Household Structure Influences Labor Allocation Decisions Due to Agricultural Technology Adoption: Evidence from Burkina Faso

Aissatou Ouedraogo
Andrew Dillon
Maria Porter

Michigan State University

January 2017

CONFERENCE DRAFT. PRELIMINARY. PLEASE DO NOT CITE.

ABSTRACT

Households adopting new agricultural technologies often face labor constraints influencing the extent to which such technologies are productive and profitable. This article explores whether such labor constraints differ for nuclear and extended-family households. Compared to nuclear households, technology adoption among larger extended households could be inhibited by coordination problems with high transaction costs or lower marginal product of labor. In a randomized control trial, we estimate the heterogeneous treatment effect of an efficacious but labor-intensive fertilization technique called microdosing by differences in household structure. The encouragement design which allocated starter packs and microdosing training to assigned households induced extended family households to reduce labor to agricultural activities, while nuclear households increased labor activities.

Acknowledgements: The authors gratefully acknowledge funding from the Bill and Melinda Gates Foundation through the GISAIA project, and BASIS-USAID. We also acknowledge, without implicating, Isabelle Diabire, Thom Jayne, Estelle Plat, Ashesh Prasann, Melinda Smale, Nicolo Tomasseli, Adama Traore, Association des grossistes et détaillants d’intrants agricoles, Institut de l'Environnement et de Recherches Agricoles, and Innovations for Poverty Action for their collaboration throughout the project.
JEL: O12, O13, Q12, J22, J12

I. Introduction

Increased agricultural productivity has proven to improve the welfare of many households in developing countries, with one notable example being the Green Revolution in India. As household labor becomes more productive, household income also increases. In addition, children's labor becomes less valuable as an agricultural input into production. For both these reasons, children's schooling increases, human capital investment increases, and infant and child mortality is reduced. With lower mortality rates and a greater potential for investing in child quality, fertility rates decline (Becker 1981). Such demographic changes may encourage economic growth (Galor 2005). While some debate continues on the exact mechanism of the demographic transition in a general model of economic growth (Galor and Weil 2000), productivity changes are central to all of the above mechanisms in explaining household size reduction.

This paper investigates a micro foundation of this macro-development model, the potential labor substitution effects of agricultural technology adoption which could increase labor availability to other productive activities and raise overall labor productivity. When additional adults are available to contribute labor to productive activities, labor constraints in technology adoption and productivity may be alleviated. We explore the potential for such economies of scale in production in the context of household adoption of new agricultural techniques having the potential to augment productivity.

Despite an increasing fragmentation of households to smaller units in the developing world, there is still evidence of the prevalence of household organization characterized by the cohabitation of extended family members in sub-Saharan African countries (Bongaarts 2001 and West 2010). The majority of these households are rural subsistence-farmers where labor remains a crucial input in their productive activities. Moreover, these regions are characterized by missing labor markets, and consequently, households in these regions heavily rely on family members as the main source of their agricultural labor.

In this article, we examine how nuclear and extended family households differ in their labor responses to the introduction of a new and productive agricultural technology. Extended households, comprised of multiple nuclear families, differ from nuclear households in that they have more adult labor available to them, and coordinate labor activities across family members in ways that nuclear households are unable to. Yet, given their larger size, labor allocation decisions among extended households could inhibit adoption if coordination problems create high transaction costs compared to nuclear households, given their larger size (Poteete and Ostrom 2004).

As household structure and technology adoption are potentially simultaneously determined, to identify heterogeneous treatment effects of technology adoption across nuclear and extended households, we must exogenously vary the availability of such technology. To do so, we conducted a randomized control trial where the treatment included training in a fertilizer application technique called microdosing, along with a starter kit comprised of certified sorghum seed and fertilizer.

We find that the microdosing intervention increased labor allocation to sorghum production among nuclear households, particularly in plowing. In contrast, the program reduced agricultural labor among extended family households. Despite these differential effects of the program on labor allocation, we found no significant effects on sorghum yield once we control for differences in land holdings across nuclear and extended households.

These differential impacts by household structure may be attributed to several possible reasons. One possibility is that extended households already allocating more labor to agricultural activities may have a lower marginal product of labor relative to nuclear households. Another possibility is that, owning to their large number of household members, extended households may have coordination problems in allocating labor to certain activities (CITE), so that microdosing substitutes for labor that would have otherwise been used for production but requires potentially significant transaction costs to using such labor. Finally, as all households received the same amount of seeds and fertilizer (for a small parcel), it is possible that the scale of the treatment was not enough to induce noticeable changes in labor allocation or sorghum yields among extended households who also have large land holdings.

A differential effect of our treatment by household structure has important implications for agricultural development policy interventions in developing countries where we find a mix of different household structures. We show that the effects of intervention programs such as microdosing are affected by the characteristics of the targeted group. This highlights the need for a better understanding of how households may differ in their agricultural production organizations depending on their composition, in order to design more inclusive agricultural development intervention programs.

The remainder of the article is structured as follows. We describe our experimental design in Section II, where we also describe the microdosing technology. In Section III, we explain how we classify households according to nuclear or extended categories. In Section IV, we describe the difference-in-difference methods used to identify the intent to treat effect of the microdosing technology intervention. In Section V, we describe the data and sample restrictions. We also summarize differences in demographic and production characteristics across nuclear and extended households, as well as balancing tests by treatment assignment within each household category. Section VI presents the results, while Section VII concludes.

