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Julia C. Collins
IFPRI

and

Jeremy D. Foltz
University of Wisconsin-Madison
Email for correspondence: jdfoltz@wisc.edu

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Julia C. Collins & Jeremy D. Foltz[1]

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Abstract

In many West African countries, large rural multigenerational households farm common household plots as well as allocate individual plots to different family members. Multiple studies have found that women plot managers achieve lower yields than men. This work uses a unique 17-year panel dataset from southern Mali to investigate this gender production differential. The long-span and specificity of the data allow us to simultaneously test many of the reasons put forth in the literature for gender production differentials: input & labor use, land tenure, polygamy, and social status. We find that female plot managers in this dataset do achieve significantly lower yields than men and that the effect is mostly explained by labor allocation and social status within the Malian household.

[1] The authors are respectively, IFPRI Senior Research Assistant and Professor, Department of Agricultural & Applied Economics, University of Wisconsin – Madison. Address for correspondence: jdfoltz@wisc.edu.

Researchers have noted for the last several decades that female farmers often achieve lower yields than male farmers in many parts of the developing world. More recently, a growing body of literature has examined intrahousehold allocative efficiency by studying productivity differences in male-managed and female-managed farm plots in West Africa. The literature takes advantage of the prevalence in many African countries of large multigenerational households in which the household head assigns individual farm plots to different (male and female) household members. Most studies find that males achieve systematically higher yields on the plots they control. Some authors explain this in terms of inefficient intrahousehold allocation of production inputs, while others offer different explanations that do not preclude efficient allocations. Some controversy remains about the existence and nature of intrahousehold production differentials. Are the production differentials the result of household decisions, social norms, or other factors?

Shedding light on the source of production differentials will help policymakers who wish to increase the yields of farming households and of women farmers in particular. Women plot managers usually have the right to keep the proceeds from their plots; increasing female yields could increase female incomes and could therefore have implications for child health and education. This study uses a unique rich panel dataset to study the gender production differential in the Sikasso region of Mali. Like many authors, we test whether women plot managers achieve significantly lower yields than men, and find this to be the case. This effect is then analyzed across multiple types of explanations common in the literature: input use, labor use, land tenure, polygamy, and social norms. Our results indicate important differences in the gender production differential depending on the female plot manager's position in the household: wives of the household head fare better than daughters-in-law, sisters-in-law, and other women.

Literature Review

The gender production differential

Early literature on the effects of gender on agricultural productivity in developing countries attempted to find differences in technical efficiency between male and female farmers. Quisumbing (1996) reviewed studies from East and West Africa and Asia from the 1970s, 80s and 90s that estimated production functions to determine whether female farmers were using inputs as efficiently as male farmers. Most studies found that women farmers were as productive as men, controlling for inputs and other individual characteristics such as education. These studies did not investigate the reasons behind different levels of input use by men and women.

A separate literature examined intrahousehold resource allocation and decision making in both developed and developing countries. Chiappori's collective rationality model (1988) departed from earlier "unitary" models by allowing individual utility functions for household members rather than a shared household utility function. He assumed that household bargaining on the allocation of labor and consumption goods would lead to Pareto efficient outcomes. Rangel (2005) and Akresh (2005) review studies using consumption data from several countries, which suggested that although household members differed in preferences, they did achieve efficient resource allocations.

Udry (1996) investigated gender productivity differentials in agriculture through the lens of household allocative efficiency rather than technical efficiency. He obtained results that challenged the assumption of the collective rationality model that households necessarily achieve Pareto efficient outcomes. His study of ICRISAT data from Burkina Faso tested for Pareto efficiency by estimating a year-crop-household fixed effects model of yield at the plot level, including a plot manager gender dummy and plot characteristics as control variables. Pareto efficiency would imply that yield differences were driven only by differences in plot characteristics. However, the female dummy was significant and negative. Udry suggested that the productivity differential was due to women's lower use of inputs; he showed that women's plots used far lower amounts of fertilizer and of male and child labor than male plots. His supplemental estimations of production functions indicated that total household productivity could be increased by 6% if inputs were reallocated from men's to women's plots.

In the following years, several other studies used Udry's specification to identify gender productivity differentials in different West African countries. Rangel (2005) found large gender differentials in Burkina Faso, Senegal, and Ghana; however, he suggested that the differentials were not due to intrahousehold inefficiency, but to unobserved differences in the quality of land allocated to men and women. He showed that the consumption decisions of the same households in Senegal and Ghana were Pareto efficient, and indicated his belief that the apparent inefficiency of production decisions most likely had another explanation.

Akresh (2005) applied Udry's specification to more recent data covering all 30 provinces of Burkina Faso, rather than just the three provinces included in the ICRISAT data Udry had used. He found significant negative gender differentials when the dataset was restricted to the ICRISAT provinces and neighboring provinces, but not when examining all other provinces. Households in the ICRISAT and neighboring provinces had larger average plot sizes and greater wealth, and were more likely to receive rainfall above the province average, than households in the other provinces. When cash crops were removed from the dataset, women still fared worse than men, but the difference was attenuated.

Akresh then examined the effects of positive and negative rainfall shocks, and found that women fared worse in relation to men in years with abundant rainfall, and fared better in relation to men in drought years. He suggested that households may incur costs (such as violating social norms) in reallocating inputs, and these costs prevent them in some cases from achieving Pareto efficient outcomes. In drought years, households are more willing to incur these costs in order to maximize output.

Goldstein and Udry (2008) found a large gender productivity differential using data from southern Ghana. However, they explained this not by allocative inefficiency but by decisions made in response to land insecurity. The gender differential could be explained completely by fallowing decisions: men left their plots fallow for longer periods and achieved higher yields due to improved soil fertility. Lower-status individuals run a higher risk of having their fallow land appropriated by others than high-status individuals do. Women fallow their plots for shorter periods in order to prevent losing them, and lower-status men also fallow for shorter periods than higher-status men.

Peterman et al. (2010) found gender productivity differentials using data from Nigeria and Uganda; their gender indicator was the gender of the household head (in Nigeria) and gender of household head or gender of plot manager (in Uganda). They differed somewhat from Udry's specification, using additional control variables, including household socioeconomic variables, input prices, and community-level indicators on access to markets and agroecological zones. The authors did not offer a single explanation for the source of the differentials, but they stressed that findings differed greatly across crops and across regions; some regions and crops showed no yield differences. In particular, female-headed households in both Uganda and Nigeria achieved lower productivity in relation to men in drier savannah regions; this may reflect the greater time women in drier areas spend transporting water and firewood.

Akresh et al. (2011) returned to intrahousehold allocative efficiency as an explanation for gender differentials. They compared yield dispersions in polygamous versus monogamous marriages to test their hypothesis that greater altruism can inhibit cooperation and lead to inefficient resource allocations. The authors found that production differentials between husbands and their wives were smaller in polygamous marriages than in monogamous marriages. They interpreted this to mean that wives cooperated to a greater extent with co-wives than with husbands, and so were able to achieve more efficient allocations and higher yields than they could in the absence of co-wives. The possibility that wives and husbands achieved greater cooperation with each other in polygamous marriages than in monogamous marriages was rejected as an explanation because polygamous husbands did not gain a yield advantage over other males. The authors suggested that individuals with less altruism toward each other, such as co-wives, were able to cooperate more effectively and achieve more efficient resource allocations because altruism increases the utility gained from inefficient outcomes.

