p_{ij}, \mathbf{pl}_{ij}, \mathbf{h}_{j}, Ic_{ij}, Im_{ij}),$$

where $Z_{ij}^{*}$ is the observed amount of fertilizer applied per hectare to a plot $i$ cultivated by an EAF $j$. The vector $\mathbf{h}$ includes household endowments, the vector $\mathbf{pl}_{ij}$ includes plot characteristics, $\mathbf{r}$ refers to a vector of market prices (including the fertilizer subsidy), and the $I$ are indicator variables for crop $c$ and plot management type $m$.

Regressions are estimated with data pooled over all plot management types. We test our three working hypotheses by including indicator variables as intercept shifts entered sequentially in the same regression model (1).

*Econometric strategy*

Nearly half (44%) of all (individual and collective) plot managers surveyed did not apply fertilizer, suggesting that a nonlinear "corner solution" model is more appropriate than a linear model for testing the effects of gender and generation on fertilizer use. A corner-solution model can be expressed as $Z_i=Z^*$ if $Z_i>0$, and $Z_i=0$ if $Z^*<=0$ and $Z_i^* = \alpha + X_i\beta + \varepsilon_i$. That is, the dependent variable in the empirical model (1) assumes a positive, observable value above a certain threshold, denoted by Z*. In such models, data are truncated or have a concentration around a single value, such as a lower limit of zero. Corner-solution models are commonly used to estimate labor supply, but also farm or firm input demands (Wooldridge 2010: 559).

We estimate two classes of corner solution models. First, we estimate a Tobit model, which posits that the binary decision to use fertilizer is determined by the same process that predicts the amount of fertilizer applied, conditional on use (given by the vector of parameters β) (Tobin 1958). Then, we estimate a Cragg model, which relaxes this assumption by allowing the regression parameters to differ between the decision to fertilize maize (0,1) and the intensity of use (>0) (Cragg 1971). To test whether the Tobit or Cragg model better fits the underlying data-generating process, we use a log-likelihood ratio test of the restricted (Tobit) vs. the unrestricted (Cragg) regressions. The Tobit is nested in the Cragg model, which allows the use and intensify decisions to be estimated in two-tiers through the use of probit regressions in the first-tier followed by truncated regressions in the second-tier.

In order to compare the qualitative results (e.g., the signs and magnitudes of coefficients) directly between the Tobit and Cragg models, we also estimate a set of unconditional average partial effects for the Cragg model. The unconditional average partial effects are the second-tier (conditional) partial effects weighted by the (conditional) first-tier average partial effects. The effects of the two tiers can be captured in a single set of average partial effects. Standard errors of unconditional average partial effects are bootstrapped to take into account the two-part estimation procedure (Burke 2009).

Finally, we test the robustness of our results by examining whether the effects of gender and generation on fertilizer use differ between maize and sorghum plots. We apply a modified Chow test (Greene 2003: 681) when estimating linear models with data subsamples. In this case, the constrained regression is the pooled regression that includes both maize and sorghum plots, and the unconstrained regression allows for an underlying fertilizer use process that differs by crop, entailing separate regressions. The modified Chow is also a log-likelihood ratio test in the case of nonlinear models such as ours.

Our cross-sectional data have the advantage that plot data are collected from the same household, so that plot-wise comparisons control to some extent for unobserved household heterogeneity.

*Variables*

Definitions, means and standard deviations of dependent and explanatory variables are shown in Table 1. Fertilizer use is measured as both a zero-one variable and in terms of intensity of use, or total kgs per ha.

In the first regression, which tests hypothesis I, the indicator variable denotes any individually-managed plot=1, 0=collectively-managed plots. In the second (hypothesis II), a dummy variable=1 if the plot is managed individually by a male family member who is not the head of EAF, 0 else. Another dummy variable has the same structure for female plot managers. In the third regression (hypothesis III), three dummy variables measure: 1) plot manager is 15 to 24 years of age=1, 0 if any other age group; 2) plot manager is the wife of the head (first or second are included)=1, 0 if any other relationship to head; 3) plot manager is a son of the head=1, 0 if any other relationship to head.

EAF characteristics **h** include two different measures of wealth and a measure of human capital, which we expect to facilitate access to and use of inputs such as fertilizer. Fertilizer is bulky, costly to transport, and labor-intensive to apply in this farming system. The first is the total number of livestock units, converted to tropical livestock units using FAO TLU conversion factors, normalized by ha, and the total value of all non-livestock household assets, normalized by the size of the EAF. Normalizing these variables expresses them in a comparable way for all extended households, since both are highly correlated with measures of size (land and persons). Non-livestock household assets including agricultural equipment, transportation equipment, material goods and communication equipment (cell phones, radio, television). We computed the value of each item in each category of assets by multiplying the number of items possessed by the EAF times a village (key informant) purchase price and summed across categories.

We measure labor supply as the total number of adults in the EAF between 12 and 55 years of age (which we consider "active" adults), again normalized by the size of the area operated by the EAF. The complementarity of labor and fertilizer inputs, and the lack of labor markets in this region, means that labor supply has the potential to constrain fertilizer use. Further, the area in cotton identifies the extent to which the EAF is engaged in the cotton program, facilitating access to inputs such as fertilizer, but also information and advice.