II. Experimental Design

Sorghum is the main food staple and most widely cultivated dryland crop among rural households in the West African Sahel. Yet, as in much of this region, average sorghum yields in Burkina Faso are estimated at 0.8 tons per hectare, despite the potential to attain over 2 tons per hectare (Ministry of Agriculture, Burkina Faso 2010). One way to improve sorghum yields is to apply a technique called microdosing

In microdosing, farmers apply 2 to 6 grams of fertilizer (about a three-finger pinch) in or near the seed hole. The amount of fertilizer applied is equivalent to about 20 to 60 kg of fertilizer per hectare. Alternatively, the fertilizer can be applied as top dressing from 3 to 4 weeks after the seeded crop begins to emerge. In case of hard soil, farmers dig small holes and fill them with manure before the rain begins. Once the rain starts, the fertilizer and seeds are placed into the moist soil. This technique captures the water, so that it does not run off the hard-crusted soil, thereby encouraging root growth (ICRISAT, Fertilizer Microdosing, January 2009).

When applied to the seeding of improved sorghum varieties, microdosing raises yields considerably. In Burkina Faso, INERA (Institut de l'Environnement et de Recherches Agricoles) has reported grain yields of nearly 2000 kg/ha for improved sorghum varieties with microdosing. The primary drawbacks to microdosing are that it is time-consuming, laborious, and it is difficult to ensure that the correct amount of fertilizer is used for each dose.

Our experimental design used an encouragement design to randomly assign microdosing training and a starter kit which included fertilizer and certified sorghum seed sufficient for one hectare of sorghum production. We worked with AGRODIA, an organization of local agro-dealers in Burkina Faso, to supply these micro packets. The seed was certified by INERA, the public agricultural research institution in the country. INERA also provided training in microdosing to all households in treated villages.

We selected three provinces for our study: Bam and Sanmatenga from the Center-North region and Passoré from the North region. These provinces were selected because there is a high prevalence of sorghum cultivation and little cultivation of cash crops such as cotton. We collected a complete list of all 925 villages in these three provinces. Because this study was part of a larger project which involved collecting social network censuses in many of the villages, we restricted our potential pool of villages to those that were not too large to conduct such censuses. We therefore kept villages where the population size was between 190 and 800, provided that the number of households was no greater than 120 households. The number of households per village varied between 70 and 120 households. From the remaining 226 villages, 80 villages were randomly selected for the treatment group studied here, and 20 villages were randomly selected for the control group. In all these villages, a village enumeration included questions about plot information, sorghum production, and adoption of improved seeds.

Using this village enumeration, in each village, we then randomly sampled approximately 30 households growing sorghum. For these households, we conducted baseline and follow-up household surveys, where we collected detailed production and socio-economic information. Thus, detailed household surveys were conducted for 2400 households in all 80 villages in the treatment group, and for 600 households in all 20 villages in the control group.

In each of 80 treated villages, approximately 15 of the 30 surveyed households were randomly selected to receive free micro-packets of certified sorghum seed and fertilizer. In our analysis here, we compare these 1200 treated households to the 600 households surveyed in control villages which did not receive any micro-packets or any training in micro-dosing. We exclude all households in treatment villages who did not receive free micro-packets, but may have received training in microdosing. We do so to eliminate any potential spillover effects due to possible technological transfer, which in turn may lead to underestimation of the program's impact on treated households.

III. Household Structure

We define a household as "a socio-economic unit within which one or more members, related or not, live in the same house or concession, pool their resources, and jointly meet the bulk of their food and other basic needs under the authority of one of them, called the head of household" (Beaman and Dillon 2012). This definition of the household may include multiple "nuclear" households cohabiting in one "extended" household. Such cohabitation of multiple nuclear households may arise through two possible channels: vertical extension of the household, where married sons and their nuclear family have common residency with their fathers; and horizontal extension, where married brothers and their respective nuclear families cohabitate (Laslett and Wall 1982; West 2010; Kazianga and Wahhaj 2015).

Therefore, we define an "extended" household as a household that meets at least one of the following criteria: households having one married male who is not the household head; or household heads having married sons, married brothers, daughters-in-law, or sisters-in-law living in the household (Table 1). Households that do not meet these criteria are classified as "nuclear" households. According to this definition, 354 of the 1,059 households in our final sample (about

33 percent) are extended households, and remaining households are classified as nuclear households.

[Table 1]

The leading criterion for being qualified as an extended household is the household having more than one married male. This condition is met by about 29 percent of the final sample. When classified by relationship to the head, approximately 16 percent of the heads have at least one married son and nearly 8 percent of them live with one or multiple married brothers. The father and married son relationship is mirrored by approximately 16 percent of heads having at least one daughter-in-law. However, while only about 9 percent of the heads cohabitate with married brothers, up to 13 percent of them have at least one sister-in-law.

IV. Identification Strategy

Our randomized study design enables us to apply difference-in-differences (DID) methods to identify the Intention to Treat (ITT) effect of being given training in microdosing and free packets of seed and fertilizer. This design is important in this context because technology adoption and household structure may be simultaneously determined. Prior literature suggests that household structure may be a constraint to adopting technology (CITE), as well as changing in response to productivity changes due to technology adoption (CITE). Our experimental design permits identification of the direction of causality.