Kazianga and Wahhaj (2013) used a different dataset from Burkina Faso from the early 1990s and found that the entire gender differential could be accounted for by the plot manager's position as household head or as junior family member. Household heads, who were overwhelmingly male, achieved higher yields than other family members; females and males who were not household heads achieved similar yields. The authors suggested that this yield differential is caused by social norms that require that multiple household members contribute labor to the common plots which are managed by the household head. Udry (1996) did not differentiate common plots from individual plots, and treated common plots as if they were individual plots managed by the household head. Kazianga and Wahhaj's results therefore present a challenge to Udry's results, and suggest that previous literature was looking along the wrong dimension for intrahousehold productivity differentials. Akresh et al. (2011) also included a regression with female and non-head male dummies in their study. Both dummies were negative and significant, which lends support to Kazianga and Wahhaj's findings on the advantage enjoyed by the household head.

Explanations of the gender production differential can be roughly divided into three groups. In the first group are authors that contest the existence of the gender differential (Kazianga and Wahhaj 2013) and those that find a differential only in certain geographical areas and crops (Akresh 2005, Peterman et al. 2010). The second group explains the gender differential as resulting from inefficient input allocation. Most studies do not examine the determinants of fertilizer and labor allocation in detail; however, Udry (1996) notes that women's plots use far less fertilizer than men's, and other authors report findings that may lend support for labor allocation as a leading explanation (for example, Peterman et al.'s (2011) result that women fared less well in dry savannah regions). The third group contains explanations for the gender differential that do not result from inefficient input allocations: unobserved differences in land quality, and differences in land tenure rights that prevent women from fallowing their land (Goldstein and Udry 2008).

Common and individual plots

Other studies on aspects of West African household and farm structure not directly concerned with the gender production differential are relevant to this project. Research on differences between common and individual plots is sparse, but recently a few studies have addressed this area. Loeffen et al. (2008) studied the adoption of soil and water conservation technologies in the Koulikoro region of southwestern Mali, north of Sikasso. Plot status (individual or common) was among their control variables for yield regressions. Their results showed that, consistent with Kazianga and Wahhaj's findings, individual plots had significantly lower yields for cotton and sorghum. The coefficient on individual plots was negative but insignificant for maize, and positive but insignificant for millet.

However, Goetghebuer (2011) argued that common plots were likely to obtain lower yields than individual plots because of the "moral hazard in team" problem, where individuals provide labor to common plots as required but do not work as hard on common plots as they do on their individual plots. The author and colleagues interviewed household heads and individual plot holders in the Sikasso and Sekou regions of Mali, and found that many heads suspected junior members of shirking labor on the common plots, and many junior members put more effort into their individual plots. Goetghebuer's empirical study on yield difference between common plots and male-managed individual plots confirmed that the individual plots achieved higher yields for most crops. The only crops not showing a difference were the relatively low labor-intensity crops sorghum and millet.

Goetghebuer's main emphasis was not on the gender production differential, but her study also sheds some light on this area. She included a female dummy in her regressions, which was originally negative and significant, but became insignificant after controlling for chemical inputs, hired labor, equipment rental, and crop choice. She stated that the female dummy became close to significant if she omitted the land rights variable (a dummy indicating whether the plot manager has permission to plant trees, a proxy for land tenure security). This last result may lend support to Goldstein and Udry's (2008) findings on the importance of land security in explaining the gender differential.

The findings of Kazianga and Wahhaj and those of Goetghebuer seem contradictory,but both papers agree that intrahousehold production differentials are more accurately described as plot status differentials than as gender differentials. Their findings on male individual plot yields vs. common plot yields, though, are in direct contradiction. Kazianga and Wahhaj find a significant difference between female individual plots and common plots whereas Goetghebuer does not. However, the explanations the authors provide for their findings apply to individual plots of both genders, with Kazianga and Wahhaj arguing that common plots achieve higher yields than individual plots due to the labor contributions of many household members, and Goetghebuer arguing that incentives for effective labor are higher on individual plots.

Hypotheses from the literature

While each addition to the literature has tested one or two hypotheses about the gender productivity differential, most have stopped short of testing all the possibilities. The unique dataset available in Mali allows us to test multiple causes of the gender differential. The literature on the gender differential suggests a set of hypotheses set out below as testable null hypotheses.

H1. Pareto optimality: Yields are equal across male and female plots within a household. As set out in Udry (1996), the household operating in a pareto optimal way will have equal yields (production per hectare) across male and female plots.

H2. Pareto optimality of input use: Controlling for other factors, input productivity is the same across different household plots. An implication of the Udry (1996) model is that controlling for other factors (e.g., soil quality), inputs (e.g., fertilizer) will be allocated equally across different plots and therefore have the same productivity level. More frequently in the literature this is expressed as unobserved input use differential being the potential cause of the gender differential (rejection of *H1*).

H3. Ownership: Ownership security of plots does not affect yields. As set out in Kazianga & Wahhaj (2013) and consistent with Goldstein & Udry (2008), differences in land tenure or plot ownership security account for the difference in plot productivity. Specifically if male plots have higher levels of security than female plots, then they will also have higher levels of productivity. The productivity effect could be due to incentives for investments in, for example, soil fertility as in Goldstein & Udry, or could be related to higher levels of productivity on (male-controlled) common plots than on individual plots as in Kazianga & Wahhaj.

H4. Labor shifting: Gender differentials are not affected by labor availability in the household. In a household that is not operating in a pareto optimal fashion, alternative activities within the household done by women (e.g., child rearing) reduce the amount of labor available for agriculture and therefore reduce their yields. If this were the case the level of the gender differential would be partially determined by the availability of women's labor within the household. Such a labor availability differential could be caused by cultural values (see e.g., Kevane & Wydick 2008) that proscribe men or women from certain activities, or by comparative advantages and capacity constraints. We consider two types of women's labor availability: the ratio of women to men and the ratio of young children to women.

H5. Polygamy: Gender differentials are the same across polygamous and monogamous households. As posited by Akresh et al. (2011), bargaining outcomes imply that the lower degree of altruism and better ability to cooperate among co-wives than between husbands and wives in polygamous households would mean no (or lower) gender differentials in polygamous households.

H6: Social Hierarchy: A woman's place in the social hierarchy of the family does not change the productivity of her plot. This is a generalization of *H5.* As in *H5,* bargaining outcomes could change the productivity of plots dependent on the bargaining position of women within the household.

Empirical context and data

Background on Mali and Sikasso

Mali is one of the poorest countries in the world, with 50.4% of the population living on less than $1.25 per day in 2010 (World Bank 2012). Agriculture plays an important role in Mali's economy, accounting for 66% of total employment (World Bank 2012). Agricultural products, particularly cotton, represent a large share of exports. Mali was Africa's largest cotton producer in 2011-2012, growing 185,000 tons of cotton, of which 131,000 tons were exported (USDA FAS 2012).