Since the key characteristics of plot managers, age and gender, are included as indicator variables, we add only the primary education of the plot manager as a characteristic *p*. Only 15% of the plot managers reported having received a primary education at any level. By comparison, the literacy rate is 48%. Adult literacy training is often provided via cotton cooperatives in this region of Mali, and is highly correlated with village cooperative membership. Primary education is a more exclusive measurement of human capital.

Consistent with the model of the family farm-firm, fertilizer prices are endogenous to these EAFs and household-specific because they depend on transactions costs that vary with capital endowments and access to cooperative structures, including the fertilizer subsidy. To handle this, we constructed a variable measuring the share of plot managers in the village who are members of cooperatives. Registered cooperatives, as compared to farmer associations, are formally recognized by the government and provide preferential access to a range of financial and information services. This is referred to as "encadrement," and includes the structures of the national cotton company (CMDT) and the Office du Niger (ON), in particular (Thériault et al. 2016). We consider that membership in these is a more important determinant of use than observed market prices for fertilizer. Membership rates in the village influences prices for all plot managers indirectly, but individual plot managers cannot influence membership rates. According to Kelly et al. (2012: 47), "access to credit is a more important determinant of fertilizer use than the fertilizer price itself." Membership decisions also precede the survey season.

In addition to the cooperative membership variable, we include the presence of a weekly market fairs in the village as a general indicator of access to local commercial markets. Many types of activities are conducted in weekly market fairs in these communities, including purchase of goods from commercial vendors and other forms of exchange among farmers. Bundling of goods for discounts, arbitrage, and non-market exchanges are examples.

## Results

### *Descriptive analysis*

We begin by comparing mean fertilizer use rates between (I) collective and individual plots and between (II) between individual plots managed by men and women who are not household heads in Table 2. Since there are only 16 plots individually manage by men, and none of the 192 individual plots managed by women are planted to maize, we compare fertilizer use between all sorghum plots and all maize plots in Table 3.

Slightly more than half of collectively-managed plots were fertilized in the survey season (57.8%), as compared to under half of individually-managed plots (45.7%), and the difference is statistically significant. Considering plots with zero use as well as those with positive values, the (unconditional) mean total kgs of fertilizer were almost five times as high on collective plots compared with individual plots. Standardizing by area of the plot, unconditional rates of use remained several times greater at the mean on collective plots than on individual plots (~104 kg/ha and ~39 kg/ha, respectively). Considering only positive values, conditional rates of use clearly remain more than twice as high on collective plots (~180kg/ha vs. 85 kg/ha). However, once we control for crop, there is no significant difference between the mean rates of use on collectively and individually-managed sorghum plots. In fact, the rate of use on individually-managed plots of sorghum are a few kgs higher on average.

Looking at the second set of comparisons in Table 2, between individual plots managed by men and those managed by women who are not household heads, the total kgs of fertilizer used by men is twice as high (51.1 v 25.4 kgs). Fertilizer application rates per ha, conditional or unconditional, do not differ significantly between the two groups, although they appear to be lower for the small sample of individual plots managed by men.

Fertilizer use on sorghum plots, which are the more widely distributed among family members than maize plots, is shown in Table 3. Unconditional rates of use appear to be higher for wives of the head, and lower for sons, relative to other members, including fathers, brothers, and daughters-in-law. Figure 1 shows that unconditional mean rates of use climb by age group (under 25, 25 to 39, and 40 or above).

Table 4 compares fertilizer use by crop. As expected based on the data reported in Table 2, and given the context described in the introduction, fertilizer use on maize and sorghum plots are vastly different. The likelihood of use is ~85% on maize plots, compared with only ~34% on sorghum plots. Unconditional means of total amounts applied are nine times as great for maize as for sorghum; unconditional means of rates of use per hectare are 177 kgs/ha for maize plots, and 28 kgs/ha on sorghum plots. Conditional means are higher: 211 kgs/ha on maize plots and 83 kgs/ha on sorghum plots. Although sorghum is expected to respond less intensively to fertilizer than is maize, the most probably explanation for the vast difference is that fertilizer applied to sorghum was subsidized at only 33% compared to 100% for maize (Theriault et al. 2015). That is, a head of EAF could obtain a subsidy for fertilizer for only 1/3 of the area planted to sorghum, and all of the area planted to maize.

The next section controls for other factors to test whether these results hold in a multivariate context.

*Regression findings*

Before testing hypotheses I-III, we conducted preliminary statistical tests on the base regression model shown in (1), excluding the indicator variables. The first null hypothesis compares the Tobit model, which restricts the coefficients in both the probability of use and intensity of use equations to be the same, to the unrestricted Cragg model. The test is conducted by comparing the value of the log-likelihood function in the Tobit model to the sum of the values in probit and truncated regressions. We are unable to accept the null hypothesis that regression parameters are the same for both the probability of use and intensity of use. Using regression output, we calculate log-likelihood ratios of 43.5, 43.9, 42.4, with d.o.f 11, 12, 14, for hypotheses I-III, respectively. Evaluating the Chi-squared distribution at these values, p-values are less than 0.01 in all three cases.