As we are interested in the differential effects of this intervention depending on whether households are comprised of either extended or nuclear family structures (as outlined above), we interact treatment assignment (T_{hj}) with an indicator variable for family structure (E_{hj}), with households indexed by h and villages indexed by j. Therefore, we estimate OLS for the following set of regressions:

$$(Y_{hj}^{1} - Y_{hj}^{0}) =$$

$$\beta_1 T_{hj} + \beta_2 E_{hj} + \beta_3 (T_{hj} \times E_{hj}) + \beta_4 L_{hj}^{0} + \beta_5 LShare_{hj}^{0} + \mu_j + (\varepsilon_{hj}^{1} - \varepsilon_{hj}^{0})\ , \qquad (1)$$

where we difference outcome measures across pre- and post- treatment survey data. Superscripts 1 or 0 refer to follow-up and baseline data respectively. Our primary outcomes are sorghum yield in kilograms per hectare and labor allocation in person-days per hectare in total and disaggregated by tasks, including this following: plowing, planting, inorganic and organic fertilizer application, weeding, and harvesting. Since treatment assignment is allocated by village, we cluster all standard errors by village.

In this specification, we also control for baseline total land holdings (L_{hj}^{0}), share of total cultivated land devoted to sorghum as the main crop at baseline ($LShare_{hj}^{0}$) and village fixed effects (μ_j). We also estimate regressions without these additional controls. To be specific, in the tables below, Model 1 refers to the base specification that does not include these additional controls; Model 2 includes village fixed effects to control for any village-specific observables and unobservables; and Model 3 also includes L_{hj}^{0} and $LShare_{hj}^{0}$ to control for possible differences in economies of scale in production.

We are also mindful of the fact that nuclear and extended households differ from one another in a variety of ways. Not only are extended households comprised of more family members, they also have significantly larger land holdings. We first check whether we get different ITT estimates for households with different land holdings by interacting assignment to treatment with land holdings at baseline. Once we rule out the possibility of such differential impacts, we focus on estimating regression (1) to determine whether ITT estimates do differ by household structure. Finally, we rule out that these differential estimates are due to differences in land holding at baseline by restricting our sample to households in the lower three quintiles of land holdings at baseline. We do so because a disproportionately higher number of extended compared to nuclear households have land holdings in the top two quintiles. For this restricted sample, we find that average land holdings at baseline are similar for both nuclear and extended households (see Table A.1). Sample means tests for this restricted sample also indicate that extended and nuclear households are similar in terms of baseline rates of fertilizer use, whether sorghum or maize is the main crop at baseline, and total sorghum production at baseline. Note that for the wider sample, extended and nuclear households differ along all of these dimensions (see Table 2).

V. Data

We collected detailed household survey data within our study villages, both before and after the intervention. We surveyed all those who received starter kits in treatment villages. In addition, we surveyed approximately 30 households at random from each of the control villages. The baseline survey took place at the end of 2013, just prior to the beginning of the agricultural season. Households received microdosing training and starter kits at planting time in January 2014. Our follow-up survey was conducted one year later, at the beginning of 2015.

Our multi-topic household surveys collected information on various demographic, socio-economic, and agricultural production characteristics. We collected data at the household level as well as at the individual plot manager level. In total, we collected 1,529 household surveys at baseline. With a household attrition rate of 6.7%, we collected household surveys both at baseline and follow-up for 1,426 households.

A. Sample Restrictions

As our interest is in determining the differential impact of the microdosing intervention by household structure, and as male and female headed households are considerably different from one another, we first restrict our sample to male-headed households. Extended households are mostly headed by men (Colson 1962; Kazianga and Wahhaj 2015), and most female headed households are nuclear households. This restriction ensures that in comparing across different household structures, we are not conflating these differences with differences in male or female headed households. This drops about 10 percent of the households.

In addition, to eliminate any potentially differentiated effects specific to gender differences, we also exclude all female-controlled plots from the sample. Preliminary analysis of the sample (results not presented here) indicated that the proportion of female-plot managers among extended households is much higher relative to that among nuclear households. Consequently, comparing labor allocation across the two types of households without eliminating female-controlled plots will likely lead to outcomes being driven by gender-specific effects rather than by differences in household structure.

Given that our identification strategy consists of investigating changes in labor allocation to sorghum production across the pre- and post- treatment periods, the sample is further restricted to male-headed households that had at least one male-controlled sorghum plot in each of the two rounds, resulting in 1,098 remaining households.

Finally, we identified outliers in yield measured in kilogram per hectare and labor allocation measured in person-days per hectare as those observations with values greater than three times the standard deviation. This restriction eliminates 39 households from our sample, resulting in a final sample size of 1,059 households. Table 1 summarizes these sequential, cumulative sample restrictions.

B. Demographic and Production Characteristics by Household Structure

Table 2 presents summary statistics of demographic and production characteristics across extended and nuclear households prior to our intervention, and shows that the two types of households are very different in terms of their demographic and production characteristics. First, the heads of extended households are on average about six years older than nuclear heads. As expected, the numbers of adult males and females are significantly higher for extended households.

[Table 2]

These differences in household composition will likely impact their labor response to the introduction of the microdosing technology. In particular, the larger number of adults in the extended households implies the need for more coordination efforts in their labor allocation decisions. As labor markets are almost nonexistent in the study zone, households rely heavily on family labor for their agricultural production activities (Udry 1996; Kazianga and Wahhaj 2013). As a result, since the microdosing technology is potentially labor-intensive, households may have to readjust their labor allocation if they were already facing labor constraints before the intervention. This possible need for labor allocation readjustment is likely to be higher for extended households relative to nuclear households.