Sikasso, Mali's southernmost region, receives relatively abundant rainfall and is a major agricultural and cotton-producing area. Northern Sikasso has been producing cotton for decades, while cotton has increased in importance more recently in other parts of the region. Despite its agricultural productivity, Sikasso does not appear to be wealthier than other regions of Mali

(Delarue et al. 2009). Sikasso's rate of child malnutrition was 16% in 2006, slightly higher than the national average of 15% (IRIN 2009).

In Sikasso, as in other areas of Mali and many West African countries, rural families live in large intergenerational households with a designated household head (usually the oldest male). Polygamy is common (about two-thirds of the households in the dataset are polygamous for at least some years). In addition to the head's wives and children, households often include the head's brothers and their wives and children. Daughters leave the household when they marry, but sons often remain with their wives and children. Heads manage the household's common plots, to which other household members contribute labor. The output of the common plot is shared among all household members.

The head also allocates individual plots to particular household members. These plots are owned by the household, but the individual plot managers supply the labor and other inputs used on their plots, make cropping and other production decisions, and are entitled to keep the output of their plots. The allocation of individual plots changes year-to-year, although there is much consistency in the group of household members who hold individual plots. In the Sikasso data, the head's wives, daughters-in-law or sisters-in-law hold most individual plots. Male relatives of the head hold a smaller number of individual plots. Goetghebuer (2011) states that many Malian households have only collective fields; however, only one household in the Sikasso dataset has no individual fields. She also notes that allocating individual plots to male household members is a more recent practice than allocating plots to females, and that in many households, only females hold individual plots. This is reflected in the Sikasso dataset; women manage over 90% of individual plots. In addition to agricultural production, female household members are responsible for childcare, food preparation, and other household activities.

Description of the dataset

This study uses panel data collected by Mali's agricultural research and extension agency, the Institut d'Economie Rurale (IER). IER enumerators recorded information on farm plots and household composition annually for 8-12 households in each of 12 villages from 1994 to 2010[2]. The data cover 88 households across these 17 years. Some households drop out of the survey and others are added, but information for most households is available for the entire 17-year span. The plot-level data contains information on plot characteristics (size, soil type and topography), crops grown, yields, fertilizer and other inputs, and the identity of the plot manager. The status of plots as common or individual was recorded for most plots in most years. The name, gender, relationship to the head of household, and animals and machinery owned are recorded for each plot manager as well as other household members.

The fertilizer data includes information on four different types of fertilizer, which we have aggregated to create a chemical fertilizer variable. There is also information on manure inputs and chemical inputs (herbicide, pesticide, and fungicide); however, we will not use these variables, because in their case it was sometimes impossible to tell whether missing values represented zeros or were genuinely missing.[3]

[2] Information on plot level yield, the dependent variable of interest, is missing for 2007.

[3] If we include data on manure and chemical inputs for those years when they were recorded consistently, the results presented below are not substantially changed. This does, however, severely restrict the number of observations, so we do not include these variables in the main specifications.

Data on soil type (including categories such as sandy, clay, gravel, etc.) and topography (including lowland, plateau, slope, etc.) were only collected by the IER in 1999. Because soil types on a particular plot do not change from year to year, we use this to impute soil data for other years.[4] The soil type variable is in the form of 28 unique combinations of soil type and topography.

The IER also collected rainfall data for each village, either daily or aggregated to 10-day totals. Rainfall data were missing for several years in several villages. In these cases, we used coefficients from regressions relating regional and village rainfall in years when data for each was available to impute village observations from regional rainfall data. Information on the prices of major crops was also collected for most villages in most years. In many cases, price data was missing for some villages or some crops. Missing data were imputed from existing data similarly by using observed relationships between prices of different crops or between prices in different localities.

Information on labor hours allocated to each plot is not included in the Sikasso data. It is likely that household members contribute labor to each other's individual plots as well as their own. Several of the authors studying gender production differentials reviewed above used data collected by ICRISAT in Burkina Faso; these data show that female, male, and child labor is used on both male and female plots (with male plots including individual and common plots). More child and nonfamily labor is used on male plots than on female plots, and women contribute more hours per hectare of labor to male plots than men do to female plots (Udry 1996).

The data we use were collected from two *cercles* (the Malian administrative category below region) in the Sikasso region: Bougouni and Kadiolo. There are a total of 88 households in Kadiolo and Bougouni that appear in the dataset for at least one year (including the 64 households that enter the dataset in 1994, and others that break off of the original households). Table 1 below shows the gender breakdown of control of the 11,586 plots for which we have data. As is evident, there is a fairly even gender distribution of control, with males having slightly more plots than women. Table 2 shows a complete list of summary statistics for all variables of interest used in this study. For further descriptive statistics, see Appendix 1.

[4] Due to differences in the variation of soil types within villages and households, soil type information was imputed with more confidence for some plots than for others. We use all soil information available in the main specification, but later limit the dataset to those observations in which soil information was imputed was high confidence to test for robustness. See Collins (2012) or contact authors for further details on the imputation process.

Table 1: Gender of Plot Manager by Region

	Kadiolo	Bougouni	Total Number
Male (%)	53.3%	52.1%	6,116
Female (%)	46.7%	47.9%	5,470
Total Number	6,581	5,005	11,586

Table 2: Means and standard deviations of variables of interest

Variable	Mean	Standard deviation
Dependent variable		
Yield (kg/ha)	841.693	911.973
Log of yield	6.260	1.252
Value of plot output/kg (1000 FCFA)	145.576	169.574
Categorical variables (0 – 1)		
Female	0.472	0.499
Common plot	0.497	0.500
Non-head common plot	0.082	0.274
Male private plot	0.031	0.174
Female private plot	0.403	0.491
Household head	0.408	0.491
Non-head male	0.128	0.334
Wife of head	0.214	0.410
Other female	0.251	0.433
Polygamous household	0.590	0.492
Fertilizer and labor variables		
Fertilizer (kg/ha)	41.558	95.792
Log Fertilizer	1.385	2.185
Ratio of women to men	1.473	0.782
Ratio of children to women	1.096	0.731
Other variables		
Total land (ha)	11.003	5.615
Rainfall deviation from yearly mean (mm)	5.995	166.629

Empirical Strategy

Baseline Regression

We will begin this study by estimating a version of Udry's (1996) original equation:

$$(YIELD)_{htci} = \alpha + \beta FEMALE_{htci} + \boldsymbol{\delta PLOT\_CHAR}_{htci} + \boldsymbol{\gamma HH * CROP}_{hc} + \theta \boldsymbol{YEAR}_t + \varepsilon_{htci} \quad (1)$$

where $YIELD_{htci}$ is yield on plot i planted with crop c by household h at time t; $FEMALE_h$ is a dummy variable equaling one if the plot in managed by a woman; $\boldsymbol{PLOT\_CHAR}_{htci}$ is a vector of characteristics of that plot (soil type, topography, and plot size); $\boldsymbol{HH * CROP}_{hc}$ is the household crop fixed effect, and $\boldsymbol{YEAR_t}$ is the time effect; and β is the gender production differential parameter of interest. In the literature's standard test for Pareto efficiency, a nonzero gender production differential indicates that plot yield is affected by factors other than plot characteristics, which suggests inefficient allocation of productive inputs.