For robustness and crop comparisons, we also begin by testing whether the same underlying process determines fertilizer use on both maize and sorghum plots. We apply a modified Chow test that compares the pooled to separate regressions by crop, rejecting the null hypothesis that the underlying process that explains fertilizer use is the same between maize and sorghum plots. In all three hypotheses, the p-value was 0.00001. The test results are supported by observable differences in statistically significant determinants between the two sets of regressions.

Consistent with these results, in tests of hypotheses I-III, we present Cragg models, pooled and separated by crop (Tables 5-7). Average partial effects, which enable us to compare the coefficients in the Tobit and Cragg models, are shown in the Appendix.

<u>Hypothesis I</u> (Table 5). When plots planted to both cereal crops are pooled, controlling for other factors, individual plots tend to have a higher likelihood of being fertilized and to be more intensively fertilized. However, on average, the probability of use and rates of are significantly lower on individual as compared to collective *maize* plots. While the likelihood of use is greater on individual as compared to collective *sorghum* fields, rates of use do not differ significantly on average. Differences in resource allocation between collective and individual plots have been cited in the literature as evidence of failure to achieve Pareto-efficient outcomes in other countries of West Africa, but results so far have focused on labor or yield comparisons

rather than fertilizer use (Guirkinger et al. 2015; Kazianga and Wahhaj 2013; Udry 1996). Like Guirkinger et al. (2015), our results for maize conflict with those for sorghum. The lack of difference in the rate on sorghum plot, conditional on use, attests to the use of the crop as food, and increasingly by women on their plots as a means of supplementing food supplies for the overall EAF and also ensuring the food security of their own children.

Hypothesis II (Table 6). Pooling by crop and differentiating by gender, plots managed by women have higher average intensity of fertilizer use while those managed by men have lower average intensity of fertilizer use, relative to collective plots (the omitted category). Again, differentiating by crop reveals that lower likelihoods and rates of use on plots managed by men who are not heads is found on maize plots. Since none of the individual maize plots are managed by women, greater fertilizer use by women occurs on sorghum plots. As noted above, these plots are both small and frequently intercropped with groundnuts (0.69 vs. 1.92 ha for fields managed by the head or designate, on average). In addition, ethnographic research suggests that these may function as "food reserve" fields, supplementing the production on the collectively-managed, larger-scale sorghum fields worked by the entire extended family. In addition, married women receive the major share of their revenues from work on these fields.

Hypothesis III. (Table 7). Instead of plot management type, the regressions presented in Table 7 highlight plot manager characteristics—specifically, the age group of the manager and relationship to head. Managers under 25 years of age apply lower rates of fertilizer per ha, but this is accounted for by maize plots rather than sorghum plots. Similarly, sons of the head have lower rates of use on sorghum plots allocated to them. Generally, youth are expected to have less decision-making authority, and a weaker bargaining position, in the EAF; they may also have other, off-farm work opportunities that generate higher returns. Overall, intensity of fertilizer use is considerably greater for wives of the head as compared to other family members who manage plots, and this is accounted for by sorghum rather than maize plots.

Other results. Signs and significant of other factors are similar across the three sets of regressions. Crop effects are salient; the pooled regression shows the large and highly significant effect of maize on likelihood of fertilizer use and use rates. The response rate to fertilizer greater for maize than for sorghum, but the subsidy also favors maize as compared to sorghum (100% of EAF hectares planted to maize are eligible for subsidized fertilizer, compared to only 33% of the area planted to sorghum). Area planted to cotton by the EAF is also statistically significant in pooled and maize crop regressions, illustrating the historical relationship of extension structures and services for the two crops.

In terms of other plot manager characteristics, education as a significant determinant of whether or not fertilizer is used on sorghum plots, but we see this in only one regression. Since sorghum is subsidized at a lower rate and is not connected to the cotton program, this finding reflects access by sorghum managers to information and knowledge independent of the subsidy and cotton programs, such as improved sorghum seed. The overall statistical weakness of the education variable, which is surprising, may reflect that other variables, such as youth, gender, and relationship to head (wife, son), are picking up its effects.

The distance of the plot from the house is positively related to fertilizer use in most of regressions. Since plots situated closer to the house tend to receive more organic fertilizer than more distant fields, this result suggests that the household considers organic and mineral fertilizer to be substitutes—at least within the range of amounts used. The costs of transporting manure to distant fields is also greater. It may also be the case that managers choose to apply fertilizer where they expect the response to be greater—on more distant fields that have been less heavily cultivated. In our final regression, on maize plots where managers have invested in soil and water structures to contain moisture and nutrients, higher rates of fertilizer are applied since these tend to be complementary inputs.

Turning to household characteristics, the number of tropical livestock units owned per hectare, which is a sign of wealth, bears a weakly positive relationship with fertilizer use overall, and a stronger relationship with use intensity on sorghum plots. We interpret this finding as an indicator that wealth facilitates access to fertilizer, playing a greater role in sorghum production because the crop is less favored by the subsidy and/or cotton program. Similar, the value of EAF assets is positively related to use rates, and especially on sorghum plots. Thus, wealthier EAFs,

A larger adult labor supply, standardized by farm size, reduces the likelihood of fertilizer use on a maize field. This may capture competition among crops other than maize and sorghum. A significant, positive sign in any of the regressions would have indicated a labor constraint.