The larger household size of the extended household (in terms of adult members who are more than 14 year-old) is further reflected in larger total land holdings devoted to agricultural production, especially for sorghum. Moreover, the proportion of households that apply fertilizer among extended households exceeds that of nuclear households by 9 percent, and the difference is statistically significant at 5 percent, though there is no significant statistical difference in the differences in mean values of the intensity of fertilizer application. Finally, relative to nuclear households, labor allocation expressed in number of person-days per hectare is higher among extended households for all activities as well as for male and female labor. However, there seems to be no statistical significant difference in sorghum yield across the two types of household structure.

C. Pre-Treatment Household Demographic and Production Characteristics

In order to attribute any changes in labor allocation among the assigned households to the microdosing treatment, it is important to ensure that households assigned to treatment and control groups share similar pre-intervention characteristics. Since we are interested in the heterogeneous effect of the microdosing treatment by household structure, we conduct balancing tests across treated and control households within each category of household structure.

Table 3 presents summary statistics of pre-intervention household demographic and production characteristics by assignment status for extended and nuclear households respectively (see Panels A and B). All p-values corresponding to the statistical significance level of the mean differences across the assigned and control households greatly exceed the 10% significance level, indicating that the randomization produced balanced assignment and control groups of households.

[Table 3]

VI. Results

We start by summarizing estimation results of the ITT effect of receiving the microdosing packets and training on both yield and total labor allocation per hectare in Table 4. Specifically, the outcome variables in Table 4 are changes in sorghum yields and total labor allocation between pre- and post- intervention periods.

[Table 4]

Since our treatment provided enough fertilizer and seed for a small parcel (one hectare), one might expect that smaller landholders may be more greatly affected by the intervention in comparison to larger landholders. Thus, baseline land holding may be a potentially important factor in determining the effectiveness of the treatment on yield and labor allocation. So we first interact treatment assignment with the log of baseline land holdings in Models A1, A2, and A3. In Model A1, we only include this set of interactions. In Model A2, we add village fixed effects to account for the potential effect of village-level unobservables, including factors such as access to input, labor and output markets. In Model A3, we add a binary indicator of household structure (extended households, with nuclear households being the comparison). Model A3 also includes a control for the share of total land holding devoted to sorghum cultivation. The prevalence of sorghum production in the household could affect labor allocation to sorghum production activities such as microdosing, with potential labor constraints to adoption decisions. Standard errors are in parentheses, and are all clustered by village.

Overall, being assigned to receive the training and microdosing kits does not have a statistically significant impact on sorghum yield or total labor. However, coefficient estimates on baseline land holding are statistically significant on changes in both sorghum yield and total labor allocation. Coefficient estimates on the interaction term between land holding and treatment assignment are not statistically significant and magnitudes are relatively low.

While land holding at baseline does not seem to be an important driving factor in determining differences in treatment effects across households, household structure does in fact play an important role in how treated households respond in terms of yield and labor allocation.

In order to explore these differences by household structure, Models B1, B2, and B3 include an interaction term between treatment assignment and household structure (extended versus nuclear households). In this case, while the effect of treatment assignment remains low, there are significant differences in ITT estimates when comparing extended and nuclear households. As with the interactions with land holding, Model B1 presents the specification where we only control for interaction between assignment status and household structure. Model B2 includes village fixed effects. Controlling for village fixed effects here allows us to control for unobservables in input and output market conditions, as well as social and cultural norms that may affect self-selection into a particular household structure. Model B3 adds total land holding and sorghum land share at baseline as additional control variables.

The ITT effect of the intervention impact for nuclear households is captured by the coefficients on the variable Assigned. In regressions on yield, when we control for village fixed effects, sorghum land holding and sorghum land share (Model B3, Panel 4.1), the corresponding coefficient estimate for assignment is 0.29 and it is statistically different from zero at the 5% significance level. That is, for nuclear households, the estimated ITT on sorghum yield is about 29%. With baseline mean values of 630 kg per hectare among nuclear households, this corresponds to an increase of 194 kg per hectare.

In regressions on labor, when we control for village fixed effects, sorghum land holding and sorghum land share, the corresponding coefficient estimate is 0.18 (Model B3, Panel 4.2) and it is statistically different form zero at the 5% significance level. This implies an average increase of approximately 15 person-days per hectare, as average total labor allocation to sorghum production at baseline is about 83 person-days per hectare.

In contrast, treatment assignment had no effect on extended households. As the overall ITT on extended households is the sum of coefficient estimates on the treatment variable and the interaction term, the net ITT estimates on yield and total labor spent on sorghum production for treated extended households is almost zero. The differential impact of the program by household structure is explicitly shown by the coefficient estimate on the interaction term between treatment assignment and household structure, which is negative and statistically different from zero.

One concern is that these differential ITT estimates on household structure may be driven by differences in land holding by household structure. As shown in Table 2, there is a large disparity between pre-program land holding across nuclear and extended family households. Sorghum land holding among extended family households is almost 50% larger (4.40 versus 2.97 hectares).

In order to rule out this possibility, we carry out additional regressions with the sample restricted to the first three quintiles of land holding, where we have balanced land holding by household structure (see Table A1). The results obtained with the sample restricted to the first three quintiles of land holding are presented in Table 5. When the outcome is change in yield, there is no detectible impact of treatment assignment; nor is there a notable differential impact by land holding on either outcome variable.

[TABLE 5]

However, in regressions on total labor allocation, when we interact treatment assignment and household structure, we find a significant difference in ITT estimates by household structure. (Models B1, B2, and B3 in Panel 4.2). In particular, in Model B3 (Panel 4.2) where we include both baseline land holding and sorghum land share as well as village fixed effects, we find that assignment to treatment induced nuclear households to increase labor allocation to sorghum production by approximately 20 person-days per hectare (coefficient estimate is 0.235).