We use household-crop fixed effects with year fixed effects, rather than the combined household-year-crop fixed effects used by Udry and others. This choice is dictated by the lack of variation within household/crop/year combinations. We use the natural log of yield (kg/ha) as the dependent variable,[5] which allows for coefficients to be interpreted as percent changes in yield.[6] Since the variation driving the model will be between multiple plots of the same crop within the same household, but potentially across years, using kilos of output allows us to compare for example kilos of sorghum to kilos of sorghum. Following Udry and several of the authors reviewed earlier, the regression includes dummy variables for plot size deciles. The first two deciles are combined, as 0.1 ha was the cutoff for both the first and second deciles. The other plot quality control variables are dummies for each soil type and topography combination.

Error terms

Equation (1) above represents a fixed effects model with the fixed effects operating at the household and crop level. We should expect meaningful variation in the error term ε_{htci} at this level of clustering, but also potentially across years. To account for this we estimate (1) with standard errors clustered at clusters defined by household, crop, and year. As a robustness check, we have also re-estimated all the equations in the model with robust Huber/White standard errors that assume no structure and find similar results.

Effect of production inputs

In order to test whether inefficient production input allocation is the source of the gender production differential, we control for fertilizer use (natural log of kg/ha) and then include a fertilizer-female interaction term:

$$(YIELD)_{htci} = \alpha + \beta_1 FEMALE_{htci} + \beta_2 Ln\ \ FERT_{htci} + \beta_3 FEMALE * Ln\ \ FERT_{htci}$$

$$+ \boldsymbol{\delta PLOT\_CHAR}_{htci} + \gamma \boldsymbol{H}\mathrm{H} * \boldsymbol{CROP_{hc}} + \theta \boldsymbol{YEAR_t} + \varepsilon_{htci} \quad (2)$$

Plot status differential

Next, we estimate versions of Kazianga and Wahhaj's (2013) and Goetghebuer's (2011) equations, to determine if the gender production differential exists separately from the common / individual plot status differential.[7] Kazianga and Wahhaj used Udry's equation, with two dummies for head of household and non-head male rather than a female dummy. Goetghebuer

[5] More precisely, the natural log of (yield + 1), in order to avoid dropping observations with zero yield. These represented 1.9 % of the sample. The fertilizer variable was adjusted in the same way.

[6] The literature has typically used the monetary value of plot output per hectare for the dependent variable. We do not in our main specification, because the local value of crops is difficult to measure and is subject to large variation throughout the year; it is not clear which price most accurately reflects crop value. However, regressions with the log of value of output per hectare as the dependent variable show the same results as presented below.

[7] For a full and detailed exploration of the relationship between the results in this paper and those in both Kazianga and Wahhaj and Goetghbuer, please see Collins (2012).

used female and common plot dummies, with similar control variables to Udry's and additional control variables, notably chemical inputs.

We first attempt to reproduce the results of each study, using specifications similar to Goetghebuer's. We are unable to reproduce all of Goetghebuer's control variables, which included dummies for plot managers who hired outside labor or rented equipment and a proxy for land security; however, we do include a variable for the log of chemical fertilizer (kg/ha). Equation (3) is our version of Goetghebuer's specification:

$$(YIELD)_{htci} = \alpha + \beta_1 FEMALE_{htci} + \beta_2 COMMON_{htci} + \beta_3 Ln\ FERT_{htci}$$

$$+ \boldsymbol{\delta PLOT\_CHAR}_{htci} + \gamma \boldsymbol{H}H * \boldsymbol{CROP}_{hc} + \theta \boldsymbol{YEAR}_t + \varepsilon_h \quad (3)$$

It should be noted that the categories represented by the dummy variables in equation (3) are not mutually exclusive. Of the 72 common plots with female managers, 25 are omitted from the estimation of equation (3) because other variables are missing, but 47 observations remain (0.8% of all observations) in which both the female dummy and the common dummy equal one. Because of the ambiguity and overlap in categories, equation (3) cannot fully identify if there is an effect of common versus individual plots nor whether this effect if present differs between men and women.

Equation (4) does this by using mutually exclusive categorical variables, with common plots as the omitted category:

$$(YIELD)_{htci} = \alpha + \beta_1 FEMALE\_INDIV_{htci} + \beta_2 MALE\_INDIV_{htci} + \beta_3 Ln\ FERT_{htci}$$

$$+ \boldsymbol{\delta PLOT\_CHAR}_{htci} + \gamma \boldsymbol{H}H * \boldsymbol{CROP}_{hc} + \theta \boldsymbol{YEAR}_t + \varepsilon_{htci} \quad (4)$$

Effect of labor inputs

Labor inputs can only be examined indirectly, because our dataset does not contain information on how many hours of labor were allocated to each plot. We will examine the effects of labor by including variables associated with labor availability at the household level. First we include the ratio of children under 8 to adult women aged 15-55 and an interaction term between this ratio and the female dummy. Then we add the ratio of adult women (15 and older) to adult men, and an interaction term between this ratio and the female dummy.

$$(YIELD)_{htci} = \alpha + \beta_1 FEMALE_{htci} + \beta_2 Ln\ FERT_{htci} + \beta_3 CHILD\_RATIO_{htci} +$$

$$\beta_4 FEMALE * CHILD\_RATIO_{htci} + \beta_5 SEX\_RATIO_{htci} + \beta_6 FEMALE * SEX\_RATIO$$

$$+ \boldsymbol{\delta PLOT\_CHAR}_{htci} + \gamma \boldsymbol{HH}_h + \theta \boldsymbol{YEAR}_t + \psi \boldsymbol{CROP}_c + \varepsilon_{htci} \quad (5)$$

Effect of polygamy

It is possible that the woman-to-man ratio variable may capture effects of polygamy, since the ratio of women to men tends to be higher in polygamous households. We add a polygamy dummy (equaling one if the head of household has more than one present wife) and a female-polygamy interaction term. Because polygamy is correlated with wealth, we add a variable for the total land that the household has under cultivation in that year, a proxy for wealth. We interact this variable with the female dummy as well to capture gendered labor effects in the household that might be due to larger land areas farmed.

$$(YIELD)_{htci} = \alpha + \beta_1 FEMALE_{htci} + \beta_2 Ln\ \ FERT_{\ htci} + \beta_3 CHILD\_RATIO_{htci} + \beta_4 FEMALE * CHILD\_RATIO_{htci} + \beta_5 SEX\_RATIO_{htci} + \beta_6 FEMALE * SEX\_RATIO + \beta_7 POLYG + \beta_8 FEMALE * POLYG + \beta_9 LAND + \beta_{10} FEMALE * LAND + \boldsymbol{\delta PLOT\_CHAR}_{htci} + \gamma \boldsymbol{HH}_{\boldsymbol{h}} + \theta \boldsymbol{YEAR}_{\boldsymbol{t}} + \psi \boldsymbol{CROP}_{\boldsymbol{c}} + \varepsilon_{htci} \qquad (6)$$

Multicollinearity

The inclusion of soil data along with household fixed effects leads to problems of multicollinearity, because several households have all plots with a single soil type-topography combination.[8] In addition, due to the necessity of imputing soil data for missing years, the soil variable may be less accurate than is desirable. However, omitting soil data would be problematic; dummies for each soil type-topography combination are jointly significant in regressions of yield, although in some regressions no individual soil dummies are significant. Udry and Goetghebuer also note that the soil type and quality dimensions they are able to measure are strongly correlated with crop, and that crop fixed effects capture much of the effect of soil quality. We will re-estimate equation (1) omitting soil data to check for any large differences in the robustness check section in Appendix 2.