Other than plot manager and crop, village characteristics are the strongest predictors of fertilizer use. Specifically, the presence of a weekly market fair in the village has a major effect on fertilizer use among both crops combined, on likelihoods of use and use rates on maize, but also on the likelihood of fertilizer use on sorghum. This finding is important, as it signals the opportunity for sorghum to become a more commercialized crop.

As expected, the share of plot managers in the village who are members of farmer cooperatives strongly affects average intensity of use, especially on maize, thus influencing both crops combined. In this region, although there are many types of farmer organization, farmer cooperatives serve as the conduits for extension advice, credit, and fertilizer subsidies. Well-organized villages receive more training and services. Reflecting the dominance of the cotton program, this effect is accounted for primarily by maize plots and is not statistically significant for sorghum.

Comparisons of initial tobit models for the three hypotheses (both crops) with unconditional APEs are shown in Appendix Table 1. Significance and direction of effect are generally similar, although coefficient magnitudes appear to differ. Thus, we find the unconditional expected effects to be similar in the Tobit and Cragg models, but prefer to maintain the qualitative results of the double hurdle model on statistical and interpretative grounds.

## Conclusions

The objective of this paper is to examine agricultural intensification within complex family-firms, with a focus on gender and age group. We test three hypotheses comparing fertilizer use among members of extended families on farms in the Sudanian Savanna of Mali. First, we test whether adoption probabilities and intensity of fertilizer use differ by plot management type (collective, individual). Second, we are able to differentiate individual plots managed by men and women who are not heads of household, testing the role of gender while controlling for plot management type. Third, we test the effects of youth ("generation") and the status of the plot manager in the household (relationship to head, including wife or son). In all cases, we test the robustness of our results by comparing two major cereals (maize and sorghum). We contribute to the literature on intra-household decision-making in the region by testing hypotheses about youth as well as gender, and comparing input use rather than productivity.

To test our hypotheses, we utilize data from 1305 maize and sorghum plots cultivated by 623 family farm enterprises in 58 villages of the Sudanian Savannah. We apply nonlinear econometric methods to accommodate a large concentration of zeros in fertilizer use, and test whether a Tobit or Cragg specification better suits the data. In all cases we find that a) the double hurdle model and b) separate regressions for maize and sorghum add statistical value and also meaning to our analysis.

Comparing use rates at the mean, it is enlightening that collective plots are more frequently fertilized with unconditional use rates per ha that are many times that found on individual plots managed by either men or women. However, when we look more closely at sorghum plots, conditional use rates are similar between collective and women's individual plots. None of the women in our sample managed maize plots. While this is not likely to be the case in a larger sample of EAFs, the history of the maize as a crop introduced into the cotton farming system leads us to expect that women's maize plots remain rare, despite the growing importance of maize as a food crop on farms.  Overall, fertilizer use rates per ha are several times higher on maize plots than sorghum plots, reflecting the favored status of maize in the cotton value chain (Thériault et al. 2015). As the first rotation crop, maize also benefits from the residue of fertilizer applied to cotton in the preceding season. Maize is followed by sorghum or millet.as a rotation crop in the cotton farming system.

Controlling for other factors in multivariate regressions, we find that when both plots are combined, fertilizer use rates are higher on individually-managed fields than on collectively-managed fields. When we estimate separate models for maize and sorghum plots, however, we learn that the higher rates occur on individual sorghum plots, while lower rates occur on individual maize plots, compared to collective plots in respective crops.

Exploring this further, higher use rates are found women's sorghum plots, which tend to less than one-third the size of collective plots, are often intercropped with groundnuts, and serve as “food reserves” for the extended family in case harvests on the large collective fields are insufficient. By contrast, lower use rates are apparent on maize plots managed by men who are not heads or household or designated team leaders. Interestingly, when we “unpack” these results, the data suggest that plot managers under 25 years of age have lower fertilizer use rates per ha on maize plots, and sons have lower fertilizer use rates per ha on sorghum fields. Controlling for these and other factors, wives of the head have the highest use rates on sorghum plots.

How agricultural policies are designed and implemented greatly influences fertilizer use. Given that subsidized fertilizer are provided to the head of EAF only and that all areas planted to maize are eligible, the fertilizer subsidy program tends to bypass youth, women and less commercialized food crops. Sorghum is included in the subsidy program, but at lower rates of coverage (Thériault et al. 2015). As it is, access to subsidized fertilizer within a family farm enterprise (EAF) depends entirely on intra-household negotiations between the EAF head and other household members. One way to encourage fertilizer use among youth and women would be to improve their direct access to subsidized fertilizer through the allocation of a quota. For instance, X% of the total fertilizer subsidy received by each EAF would have to be allocated to women and youth. Another way would be to expand the subsidy coverage to crops that are most likely to be planted by youth and women. In the short-run, improving access to the fertilizer subsidy program may be helpful, but it is not a long term viable solution to increase fertilizer use. Agricultural policies should focus on removing constraints that prevent farmers, including women and youth, to access and use fertilizer. For instance, increasing women and youth participation in formal farmer cooperatives could facilitate their access to credit and information services, but with recognition of the importance of protecting the cohesion of the EAF family-firm structure. Extension services should be more inclusive and targeted to crops most likely grown by youth and women.