The differential impact of household structure is shown by the negative coefficient on the interaction term Assigned*Extended, which is -0.52 (Model B3, Panel 4.2) and is statistically significant at the 1% level. These results provide evidence that the differential ITT estimates by household structure on total labor allocation devoted to sorghum production with the full sample (Table 4) is unlikely to be driven by differences in land holding across nuclear and extended family households. In fact, the prior estimates may have underestimated such differences. In this restricted sample, we find that ITT estimates on labor allocation are positive for nuclear households and negative for extended households.

To understand how the intervention increased total labor allocation among the assigned nuclear households, we also present results for specific activities in Table 6. Here, we focus on Model B3, where treatment is interacted with household structure using the most exhaustive specification –that is, where we control for baseline land holding, sorghum land share and village fixed effects. The outcome variables are time spent on: plowing, planting, manure application, inorganic fertilizer application, weeding, and harvesting.

[TABLE 6]

Labor allocation results with respect to plowing indicate that the program had a significant impact for all treated households. Compared to households in control villages, households in treatment villages increased their time spent on plowing by nearly 65% and 59%, respectively for nuclear and extended households, and this effect is statistically significant at 1%. With an average baseline level of 11.3 and 9.8 person-days for nuclear and extended households respectively, these results indicate that the treatment induced an increase of about 7 and 6 person-days per hectare on time devoted to plowing by nuclear and extended households respectively.

While the program seems to have similarly affected nuclear and extended households in terms of their labor devoted to plowing and inorganic fertilizer application, ITT estimates on labor allocation with respect to the other labor activities indicate that the program had significant negative impacts on extended households. This indicates that the household differential impact on total labor is likely to originate from differences in the amount of labor allocated to these activities (planting, manure application, weeding, and harvesting).

The differential effect by household structure can be explained by the fact that extended households may be constrained in terms of how much labor can be allocated to such activities, either because of a lower marginal product of labor at higher labor allocations to begin with relative to nuclear households, or to coordination costs, or to some combination of both. Further research is needed to delineate between these two potential explanations.

VII. Conclusion

(TBD)

References

Aune, J.B. and Coulibaly, A., 2015. Microdosing of Mineral Fertilizer and Conservation Agriculture for Sustainable Agricultural Intensification in Sub-Saharan Africa. In Sustainable Intensification to Advance Food Security and Enhance Climate Resilience in Africa (pp. 223-234). Springer International Publishing.

Beaman, L. and Dillon, A., 2012. Do household definitions matter in survey design? Results from a randomized survey experiment in Mali. Journal of Development Economics, 98(1), pp.124-135.

Becker, G. 1981. A Treatise on the Family. Cambridge, Mass.: Harvard University Press.

Bongaarts, J., 2001. Household size and composition in the developing world in the 1990s. Population studies, 55(3), pp.263-279.

Bielders, C.L. and Gérard, B., 2015. Millet response to microdose fertilization in southwestern Niger: effect of antecedent fertility management and environmental factors. Field Crops Research, 171, pp.165-175.

Camara, B.S., Camara, F., Berthe, A. and Oswald, A., 2013. Micro-dosing of fertilizer-a technology for farmers' needs and resources. International Journal of AgriScience, 3(5), pp.387-399.

Colson, E., 1962. Family change in contemporary Africa. Annals of the New York Academy of Sciences, 96(2), pp.641-652.

Galor, O., 2005. The demographic transition and the emergence of sustained economic growth. Journal of the European Economic Association, 3(2-3), pp.494-504.

Galor, O. and Weil, D.N., 2000. Population, technology, and growth: From Malthusian stagnation to the demographic transition and beyond. American economic review, pp.806-828.

ICRISAT. 2012. Fertilizer Microdosing, July 2012

Kazianga, H. and Wahhaj, Z., 2015, May. Norms of Allocation within Nuclear and Extended-Family Households. In 2015 AAEA & WAEA Joint Annual Meeting, July 26-28, San Francisco, California (No. 205534). Agricultural and Applied Economics Association & Western Agricultural Economics Association.

Laslett, P., Wall, R., Nakamura, J.I. and Miyamoto, M., 1982. Household and family in past time. Economic Development and Cultural Change, 30(2), pp.229-269.

Ministere de l'Agriculture, de l'Hydraulique et des Resources Halieutiques. 2010. Diagnostic du secteur Semencier du Burkina Faso. Document final. Ouagadougou, Burkina Faso, November.

Poteete, A.R. and Ostrom, E., 2004. Heterogeneity, group size and collective action: The role of institutions in forest management. Development and change, 35(3), pp.435-461.

Rosenzweig, M.R. and Wolpin, K.I., 1985. Specific experience, household structure, and intergenerational transfers: farm family land and labor arrangements in developing countries. Quarterly Journal of Economics, pp.961-987.

Udry, C., 1996. Gender, agricultural production, and the theory of the household. Journal of Political Economy, pp.1010-1046.

West, Colin Thor. 2010. Household Extension and Fragmentation: Investigating the Socio-Environmental Dynamics of Mossi Domestic Transitions. Human Ecology 38.3, pp 363-76.