Results

Baseline Results

Results from our estimation of equation (1) are displayed in column 1 of Table 3.[9] Like Udry (1996) and other authors, we find that female plot managers achieve significantly lower yields than male plot managers. The gender differential is not negligible; plots managed by women produce yields that are almost 10% lower than yields of plots growing the same crop, managed by men.

The magnitude of this effect, while economically significant, is smaller than that found in several other studies of the gender differential. Peterman et al. (2010) found that female-headed households in Nigeria achieved 32.1% lower yields than male-headed households, and female plot managers in Uganda achieved 26.9% lower yields than men. Akresh (2005) found female differentials of 28.5% and 50.0% in some regions of Burkina Faso (and a weakly significant female advantage of 32.5% in other regions). Udry (1996) used the level form of value of plot output as the dependent variable; the female differential he found represented 31.1% of the mean value of plot output. Akresh et al.'s (2011) baseline regression showed a female differential of 83.8% of the mean value of plot output.

The negative coefficients on most plot size deciles relative to the first and second deciles indicate that yields tend to decrease as plot size increases. The effect is large; plots in the first two deciles obtain yields around 20% higher than the yields of plots in the next five deciles.

[8] In regressions using Stata that include soil type variables, several household dummies are dropped due to multicollinearity. When regressions are limited to one crop, several soil dummies are dropped. In regressions of equation (1), 5 of the remaining household dummies and 12 soil dummies have Variance Inflating Factors (VIFs) over 10, a common rule of thumb indicating the presence of multicollinearity. Two of the soil dummies have VIFs over 100.

[9] In this table and those that follow, we omit coefficients for year, plot size decile, and soil type and topography to save space.

This plot size result was also found by Udry (1996) and most other studies of the gender production differential. However, in the Sikasso data, the plot size effect seems to lessen and even reverse itself in the largest plot sizes: the coefficient on the 10^{th} plot size decile is positive and weakly significant. To the extent that very large plots are held by wealthier households, it may be that these large plots are farmed with more chemical inputs, equipment, and livestock than the smaller plots.

Explaining the gender production differential: Fertilizer

Udry (1996) and several other authors suggested that gender production differentials were caused by the inefficient allocation of production inputs, particularly fertilizer and labor. Columns 2a and 2b of Table 3 show results from estimating equation (2), a version of Udry's equation with the addition of a control for fertilizer and a fertilizer-female interaction term. Controlling for fertilizer does not reduce the female differential significantly in magnitude.

The non-significant interaction effect indicates that fertilizer does not increase yields more on female plots than on male plots. This is somewhat surprising given that female plots use much less fertilizer than male plots, and suggests that the difference in fertilizer use might be explained more by crop choice than by gender. Not all crops are responsive to fertilizer, and certain crops grown in Sikasso receive more or less fertilizer irrespective of the gender of the plot manager. The largest amounts of fertilizer are applied to cotton (an overwhelmingly male crop) and maize (a mostly male crop); smaller amounts are applied to rainfed rice (a majority female crop that significant numbers of men grow too), followed by lowland rice (a mostly female crop). Other crops receive much smaller amounts of fertilizer.

It is likely that fertilizer use does have a significant effect on the female differential for particular crops. Regressions limited to maize (available from the authors) show a negative and significant female differential which becomes smaller in magnitude and insignificant when a control for fertilizer use is added; however, the female-fertilizer interaction term is still insignificant. Based on the results for all crops, though, it is clear that we must look beyond fertilizer to explain the overall gender differential.

Table 3: Estimations of plot yield using household, crop fixed effects

	(1)	(2a)	(2b)
VARIABLES	Log of yield	Log of yield	Log of yield
Female	-0.153***	-0.148***	-0.147***
	(0.0506)	(0.0522)	(0.0536)
Ln fertilizer		0.0713***	0.0724***
		(0.0150)	(0.0178)
*Female*ln_fert*			-0.00321
			(0.0231)
Plot size:			
Decile 3	-0.215***	-0.235***	-0.235***
	(0.0472)	(0.0486)	(0.0485)
Decile 4	-0.224***	-0.249***	-0.248***
	(0.0478)	(0.0502)	(0.0502)
Decile 5	-0.284***	-0.299***	-0.299***
	(0.0572)	(0.0584)	(0.0585)
Decile 6	-0.325***	-0.333***	-0.332***
	(0.0622)	(0.0629)	(0.0630)
Decile 7	-0.388***	-0.414***	-0.413***
	(0.0969)	(0.0986)	(0.0987)
Decile 8	-0.218**	-0.269***	-0.269***
	(0.0857)	(0.0889)	(0.0889)
Decile 9	-0.0503	-0.0880	-0.0880
	(0.0848)	(0.0881)	(0.0882)
Decile 10	0.00886	-0.0220	-0.0223
	(0.0969)	(0.101)	(0.101)
Constant	7.414***	6.948***	6.943***
	(0.247)	(0.258)	(0.262)
Observations	7,635	7,147	7,147
R-squared	0.395	0.406	0.406
Clustered hyc SE	Yes	Yes	Yes
HH+Crop FE	Yes	Yes	Yes
Parcel decile dummies	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes
Soiltype dummies	Yes	Yes	Yes

Robust standard errors clustered at the hh, crop & year in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Common plot-individual plot differentials

Table 4 displays results from the estimation of equations (3) and (4). The first column shows our version of Goetghebuer's (2011) specification. Our results agree with Goetghebuer's in that we find a negative (but in our case insignificant) effect of common plots as compared to male individual plots. Unlike her, we find that the female plot coefficient remains negative and significant: female plots achieve 20.5% lower yields than male individual plots, even when controlling for common plot status.[10]

Exclusive categorical variables were used to estimate equation (4), with common plots (male and female) as the omitted category. Results are shown in the second column of Table 4. The female individual plot dummy is negative and significant, and the male individual plot dummy is positive but not significant. This may indicate a hierarchy in plot productivity, with female individual plots achieving the lowest yields and male individual plots the highest, although the latter is not statistically significant.

Unlike Goetghebuer, and Kazianga & Wahhaj (2013), we find that a female production differential exists separately from any plot status differential. Part of this difference may be due to the additional control variables used by Goetghebuer, in particular her "land security" variable, which was significant in each of her regressions. Goetghebuer stated that when the land security variable was removed, the female dummy became close to significant.[11]

Explaining the gender production differential: Labor availability and polygamy

The other main production input of interest in this analysis is labor. It may be that women's childcare and other household responsibilities affect their ability to allocate labor to their plots. Table 5 shows results from the estimation of equation (5), which adds a variable for the ratio of children under 8 to adult women in each household. Household fixed effects are still included, so the children-per-woman variable captures changes in the ratio within households. Column 1 results show that the number of children per woman causes the female production differential to become very small and insignificant, implying that women in households with no children do not achieve significantly lower yields than men. The interaction term is negative and not significant, but a test of the joint coefficient of *female* and its interaction with children is significantly different from zero and negative. This suggests that women achieve lower yields relative to men as the number of children in the household increases. The main effect of the ratio of children to women is positive and insignificant.