The analysis presented here raises a number of questions for future research. Do differential use rates among plot managers within extended family farms imply inefficiencies in economic decision-making? If we have controlled for all plot, plot manager, and household characteristics, we would expect use rates to be the same across plots planted to the same crop when families have achieved cooperative outcomes. Additional information about soils could affect our results. Are the higher (lower) use rates among women (youth) related to measurement error, intercropping patterns, different production technology or different shadow prices? Do differential rates of use also occur in other farming areas of Mali, and in crops other than sorghum or maize? Is work on collective fields less and less viable? Will we see more individualization of plots, as has occurred in the rice system?

Results also raise questions concerning food security policy. Understanding adoption and intensification of food crop production within and among households is important for the future of farming in Mali. By what mechanism should the participation of women and youth be increased in existing programs? More research and policy discussion is needed to answer this question, including both qualitative and quantitative analysis. Social norms change, but they are also heterogeneous. For example, in key informant interviews conducted in study villages, the research team found three models of decision-making for allocating fertilizer received through the subsidy program. In the first, le chef prend en compte tous les champs de son exploitation et réparti les quantités d'engrais reçu en fonction de la demande des gérants. Puis, il se fait rembourser par eux (chacun selon la quantité qu'il a reçu). In the second, le chef prend sur lui-même la décision d'augmenter la quantité qu'il demande et reparti en fonction des priorités (surtout des femmes: la plus vielle est celle qui est la plus encline à avoir un champ; généralement les plus jeunes n'ont pas de champ individuel). Dans le troisième cas, le chef demande de l'engrais seulement pour les champs communs et les femmes doivent payer leur engrais sur le marché. Each of these cases pertains to zones qui sont encadrées par la CMDT, ou l'engrais est donné à crédit et est remboursé avec le coton. Seules les demandes des personnes fiables peuvent être prises en compte par le chef d'exploitation.

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Table 1. Definition of variables

| Variable | Definition |
|---|---|
| Fertilizer use (0,1) | fertilizer use=1, 0 else |
| Intensity of use (>0) | total fertilizer kgs/ha, >0 |
| Plot management type | |
| Individually-managed | plot managed by individual==1, 0=plot managed by head of EAF or designate |
| Individually-managed, male | plot managed individually by male who is not the EAF head or designate=1, else 0 |
| Individually-managed, female | plot managed individually by female, not head or designate=1, 0 else |
| Youth | age of plot manager is under 25==1, 0 else |
| Wife | plot is managed by first or second wife of head==1, 0 else |
| Education of plot manager | plot manager attended primary school==1; 0 else |
| Maize plot | plot planted to maize=1, 0 else |
| EAF livestock units per ha | number of animals by type converted to tropical livestock units according to FAO l |
| Plot has SWC structure | plot has stone bunds, zai, tree belts or other structures |
| Minutes house to plot | minutes from house to plot |
| EAF ha in cotton | total ha planted to cotton by EAF in survey season |
| EAF assets per capita | non-livestock assets, including equipment, material goods and communication items |
| Active adults per ha | number of adults in EAF between 12 and 55 years of age (inclusive)/total area operated by EAF |
| Village market fair | village hosts weekly market fair=1, 0 else |
| Village coop membership | share of plot managers in village who are coop members |

Source: Authors.

Table 2. Fertilizer use (kgs) on collectively- and individually-managed plots, including both sorghum and maize

| | Collective | Individual | Individual, male | Individual, female | p-value, 1 v 2 | p-value, 3 v 4 |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | | |
| % fertilized | 57.8 | 45.7 | 43.8 | 45.8 | 0.001 | 0.872 |
| unconditional, total kgs | 154 | 27.3 | 51.1 | 25.4 | 0.000 | 0.045 |
| unconditional, kgs/ha | 104 | 38.7 | 29.2 | 39.5 | 0.000 | 0.505 |
| conditional, kgs/ha | 180 | 84.7 | 66.7 | 86.1 | 0.000 | 0.425 |
| conditional, kgs/ha, sorghum plots | 82.3 | 85.2 | 69.1 | 86.1 | 0.772 | 0.552 |

Source: Authors. Conditional considers only positive values; unconditional includes zero use.
Notes: test on percentages is Pearson chi, others are difference of means, ttests.
Subsamples of individual plots are too small to test for plot management differences among maize plots.

Table 3. Fertilizer use (kgs) on sorghum plots, by relationship of plot manager to head

| | Mean | n |
|---|---|---|
| Head | 23.1 | 380 |
| First wife | 39.4 | 109 |
| Second wife | 49.5 | 48 |
| Son | 17.8 | 80 |
| Father | 38.2 | 3 |
| Brother | 31.9 | 79 |
| Daughter-in-law | 26.0 | 35 |
| | | |
| All | 27.8 | 734 |

Source: Authors.
Notes: Table reports unconditional means (including zeros).

Table 4. Fertilizer use (kgs) on sorghum and maize plots, including both collective and individually-managed plots

| | Maize | Sorghum | Test | p-value |
|---|---|---|---|---|
| % fertilized | 84.6 | 33.5 | Pearson chi | 0.000 |
| unconditional, total kgs | 268 | 30.6 | difference of means, t | 0.000 |
| unconditional, kgs/ha | 177 | 27.8 | difference of means, t | 0.000 |
| conditional, kgs/ha | 211 | 83.4 | difference of means, t | 0.000 |

Source: Authors. Conditional considers only positive values; unconditional includes zero use.