Table 1: Sample Restrictions and Household Structure

Sample restrictions	**Number excluded**	**Number remaining**
All households in baseline	0	1,522
All households in followup	0	1,428
Households in both surveys	102	1,420
Remaining male-headed HHs	133	1,287
Remaining male-headed HHs with at least one plot managed by male	32	1,255
Remaining male-headed HHs producing sorghum at baseline	73	1,182
Remaining male-headed HHs producing sorghum both at baseline and followup	94	1,098
Final sample after dropping outliers and missing values	39	1,059
Household structure	**Number of Households**	
HH has at least one additional married male besides the head	311	
HH head has at least one married son	170	
HH head has at least one married brother	89	
HH head has at least one daughter-in-law	162	
HH head has at least one sister-in-law	133	
Extended HHs (HHs that meet at least one of the criteria above)	354	
Nuclear HHs (HHs that meet none of the criteria above)	705	
Total number of HHs	**1,059**	

Note: Observations are at the household level
Outliers identified as observations with values more than three times the standard deviation above the mean
Sorghum plot is identified as a plot on which sorghum is the main crop

Table 2: Demographic And Production Characteristics Across Extended And Nuclear Households

	Nuclear HHs (N=705)		**Extended HHs (N=354)**		
VARIABLES	Mean	Sd	Mean	Sd	P-Value
Household is Assigned Treatment	0.66	0.48	0.65	0.48	0.94
Head Age	46.24	14.08	52.10	15.41	0.00
Number of Adult Males	1.90	1.13	3.61	1.79	0.00
Number of Adult Females	2.18	1.27	4.15	2.23	0.00
Household size (members older than 15 years)	4.51	1.88	8.12	3.45	0.00
Household more than one married male	0.00	0.00	0.88	0.32	0.00
Household head has at least one married son	0.00	0.00	0.48	0.50	0.00
Household head has at least one married brother	0.00	0.00	0.26	0.44	0.00
Household head has at least one daughter-in-law	0.00	0.00	0.45	0.50	0.00
Household head has at least one sister-in-law	0.00	0.00	0.38	0.49	0.00
Household Uses Fertilizer	0.39	0.49	0.48	0.50	0.01
Intensity of fertilizer (kg/ha)	8.95	20.40	9.86	15.97	0.42
Total Land Holding (ha)	3.85	2.50	5.66	4.10	0.00
Total land where sorghum is main crop (ha)	2.97	2.14	4.40	3.61	0.00
Total land where millet is main crop (ha)	0.71	1.24	0.94	1.41	0.00
Total land where maize is main crop (ha)	0.05	0.22	0.09	0.32	0.02
Total land where rice is main crop (ha)	0.01	0.11	0.09	1.10	0.32
Total land where peanut is main crop (ha)	0.04	0.21	0.03	0.19	0.72
Total Labor Allocation to Plowing (person-days/ha)	9.779	9.924	11.34	11.91	0.05
Total Labor Allocation to Planting (person-days/ha)	13.62	10.55	15.64	10.75	0.00
Total Labor Allocation to Fertilizer Application (person-days/ha)	2.390	4.451	3.259	5.169	0.01
Total Labor Allocation to Manure Application (person-days/ha)	4.651	5.963	5.714	7.206	0.02
Total Labor Allocation to Weeding (person-days/ha)	37.44	37.66	40.16	31.67	0.21
Total Labor Allocation to Harvest (person-days/ha)	14.85	13.88	17.72	14.15	0.00
Total Male Labor (person-days/ha)	36.60	32.39	41.54	30.72	0.02
Total Female Labor (person-days/ha)	35.38	29.14	41.70	29.37	0.00
Total Child Labor (person-days/ha)	10.81	17.85	10.64	16.38	0.87
Total Labor Allocation (person-days/ha)	82.80	60.20	93.88	57.73	0.00
Total sorghum production	1,513	1,288	2,144	1,877	0.000
Total sorghum yield (kg/ha)	630.3	546.2	583.8	477.3	0.11

Notes: Bold variables are balanced between extended and nuclear households when we restrict to households with total landholdings in the top three quintiles.

Table 3: Balancing Test Results Across Assigned and Control Households By Household Structure