In column 2, we add another variable reflecting women's labor availability, the ratio of adult women (15 and over) to adult men in the household. If women are able to allocate labor more efficiently among themselves than men and women are able to do, due to the sexual division of labor that prevents men from engaging in certain tasks, one might expect to see an effect. Here, neither the children-to-women ratio main effect nor the women-to-men ratio main effect is significant. The interaction effect between female and the children-to-women ratio is still negative but not significant. The interaction effect between female and the women-to-men ratio is positive and significant. The coefficient on the female dummy is negative, more significant, and much larger in column 2 than in column 1. This also reflects the importance of the women-to-men ratio to women's productivity. The insignificant female coefficient in

[10] Results are not substantially changed when observations that overlap categories are dropped (not shown).

Table 4: Land ownership and the gender differential

	(1)	(2)
VARIABLES	Log of yield	Log of yield
Female	-0.205**	
	(0.0852)	
Common	-0.0587	
	(0.0893)	
Female private plot		-0.153**
		(0.0614)
Male private plot		0.146
		(0.0993)
ln_fertilizer	0.0755***	0.0759***
	(0.0175)	(0.0175)
Constant	6.858***	6.805***
	(0.279)	(0.275)
Observations	5,956	5,956
R-squared	0.425	0.426
Clustered hyc SE	Yes	Yes
HH+Crop FE	Yes	Yes
Parcel decile dummies	Yes	Yes
Year dummies	Yes	Yes
Soiltype dummies	Yes	Yes

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

column 1 represents the intercept shifter for a female plot manager living in a household with no children. The larger and significant coefficient in column 2 represents the (hypothetical) intercept shifter for a female plot manager living in a household with no children and a zero women-to-men ratio. The presence of additional women in the household has a beneficial effect for women's yields, perhaps due to women's ability to allocate labor among themselves.

Polygamous households tend to have a higher women-to-men ratio; therefore, the positive interaction term between female and the women-to-men ratio echoes the result of Akresh et al. (2011). Their study found that the interaction term between the female dummy and a dummy for polygamous households was positive and significant, indicating that women's yields improve relative to men's when additional wives are added to the household. They explain the effect as due to the lower degree of altruism and better ability to cooperate among co-wives than between husbands and wives.

In column 3 of Table 5, we omit the child-to-women and women-to-men ratio variables and add instead a dummy for polygamous households (ie, households in which the head currently has more than one wife). Because polygamous households may be wealthier than others, we add a variable for the total land area farmed, a proxy for wealth, and an interaction term between female and the total land area.[12] The polygamy main effect on yield is positive but not significant; however, the polygamy-female interaction term is large, negative and weakly significant. This indicates that the female differential is larger in polygamous households, and suggests that the positive interaction term between female and the woman-to-man ratio seen in column 2 was not due to the woman-to-man ratio capturing effects of polygamous households. The main effect of total land is insignificant, while the total land-female interaction term is small, negative, and weakly significant, suggesting that female plot managers achieve lower yields relative to men when households have more land under cultivation.

In the final column of Table 5, we include the child-to-women and women-to-men ratio variables along with the polygamy and land variables. The effects of the labor availability variables are more strongly evident than without the polygamy control: the interaction term between female and the children-to-women ratio is negative and now weakly significant, and the interaction term between female and the women-to-men ratio is positive, larger and more significant than in column 2. The female-polygamy interaction term remains negative and is now significant at the 5% level. These last two results suggest that there is a beneficial effect for women's yields from increasing the number of women relative to men in the household, but not from living in a polygamous household specifically. In fact, living in a polygamous household seems to have a negative effect on women's yields relative to men's. The marginal effect of gender for a female plot manager in a monogamous household with the mean number of children per woman and the mean number of women per man is -0.0362; the marginal effect in a polygamous household is -0.2168.

The implications of the labor availability results are that the Pareto inefficient resource allocations suggested by the literature may be more consequential for labor than for fertilizer in Mali. In a Pareto efficient household, labor would be allocated across activities such that the marginal product of a particular type of labor is equal for each activity. Men would either contribute to childcare and other household activities, giving women more opportunities to work in their fields, or alternatively men would allocate more of their labor to women's plots than they do presently. Social norms in Sub-Saharan Africa prevent men from engaging in childcare, cooking, and household tasks. However, if the marginal product of male labor is higher on

[12] Results are similar when livestock is used as a proxy for wealth rather than land.

women's plots than on men's plots, the question remains what factors prevent men from contributing more labor to women's plots, thereby increasing total household output.

Table 5: Yield with controls for female labor availability and polygamy

	Child care labor	Labor share in HH	Polygamy	Polygamy & HH labor
VARIABLES	(1)	(2)	(3)	(4)
Female	-0.0896	-0.2023**	0.1029	0.0515
	(0.0758)	(0.0966)	(0.1183)	(0.143)
Children per woman	0.0384	0.0391		0.0414
	(0.0305)	(0.0309)		(0.0311)
*Female*Children per W*	-0.0613	-0.0702		-0.0848*
	(0.0423)	(0.0430)		(0.0433)
Woman to man ratio		0.0065		-0.0006
		(0.0284)		(0.0286)
Female W to man ratio*		0.0813**		0.1011**
		(0.0403)		(0.0404)
Polygamous hh			0.1086	0.0971
			(0.0689)	(0.0656)
*Female*Polygamous hh*			-0.1374*	-0.1633**
			(0.0790)	(0.0796)
Total land (ha)			0.0020	0.00124
			(0.00665)	(0.0066)
*Female*Total land*			-0.0150*	-0.0139*
			(0.00805)	(0.00805)
Ln fertilizer	0.0719***	0.0716***	0.0769***	0.0728***
	(0.0157)	(0.0158)	(0.0159)	(0.0158)
Constant	6.938***	6.926***	6.843***	6.810***
	(0.259)	(0.264)	(0.281)	(0.284)
Observations	6,679	6,679	6,758	6,662
R-squared	0.408	0.408	0.407	0.411
Clustered hyc SE	Yes	Yes	Yes	Yes
HH+Crop FE	Yes	Yes	Yes	Yes
Parcel decile dummies	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes
Soiltype dummies	Yes	Yes	Yes	Yes

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Explaining the gender differential: The other woman problem

The results of the last two tables indicate that a higher women-to-men ratio is generally beneficial for female plot managers, and that this does not reflect a confounding of this ratio with polygamy. However, our polygamy dummy is imprecise: it indicates whether or not the head of the household each plot belongs to is polygamous, but does not necessarily reflect the plot manager's marital status. The majority of male plot managers are household heads, so the polygamy variable will provide useful information for most male plots, but wives of a household head manage slightly less than half of all female plots. For plots managed by other women, the polygamy variable indicates only whether the manager lives in a household with a polygamous head.