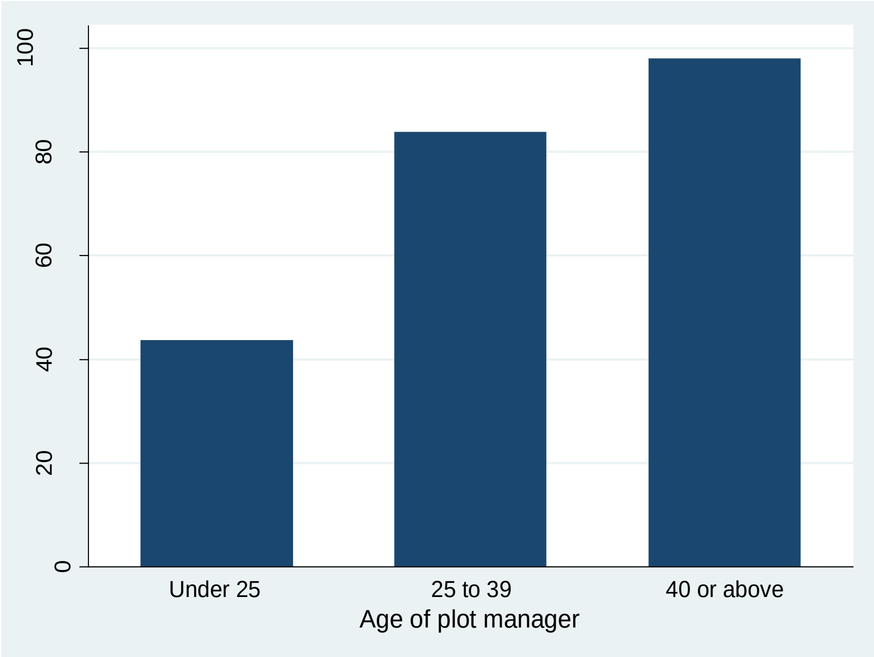


Figure 1. Mean unconditional fertilizer use, kgs/ha, by age of plot manager

Table 5. Hypothesis I: Cragg models explaining fertilizer use by plot management type

| | Both crops | | Maize | | Sorghum | |
|---|---|---|---|---|---|---|
| | Use (0,1) | Kgs/ha (>0) | Use (0,1) | Kgs/ha (>0) | Use (0,1) | Kgs/ha (>0) |
| Individually-managed | 0.489*** | 0.181** | -1.427** | -1.419*** | 0.469*** | 0.182 |
| | (0.110) | (0.0853) | (0.591) | (0.375) | (0.115) | (0.113) |
| Education of plot manager | 0.0114 | -0.0358 | 0.00527 | 0.0847 | 0.0795 | -0.245* |
| | (0.108) | (0.0649) | (0.195) | (0.0673) | (0.136) | (0.130) |
| Maize plot | 1.597*** | 1.139*** | | | | |
| | (0.0884) | (0.0586) | | | | |
| EAF livestock units per ha | 0.0621* | 0.0168 | 0.0755 | -0.0133 | 0.0400 | 0.149*** |
| | (0.0327) | (0.0193) | (0.0537) | (0.0186) | (0.0415) | (0.0472) |
| Plot has SWC structure | 0.00706 | 0.0888 | 0.133 | 0.0977* | -0.0256 | 0.0820 |
| | (0.103) | (0.0602) | (0.194) | (0.0586) | (0.132) | (0.140) |
| Minutes house to plot | 0.00107 | 0.00541*** | 0.0106** | 0.00322** | -0.00380 | 0.0109*** |
| | (0.00219) | (0.00148) | (0.00494) | (0.00151) | (0.00268) | (0.00308) |
| EAF has in cotton | 0.0526*** | 0.0241** | 0.212*** | 0.0156 | 0.0365* | 0.0480** |
| | (0.0179) | (0.0102) | (0.0552) | (0.0103) | (0.0217) | (0.0213) |
| EAF assets per cap | -0.0659 | 0.112*** | -0.163 | 0.0469 | -0.0443 | 0.221*** |
| | (0.0592) | (0.0367) | (0.107) | (0.0386) | (0.0743) | (0.0744) |
| Active adults per ha | 0.00135 | 0.00743 | -0.174** | -0.00751 | 0.123 | 0.00688 |
| | (0.0602) | (0.0349) | (0.0887) | (0.0398) | (0.0807) | (0.0614) |
| Village market fair | 0.374*** | 0.155*** | 0.501** | 0.140** | 0.376*** | 0.160 |
| | (0.101) | (0.0575) | (0.211) | (0.0582) | (0.123) | (0.123) |
| Village coop membership | 0.277 | 0.293** | 1.125*** | 0.408*** | -0.363 | -0.0434 |
| | (0.192) | (0.119) | (0.342) | (0.119) | (0.249) | (0.260) |
| Constant | -0.880*** | 3.576*** | 0.393 | 4.833*** | -0.626*** | 3.287*** |
| | (0.166) | (0.109) | (0.251) | (0.101) | (0.208) | (0.207) |
| Observations | 1,301 | 1,301 | 570 | 570 | 731 | 731 |