	Panel A: Extended Households					Panel B: Nuclear Households				
	Control (N=120)		Assigned (N=234)			Control (N=240)		Assigned (N=465)		
VARIABLES	Mean	Sd	Mean	Sd	P-Value	Mean	Sd	Mean	Sd	P-Value
Head Age	52.08	15.66	52.1	15.3	0.994	46.27	14.38	45.95	14.02	0.785
Number of Adult Males	3.525	1.773	3.632	1.678	0.674	1.858	1.009	1.927	1.187	0.498
Number of Adult Females	4.092	1.879	4.184	2.39	0.742	2.192	1.296	2.178	1.218	0.9
Total number of adults	8.008	2.932	8.124	3.63	0.795	4.529	1.785	4.443	1.868	0.615
Household more than one married male	0.85	0.359	0.893	0.31	0.318	0	0	0	0	.
Household head has at least one married son	0.483	0.502	0.483	0.501	0.994	0	0	0	0	.
Household head has at least one married brother	0.25	0.435	0.252	0.435	0.964	0	0	0	0	.
Household head has at least one daughter-in-law	0.483	0.502	0.444	0.498	0.518	0	0	0	0	.
Household head has at least one sister-in-law	0.358	0.482	0.385	0.488	0.67	0	0	0	0	.
Household Uses Fertilizer	0.392	0.49	0.521	0.501	0.107	0.338	0.474	0.417	0.494	0.157
Intensity of fertilizer (kg/ha)	8.124	16.75	10.74	15.51	0.218	7.368	19.41	9.768	20.87	0.286
Total Land Holding (ha)	4.324	3.029	3.974	3.046	0.46	2.977	2.066	2.782	1.952	0.401
Total land where sorghum is main crop (ha)	4.672	3.652	4.234	3.523	0.449	3.009	2.11	2.869	2.154	0.551
Total Labor Allocation to Plowing (person-days/ha)	11.62	14.32	11.2	10.5	0.817	9.319	9.517	10.02	10.13	0.486
Total Labor Allocation to Planting (person-days/ha)	15.25	10.5	15.84	10.9	0.688	13.54	9.754	13.66	10.94	0.896
Total Labor Allocation to Fertilizer Application (person-days/ha)	2.957	5.046	3.413	5.236	0.472	2.077	4.167	2.551	4.587	0.357
Total Labor Allocation to Manure Application (person-days/ha)	4.761	6.29	6.203	7.6	0.108	5.074	6.917	4.432	5.401	0.34
Total Labor Allocation to Weeding (person-days/ha)	38.1	28.42	41.21	33.22	0.385	38.6	35.14	36.85	38.92	0.562
Total Labor Allocation to Harvest (person-days/ha)	16.35	13.36	18.41	14.52	0.261	14.65	11.62	14.95	14.93	0.786
Total Labor Allocation (person-days/ha)	89.11	57.31	96.33	57.91	0.34	83.37	59.13	82.5	60.81	0.859
Total sorghum yield (kg/ha)	537.4	544.3	607.6	438.4	0.259	671	640.1	609.3	490.1	0.225

Table 4: Yield and total labor results using full sample

	Panel 4.1: CHANGES IN LOG OF YIELD						Panel 4.2: CHANGES IN LOG OF TOTAL LABOR					
	Interaction with log of land			Interaction with household structure			Interaction with log of land			Interaction with household structure		
VARIABLES	Model A1	Model A2	Model A3	Model B1	Model B2	Model B3	Model A1	Model A2	Model A3	Model B1	Model B2	Model B3
Assigned	0.159	0.506*	0.480*	0.047	0.333***	0.285**	-0.013	0.129	0.142	0.081	0.263***	0.185**
	(0.245)	(0.258)	(0.257)	(0.081)	(0.108)	(0.128)	(0.142)	(0.153)	(0.158)	(0.079)	(0.085)	(0.085)
Logland	0.359**	0.410**	0.442**			0.252***	0.383***	0.477***	0.509***			0.451***
	(0.160)	(0.180)	(0.182)			(0.091)	(0.076)	(0.087)	(0.087)			(0.064)
Assigned*Logland	-0.133	-0.285	-0.291				0.036	-0.081	-0.087			
	(0.178)	(0.202)	(0.202)				(0.102)	(0.119)	(0.117)			
Extended			-0.081	0.220*	0.167	0.093			-0.032	0.264***	0.249**	0.116
			(0.082)	(0.124)	(0.120)	(0.129)			(0.058)	(0.095)	(0.096)	(0.099)
Assigned*Extended				-0.241	-0.282*	-0.268*				-0.205*	-0.256**	-0.231*
				(0.150)	(0.153)	(0.161)				(0.114)	(0.117)	(0.117)
Village FE	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Sorghum share included?	No	No	Yes	No	No	Yes	No	No	Yes	No	No	Yes
Observations	1,059	1,059	1,059	1,059	1,059	1,059	1,059	1,059	1,059	1,059	1,059	1,059
R-squared	0.0184	0.1491	0.1503	0.0037	0.139	0.1495	0.0596	0.1915	0.1929	0.0083	0.1451	0.1958

Notes: Standard errors clustered by village in parentheses. * p<0.1 ** p<0.05 *** p<0.01.

Sample restricted to households with at least one male-controlled sorghum plots across baseline and follow-up surveys

For extended household definition, see section III

Sorghum land is the total land where sorghum is the main crop

All specifications for Models A3 and B3 include the share of total land devoted to sorghum cultivation.

Table 5: Results using sample restricted to the first three quintiles of total sorghum land holding

	Panel 5.1: CHANGES IN LOG OF YIELD						Panel 5.2: CHANGES IN LOG OF TOTAL LABOR					
VARIABLES	Interaction with log of land			Interaction with household structure			Interaction with log of land			Interaction with household structure		
	Model A1	Model A2	Model A3	Model B1	Model B2	Model B3	Model A1	Model A2	Model A3	Model B1	Model B2	Model B3
Assigned	0.273	0.052	0.069	0.119	0.102	0.114	-0.196	-0.341	-0.267	0.159*	0.209**	0.235**
	-0.44	-0.514	-0.538	-0.106	-0.195	-0.21	-0.239	-0.279	-0.284	-0.09	-0.1	-0.098
Logland	0.472	0.323	0.375			0.263	0.217	0.254	0.334*			0.440***
	(0.363)	(0.432)	(0.439)			(0.203)	(0.200)	(0.205)	(0.201)			(0.126)
Assigned*Logland	-0.226	-0.143	-0.161				0.24	0.196	0.167			
	(0.403)	(0.479)	(0.484)				(0.242)	(0.260)	(0.255)			
Extended			-0.053	0.237	0.203	0.175			-0.008	0.373***	0.378***	0.330***
			(0.127)	(0.229)	(0.239)	(0.240)			(0.082)	(0.116)	(0.121)	(0.119)
Assigned*Extended				-0.295	-0.353	-0.349				-0.431***	-0.527***	-0.522***
				(0.261)	(0.276)	(0.282)				(0.145)	(0.153)	(0.149)
Village FE	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Sorghum share included?	No	No	Yes	No	No	Yes	No	No	Yes	No	No	Yes
Observations	677	677	677	677	677	677	677	677	677	677	677	677
R-squared	0.0091	0.1771	0.1786	0.0039	0.1777	0.1822	0.0193	0.2109	0.2176	0.0133	0.2101	0.2306

Notes: Sample restricted to the first three quintiles of total sorghum land holding (with mean of total land holding=1.84 and 1.94 for nuclear and extended households, respectively).
Standard errors clustered by village in parentheses. * p<0.1 ** p<0.05 *** p<0.01.