In Table 6, we replace the female dummy with different dummies for wife of the head and other females in the household. Here, the polygamy-wife interaction term will indicate the effect on wives of being in a polygamous marriage. The insignificant wife-polygamy interaction term of Table 6 shows that the productivity of wives of household heads, relative to men, is not affected by the presence of co-wives. However, the productivity of other female household members relative to men is positively affected by a higher women-to-men ratio. This leaves open the possibility that other females' yields are positively affected by their own co-wives in particular rather than by the women-to-men ratio in general; however, given all results above, there is no evidence that being in a polygamous marriage has a positive effect on a woman's yields relative to male yields. There is considerable evidence that living in a household with a higher ratio of women to men does improve female yields relative to men's.

Table 6 shows several interesting differences between wives of household heads and other females. The interaction effect with the number of women per man is insignificant for wives, but positive and highly significant for other females; the interaction effect with the number of children per woman is negative and highly significant for other females, but insignificant for wives. These results suggest that labor constraints may be more detrimental for other females than for wives, and are well worth exploring further in future research. Perhaps wives of household heads are better able to control their own labor, or to recruit the labor of other women in the household; this latter interpretation is consistent with the large, negative and significant effect for other women of living in a household where the head has multiple wives. Alternatively, if Goldstein and Udry (2008)'s land security hypothesis explains part of the gender production differential, wives of the head may be better able to fallow their land without its being appropriated, due to the higher status of their husbands.[13]

[13] It is likely also worth exploring potential differences between first wives and subsequent wives of the head. In the Sikasso data, separating wives into first and subsequent wives does not change the results significantly; for both categories of wives, the main effect on yields and all interaction terms are insignificant.

Table 6: Decomposing the gender effect into wife of household head and other female

VARIABLES	Log of yield kg
Other woman in hh	0.0419
	(0.1534)
Wife of hh head	-0.0026
	(0.1301)
Children per woman	0.0386
	(0.0348)
*OtherW*Children per woman*	-0.1286***
	(0.0488)
*Wife*Children per woman*	-0.0400
	(0.0530)
Women/men ratio	0.0166
	(0.0314)
*Wife*Women/men ratio*	0.0173
	(0.0483)
*OtherW*Women/men ratio*	0.1327***
	(0.0509)
Polygamous hh	0.0899
	(0.0786)
*OtherW*polygamy*	-0.1952**
	(0.0993)
*Wife*polygamy*	0.0485
	(0.1076)
Total land (ha)	0.0064
	(0.0071)
*Other*total land*	-0.0132
	(0.0084)
*Wife*total land*	-0.0118
	(0.0089)
Ln fertilizer	0.0717***
	(0.0172)
Constant	6.9267***
	(0.3125)
Observations	5,828
R-squared	0.3987
Clustered hyc SE	Yes
HH+Crop FE	Yes
Year, parcel size, Soiltype dummies	Yes

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Conclusion

This work confirms the existence of yield differentials between male and female-managed farm plots in Sikasso, Mali. This production differential is not explained by a plot status differential between common and private plots. Overall, the results of controls for production inputs suggest that fertilizer use does not contribute greatly to the gender production differential, but that female labor availability does contribute to it very significantly. Female yields are negatively impacted relative to male yields as the number of children per woman in the household increases; the yield differential improves when there are more women in the household to share labor with. An increase in the number of children per woman in the household lowers women's yields relative to men's, but an increase in the ratio of women to men in the household decreases the female production differential, perhaps through the effects of labor-sharing among women. These labor effects are particularly important among junior women of the household rather than among wives of the household head.

A central finding of this work is that constraints on women's labor availability are an important factor in explaining the gender production differential. A much more in-depth study of factors affecting women's labor availability is called for. These could include the prevalence of cash crops,[14] rainfall differences that affect the amount of weeding required, and other household demographic variables.

Finding ways to alleviate labor constraints could improve other outcomes in addition to women's agricultural productivity. Child care and other household responsibilities affect women's ability to achieve higher yields on their plots, but the need to allocate labor to farming to produce food and income may also affect the quality of child care that women are able to provide. In a 2009 article on child malnourishment in Sikasso, IRIN, the news service of the UN's Office for the Coordination of Humanitarian Affairs, quotes community educator Oumou Cissé speaking about the demands on women's time: "In Sikasso, women are very active. They compete with men in the fields, which means they are absorbed not only with their field work, but also their housework. The children are not their only focus. We neglect a bit the children's health care."

This project touched upon the differences between wives of the household head and other female household members: the former are not affected by the ratio of children to women or the ratio of women to men in the household. These differences should be investigated further, as they could increase greatly to understanding the gender production differential. They may reflect the importance of female labor availability and the differing levels of control that wives and other females may have over their own or others' labor. Alternatively, they could offer support for the hypothesis of Goldstein and Udry (2008), in which land tenure security, which is directly determined by an individual's status, explains the female production differential.

[14] Interaction terms between the female dummy and the percentage of household land devoted to cotton, a labor-intensive cash crop, were not significant. However, members of poorer households often provide labor for wealthier households in exchange for cash or in-kind wages during cotton planting and harvesting times (Moseley 2008). Village-level measures of cotton prevalence may indicate whether this practice affects women's productivity on their own fields more than men's.

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Appendix 1: Summary Statistics

The demographic information on households contains listings for members who have temporarily or permanently migrated as well as present household members. The average number of present family members per household in Kadiolo and Bougouni is 16.1. This number ranges from just one (in a few cases where larger households have broken up) to 51. Each family member's relationship to the head of household was recorded for most years, but other relationships were usually not recorded, so it is usually not possible to tell which children belong to a particular mother, etc. The average number of present children under 8 per woman aged 15-55 in the household is 1.08. The average ratio of present women 15 and older to men is 1.44; this partly reflects polygamous marriages, and may also reflect the fact that male household members are more likely to be absent, having migrated for school or work.

There are a total of 88 households in Kadiolo and Bougouni that appear in the dataset for at least one year (including the 64 households that enter the dataset in 1994, and others that break off of the original households). Of those, 31 are never polygamous, 15 are always polygamous, and 42 are polygamous in some years and not in others. We define "polygamous" as indicating that the household head has more than one wife; this means that a household can enter or leave polygamy either when the household head's polygamous status changes or when the household head changes.

The polygamous households are wealthier than the others, if total landholdings are used as a proxy for wealth: the mean total of land being farmed each year is 9.8 ha for the never polygamous households, 11.0 ha for the sometimes polygamous households, and 13.7 ha for the always polygamous households. The woman-to-man ratio, not surprisingly, is highest in always polygamous households (1.61), followed by sometimes polygamous households (1.55) and never polygamous households (1.14).

Each household farms an average of 12.5 plots each year. The number of plots for a given household usually changes slightly from year to year. The number of plots ranges from one to 75 (only one household had more than 40 plots in a single year). An average of 4.4 household members have plots; this number ranges from one to 18.

Most male-managed plots belong to the household head, with smaller percentages managed by the head's sons, brothers, or other relatives. Among female plots, about 46% belong to wives of the household head, with the next largest categories being daughters-in-law and sisters-in-law.