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 6. Hypothesis II: Cragg models explaining fertilizer use by plot management type and gender

| | Both crops | | Maize | | Sorghum | |
|---|---|---|---|---|---|---|
| | Use (0,1) | Kgs/ha (>0) | Use (0,1) | Kgs/ha (>0) | Use (0,1) | Kgs/ha (>0) |
| Individually-managed, female | 0.542*** | 0.257*** | | | 0.464*** | 0.206* |
| | (0.113) | (0.0869) | | | (0.117) | (0.114) |
| Individually-managed, male | -0.0678 | -0.669*** | -1.427** | -1.419*** | 0.569 | -0.275 |
| | (0.327) | (0.242) | (0.591) | (0.375) | (0.406) | (0.356) |
| Education of plot manager | 0.0377 | -0.0108 | 0.00527 | 0.0847 | 0.0765 | -0.213 |
| | (0.109) | (0.0646) | (0.195) | (0.0673) | (0.137) | (0.132) |
| Maize plot | 1.612*** | 1.153*** | | | | |
| | (0.0888) | (0.0582) | | | | |
| EAF livestock units per ha | 0.0613* | 0.0149 | 0.0755 | -0.0133 | 0.0405 | 0.142*** |
| | (0.0327) | (0.0192) | (0.0537) | (0.0186) | (0.0415) | (0.0474) |
| Plot has SWC structure | 0.00924 | 0.0886 | 0.133 | 0.0977* | -0.0250 | 0.0787 |
| | (0.103) | (0.0597) | (0.194) | (0.0586) | (0.132) | (0.139) |
| Minutes house to plot | 0.000914 | 0.00545*** | 0.0106** | 0.00322** | -0.00379 | 0.0110*** |
| | (0.00219) | (0.00147) | (0.00494) | (0.00151) | (0.00268) | (0.00307) |
| EAF has in cotton | 0.0519*** | 0.0240** | 0.212*** | 0.0156 | 0.0367* | 0.0467** |
| | (0.0180) | (0.0101) | (0.0552) | (0.0103) | (0.0217) | (0.0213) |
| EAF assets per cap | -0.0669 | 0.113*** | -0.163 | 0.0469 | -0.0445 | 0.227*** |
| | (0.0592) | (0.0364) | (0.107) | (0.0386) | (0.0743) | (0.0743) |
| Active adults per ha | -0.00175 | 0.00544 | -0.174** | -0.00751 | 0.123 | 0.00508 |
| | (0.0601) | (0.0346) | (0.0887) | (0.0398) | (0.0808) | (0.0612) |
| Village market fair | 0.375*** | 0.153*** | 0.501** | 0.140** | 0.377*** | 0.154 |
| | (0.101) | (0.0569) | (0.211) | (0.0582) | (0.123) | (0.123) |
| Village coop membership | 0.270 | 0.283** | 1.125*** | 0.408*** | -0.361 | -0.0415 |
| | (0.192) | (0.118) | (0.342) | (0.119) | (0.249) | (0.259) |
| Constant | -0.879*** | 3.569*** | 0.393 | 4.833*** | -0.627*** | 3.291*** |
| | (0.166) | (0.108) | (0.251) | (0.101) | (0.208) | (0.206) |
| Observations | 1,301 | 1,301 | 570 | 570 | 731 | 731 |

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 7. Hypothesis III: Cragg models explaining fertilizer use by age and relationship to head

| | Both crops | | Maize | | Sorghum | |
|---|---|---|---|---|---|---|
| | Use (0,1) | Kgs/ha (>0) | Use (0,1) | Kgs/ha (>0) | Use (0,1) | Kgs/ha (>0) |
| Youth | 0.0218 | -0.344** | -0.233 | -0.444** | 0.186 | -0.381 |
| | (0.225) | (0.161) | (0.432) | (0.215) | (0.262) | (0.253) |
| Wife | 0.516*** | 0.285*** | | | 0.457*** | 0.168 |
| | (0.121) | (0.0906) | | | (0.126) | (0.117) |
| Son | 0.00530 | -0.115 | -0.205 | -0.0196 | 0.141 | -0.350** |
| | (0.124) | (0.0749) | (0.205) | (0.0765) | (0.160) | (0.162) |
| Education of plot manager | 0.0325 | -0.0309 | -0.0905 | 0.0638 | 0.0834 | -0.212 |
| | (0.109) | (0.0645) | (0.189) | (0.0681) | (0.136) | (0.129) |
| Maize plot | 1.579*** | 1.145*** | | | | |
| | (0.0874) | (0.0564) | | | | |
| EAF livestock units per ha | 0.0594* | 0.0278 | 0.0734 | -0.00463 | 0.0290 | 0.161*** |
| | (0.0330) | (0.0197) | (0.0522) | (0.0196) | (0.0419) | (0.0471) |
| Plot has SWC structure | -0.00109 | 0.0881 | 0.128 | 0.109* | -0.0405 | 0.0326 |
| | (0.103) | (0.0595) | (0.193) | (0.0592) | (0.132) | (0.137) |
| Minutes house to plot | 0.00102 | 0.00510*** | 0.0112** | 0.00305** | -0.00382 | 0.0103*** |
| | (0.00218) | (0.00147) | (0.00496) | (0.00153) | (0.00267) | (0.00304) |
| EAF has in cotton | 0.0531*** | 0.0229** | 0.202*** | 0.0128 | 0.0370* | 0.0474** |
| | (0.0180) | (0.0101) | (0.0544) | (0.0105) | (0.0217) | (0.0210) |
| EAF assets per cap | -0.0723 | 0.122*** | -0.141 | 0.0685* | -0.0550 | 0.242*** |
| | (0.0594) | (0.0369) | (0.108) | (0.0394) | (0.0745) | (0.0745) |
| Active adults per ha | -0.00510 | 0.00496 | -0.160* | -0.00483 | 0.112 | -0.00259 |
| | (0.0599) | (0.0346) | (0.0890) | (0.0403) | (0.0800) | (0.0602) |
| Village market fair | 0.362*** | 0.134** | 0.474** | 0.133** | 0.374*** | 0.104 |
| | (0.101) | (0.0573) | (0.210) | (0.0592) | (0.124) | (0.122) |
| Village coop membership | 0.226 | 0.300** | 1.180*** | 0.443*** | -0.444* | -0.0874 |
| | (0.189) | (0.117) | (0.341) | (0.119) | (0.245) | (0.252) |
| Constant | -0.818*** | 3.574*** | 0.369 | 4.793*** | -0.546*** | 3.376*** |
| | (0.163) | (0.106) | (0.252) | (0.102) | (0.203) | (0.199) |
| Observations | 1,301 | 1,301 | 570 | 570 | 731 | 731 |