Sample restricted to households with at least one male-controlled sorghum plots across baseline and follow-up surveys

For extended household definition, see section III
Sorghum land is the total land where sorghum is the main crop
All specifications for Models A3 and B3 include the share of total land devoted to sorghum cultivation

Table 6: Labor allocation results by activity using sample restricted to the first three quintiles of total sorghum land holding

VARIABLES	Total Labor	Plowing	Planting	Manure	Fertilizer	Weeding	Harvest
Assigned	0.235**	0.646***	-0.178	0.093	0.304	0.063	0.141
	-0.098	-0.204	-0.121	-0.175	-0.185	-0.192	-0.126
Extended	0.330***	-0.108	0.257*	0.568***	-0.058	0.385*	0.378**
	(0.119)	(0.229)	(0.146)	(0.211)	(0.226)	(0.231)	(0.148)
Assigned*Extended	-0.522***	-0.06	-0.384**	-0.643**	0.041	-0.534*	-0.464**
	(0.149)	(0.285)	(0.175)	(0.268)	(0.314)	(0.306)	(0.199)
Logland	0.440***	0.32	0.452***	0.278	-0.107	0.12	0.533***
	(0.126)	(0.266)	(0.144)	(0.227)	(0.224)	(0.245)	(0.166)
Village FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sorghum share included?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	677	677	677	677	677	677	677
R-squared	0.2306	0.189	0.1846	0.1749	0.1726	0.2399	0.2068

Notes: Sample restricted to the first three quintiles of total sorghum land holding (with mean of total land holding=1.84 and 1.94 for nuclear and extended households, respectively).
Standard errors clustered by village in parentheses. * p<0.1 ** p<0.05 *** p<0.01.

Sample restricted to households with at least one male-controlled sorghum plots across baseline and follow-up surveys

For extended household definition, see section III
Sorghum land is the total land where sorghum is the main crop
All specifications include the share of total land devoted to sorghum cultivation

Table A1: Demographic And Production Characteristics Across Extended And Nuclear Households with sample restricted to the first three quintiles of land holding

	Nuclear HHs (N=496)		**Extended HHs (N=181)**		
VARIABLES	Mean	Sd	Mean	Sd	P-Value
Household is Assigned Treatment	0.66	0.48	0.65	0.48	0.997
Head Age	45.09	14.32	52.01	15.93	0.000
Number of Adult Males	1.776	1.096	3.243	1.357	0.000
Number of Adult Females	1.976	1.121	3.624	1.681	0.000
Household size (members older than 15 years)	4.141	1.712	7.215	2.360	0.000
Household more than one married male	0	0	0.867	0.340	0.000
Household head has at least one married son	0	0	0.464	0.500	0.000
Household head has at least one married brother	0	0	0.238	0.427	0.000
Household head has at least one daughter-in-law	0	0	0.403	0.492	0.000
Household head has at least one sister-in-law	0	0	0.354	0.479	0.000
Household Uses Fertilizer	0.379	0.486	0.464	0.500	0.080
Intensity of fertilizer (kg/ha)	9.898	22.40	11.81	18.63	0.245
Total Land Holding (ha)	1.839	0.779	1.940	0.775	0.094
Total land where sorghum is main crop (ha)	1.882	0.905	2.109	1.601	0.049
Total land where millet is main crop (ha)	0.749	1.277	1.006	1.410	0.033
Total land where maize is main crop (ha)	0.0462	0.211	0.0762	0.279	0.162
Total land where rice is main crop (ha)	0.00479	0.0436	0.122	1.489	0.313
Total land where peanut is main crop (ha)	0.0286	0.165	0.0138	0.0902	0.161
Total Labor Allocation to Plowing (person-days/ha)	10.16	10.83	14.15	14.57	0.003
Total Labor Allocation to Planting (person-days/ha)	14.52	11.60	18.74	12.76	0.000
Total Labor Allocation to Fertilizer Application (person-days/ha)	2.636	4.855	3.968	6.046	0.008
Total Labor Allocation to Manure Application (person-days/ha)	4.899	6.367	7.064	8.882	0.004
Total Labor Allocation to Weeding (person-days/ha)	41.28	42.21	48.32	37.83	0.027
Total Labor Allocation to Harvest (person-days/ha)	16.19	15.66	21.95	17.32	0.001
Total Male Labor (person-days/ha)	40.29	36.10	51.75	37.13	0.001
Total Female Labor (person-days/ha)	38.32	32.18	49.45	34.89	0.000
Total Child Labor (person-days/ha)	11.14	19.46	13.04	19.81	0.253
Total Labor Allocation (person-days/ha)	89.75	66.29	114.2	67.08	0.000
Total sorghum production	1,188	966.0	1,352	1,053	0.099
Total sorghum yield (kg/ha)	705.0	605.4	689.7	574.5	0.751