Table A1: Plot managers' relationship to head of household

Male plots	**Female plots**
Head: 78.4%	Wife: 45.6%
Son: 14.1%	Daughter-in-law: 34.8%
Brother: 4.8%	Sister-in-law: 10.4%
Nephew: 1.6%	Mother: 3.2%
Other: 1.1%	Other: 6%

Plot, crop and yield information

The average plot size overall is 0.78 ha. Female plots are considerably smaller than male plots, with a mean size of 0.21 hectares for females and 1.28 ha for males. About 8.8% of male plots and 7.5% of female plots are intercropped, with multiple crops grown at the same time;

these plots are excluded from the analysis, as there is no way to accurately measure the yield for each crop.

Crop choice varies by gender, as in many West African countries where men and women specialize in different crops. However, there is considerable overlap:

Table A2: Most common crops by gender (single-cropped plots only)

Male	Female
Maize (24.2%)	Peanuts (29.9%)
Sorghum (13.8%)	Lowland rice (23.1%)
Millet (10.3%)	Rainfed rice (20.6%)
Cotton (19.2%)	Fonio (13.8%)
Peanuts (15.8%)	Sorghum (8.2%)
Rainfed rice (5.0%)	Bambara groundnuts (2.1%)
Cowpeas (2.8%)	Maize (1.1%)

Smaller numbers of males also grow lowland rice, fonio, and Bambara groundnuts.

Most individual plots are female-managed (92.9%). An even larger percentage of common plots are male-managed (98.4%). Common plots are usually managed by the household head, or by a male relative of the head if the head is temporarily absent.

Table A3: Plot status by gender[15]

	Common Plots	Individual Plots
Male	4,377 (98.4%)	319 (7.1%)
Female	72 (1.6%)	4,176 (92.9%)
Total	4,449 (100%)	4,495 (100%)

There is a strong correlation between common plot status and household headship of the plot manager, but the relationship is not one-to-one. In 80 observations, household heads manage individual plots. It is not unusual to observe a common plot that is managed by someone other than the household head; usually this is a brother or son of the head. Sometimes the head is listed as temporarily absent from the household during years that the common plots are being managed by another household member; in other cases the head is present, and there is no way to know why another household member is managing the common plots. When a household head dies, a new head may be designated immediately, or the data may record that the household has no head for several years, during which a non-head male manages the common plots. (Usually that male eventually becomes the designated head, but sometimes the headship goes to another male household member.) We have recorded headship exactly as specified in the demographic data. There are very few female heads of household; just seven plot observations are managed by female heads.

[15] The number of observations in this table and the next differ from the number of observations in other tables, because information on plot status and household head status were each missing for several years of data.

Table A4: Plot status by household headship

	Common Plots	**Individual Plots**
Heads	3,038 (79.9%)	80 (2.5%)
Non-heads	763 (20.1%)	3,182 (97.5%)
Total	3,801 (100%)	3,262 (100%)

Correlation coefficient between head status and common plot status: 0.778

The yield variable contains numerous possible high outliers. We deleted the highest 1% of yield observations for each crop in order to avoid the influence of outliers. Of these, 54.3% were male-managed plots and 45.7% were female-managed, similar to the gender breakdown in the dataset as a whole.

Summary statistics on yield show that women plot managers achieve lower yields on some crops, but higher yields on others, particularly crops that women traditionally specialize in such as rice.

Table A5: Mean yield by gender (top 1% of yields excluded)

Crop	**Male mean yield (kg/ha)**	**Female mean yield (kg/ha)**
Sorghum	533.09 (705 obs)	370.54 (396 obs)
Peanuts	629.78 (797 obs)	559.19 (1309 obs)
Rainfed rice	800.19 (251 obs)	1029.84 (958 obs)
Fonio	372.40 (70 obs)	341.07 (659 obs)
Bambara groundnuts	401.65 (70 obs)	919.06 (88 obs)
Maize	1342.37 (1229 obs)	838.11 (49 obs)
Lowland rice	1172.07 (67 obs)	1020.59 (1018 obs)

Comparisons of average yields for common and individual plots look similar to the comparisons of male and female plots. Among male individual plots and male common plots, some crops show higher yields on common plots while others show higher yields on individual plots.

Table A6: Mean yield, male common plots and male individual plots (top 1% of yields excluded)

Crop	**Male common mean yield (kg/ha)**	**Male individual mean yield (kg/ha)**
Peanuts	640.11 (516 obs)	583.47 (131 obs)
Maize	1397.69 (890 obs)	1020.04 (48 obs)
Cotton	1014.13 (688 obs)	1022.62 (21 obs)
Sorghum	534.84 (525 obs)	743.74 (19 obs)

Some yield differences across gender and plot status may be explained by fertilizer use. Male-managed plots use much larger amounts of fertilizer than female plots. Among male plots, common plots use more fertilizer than individual plots. Families in Sikasso can most easily obtain fertilizer through the cotton parastatal company, the CMDT (Compagnie Malienne pour le Développement des Textiles); therefore cotton-growers have better access to fertilizer than others. Cotton is an overwhelmingly male crop, and is grown much more often on common plots than on male individual plots.

Table A7: Mean fertilizer use by gender and plot status

	Mean fertilizer use (kg/ha)
Male plots	66.81
Female plots	12.98
Male common plots	70.71
Male individual plots	31.88

Appendix 2: Robustness Checks

Alternate estimates of equation (1)

Estimations of equation (1) under alternative specifications are displayed in Table A8. Column 1 shows results when the dataset is limited to observations in which soil data was imputed with high confidence[16]. The female coefficient remains negative and significant, and is slightly smaller in magnitude than when using the entire dataset. We omit soil data entirely in column 2 to check whether multicollinearity resulting from the inclusion of soil data has large effects on the results. The female coefficient becomes slightly smaller in magnitude than in the original specification, with a similar significance level. Soil type and topology do seem to be important control variables, and we therefore use imputed soil data for the main analysis.

We estimate equation (1) using combined household-year-crop fixed effects rather than separate household, year, and crop fixed effects in column 3. The female coefficient becomes slightly larger and remains significant.

In column 4, we estimate equation (1) using the log value of plot output per hectare as the dependent variable. We use village-level price data for corn, sorghum, millet, and rice, and *cercle*-level (Kadiolo and Bougouni) data for other crops for which data was available. The female coefficient remains negative and significant, although its significance level has decreased to 7%.

Table A8: Estimations of plot yield: alternative specifications

Explanatory variables	(1) High confidence soil data only	(2) Omitting soil data	(3) Household-year-crop fixed effects	(4) Log value of output/ha as dep var
Female	-0.1376**	-0.1203***	-0.1803**	-0.1463*
	(0.0648)	(0.0462)	(0.0795)	(0.0796)
Constant	7.4217***	7.2311***	7.1207***	11.7144***
	(0.2655)	(0.1370)	(0.3348)	(0.5110)
Observations	5623	9527	7635	6341
R-squared	0.4033	0.3834	0.7657	0.3583
Clustered hyc SE	Yes	Yes	Yes	Yes
HH+Crop FE	Yes	Yes	No (HYC FE)	Yes
Plot decile dummies	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	No (HYC FE)	Yes
Soiltype dummies	Yes	No	Yes	Yes

Standard errors in parentheses
***Significant at 1% level ** Significant at 5% *Significant at 10%

[16] These observations represent 57.9% of all observations.