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Appendix Table 1. Tobit and Cragg APEs, Hypotheses I-III, both crops combined

| | APEs, bootstrapping | | Tobit, Delta method | |
|---|---|---|---|---|
| Hypothesis I | coeff | pvalue | coeff | pvalue |
| Individually-managed | .7482046 | 0.000 | 1.580813 | 0.000 |
| Education of plot manager | -.0049105 | 0.973 | 0.0057931 | 0.982 |
| Maize plot | 2.750414 | 0.000 | 4.931689 | 0.000 |
| EAF livestock units per ha | .0916028 | 0.085 | 0.1552945 | 0.044 |
| Plot has SWC structures | .0589795 | 0.675 | 0.0431724 | 0.860 |
| Minutes house to plot | .0044376 | 0.210 | 0.0050811 | 0.352 |
| EAF has in cotton | .0831 | 0.000 | 0.1339459 | 0.001 |
| EAF assets per cap | -.0243988 | 0.771 | -0.082694 | 0.572 |
| Active adults per ha | .0059383 | 0.944 | 0.0188447 | 0.899 |
| Village market fair | .5810757 | 0.000 | 0.9685547 | 0.000 |
| Village coop membership | .5307716 | 0.029 | 0.7906314 | 0.090 |
| | | | | |
| Hypothesis II | coeff | pvalue | coeff | pvalue |
| Individually-managed, female | .8579916 | 0.000 | 1.775349 | 0.000 |
| Individually-managed, male | -.4638445 | 0.491 | -0.4835738 | 0.587 |
| Education of plot manager | .0436865 | 0.752 | 0.081812 | 0.756 |
| Maize plot | 2.770491 | 0.000 | 4.970816 | 0.000 |
| EAF livestock units per ha | .0891336 | 0.141 | 0.1528226 | 0.046 |
| Plot has SWC structures | .0617707 | 0.661 | 0.0475826 | 0.845 |
| Minutes house to plot | .0042551 | 0.128 | 0.0046418 | 0.394 |
| EAF has in cotton | .0818301 | 0.000 | 0.131986 | 0.002 |
| EAF assets per cap | -.024876 | 0.782 | -0.0868656 | 0.551 |
| Active adults per ha | .0007381 | 0.993 | 0.0097832 | 0.948 |
| Village market fair | .5794615 | 0.000 | 0.9659661 | 0.000 |
| Village coop membership | .5143891 | 0.038 | 0.7579838 | 0.103 |

Source: Authors

| | APEs, bootstrapping | | Tobit, Delta method | |
|---|---|---|---|---|
| Hypothesis III | Coef. | pvalue | Coef. | pvalue |
| Youth | -.163686 | 0.656 | -0.12911 | 0.829 |
| Wife | .8422767 | 0.000 | 1.716692 | 0.000 |
| Son | -.0572924 | 0.718 | -0.05088 | 0.866 |
| Education of plot manager | .0256464 | 0.848 | 0.0619 | 0.814 |
| Maize plot | 2.730042 | 0.000 | 4.877145 | 0.000 |
| EAF livestock units per ha | .0941285 | 0.068 | 0.154458 | 0.048 |
| Plot has SWC structures | .0478339 | 0.707 | 0.023087 | 0.925 |
| Minutes house to plot | .0042 | 0.222 | 0.004846 | 0.374 |
| EAF has in cotton | .0830824 | 0.000 | 0.134088 | 0.001 |
| EAF assets per cap | -.0271078 | 0.766 | -0.09781 | 0.505 |
| Active adults per ha | -.0039696 | 0.966 | 0.002572 | 0.986 |
| Village market fair | .5545427 | 0.000 | 0.93523 | 0.000 |
| Village coop membership | .4671371 | 0.049 | 0.662652 | 0.151 |