Proxy response bias in agricultural statistics

Andrew Dillon
Michigan State

Andrew Jones
University of Michigan

Edouard Mensah
Michigan State University

Abstract Nonrandom measurement error biases descriptive statistics and increases internal validity concerns in the estimation of causal relationships. We investigate the relative effects of self-reporting and proxy response in a randomized control trial in Burkina Faso. Survey design treatments vary who reports for the household in an agricultural survey. Three alternative respondents including a self-report, the household head and a randomly chosen adult proxy are designated in the three treatment groups to report agricultural information. We find no effects of respondent type on total landholdings reported for the household, but statistically significant effects of area cultivated by random proxy reports relative to self-reported land data (11% of the standard deviation). Effect sizes are much larger on land reported by household heads and random proxies relative to self-reports for field crops and pasture land. We do not find that biases in land reported influences estimates of the inverse land size relationship. Household heads also over-report production of cereals, cash crops and computed crop diversity scores relative to self-reports. Household heads (+ 18% of a standard deviation) and random proxies (- 37% of a standard deviation) also provide different biases relative to self-reported agricultural labor. Female proxies report lower levels of fertilizer for the household and higher frequencies of crops such as legumes and vegetables that women traditionally produce in Burkina Faso.

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1. INTRODUCTION

Nonrandom measurement error biases descriptive statistics and increases internal validity concerns in the estimation of causal relationships. In agricultural settings, causal relationships such as the inverse-farm size relationship (Carletto et al. 2013, Dillon et al. 2016, Bevis and Barrett 2017, Desiere and Jolliffe 2017, Dillon and Rao 2017), estimating the efficiency of farms (Gollin and Udry 2017), or the relationship between health, effort and agricultural labor productivity (Akogun et al. 2017) may be biased by mismeasurement. An emerging survey design and measurement literature in development economics has provided estimates of the effects of questionnaire design choices on agricultural statistics such as the household definition (Beaman and Dillon 2012), recall period (Beegle et al. 2012, Arthi et al. 2018), and the inclusion of screening questions on employment in agriculture (Bardasi et al. 2011). A smaller literature has investigated proxy response in agricultural labor statistics (Bardasi et al. 2011, Dillon et al. 2012), but proxy response has received much less attention in development economics than it has in labor economics (Hussmanns et al. 1990, Bound et al. 2001, Glewwe and Grosh 2000). Much of this survey design literature has focused on variation in either questionnaire design to estimate bias or differences in measurement methods without considering the bias induced by proxy reporting methods.

A frequent survey protocol for collecting agricultural statistics is to collect agricultural statistics at the plot-level from farmer's self-reports (Glewwe and Ghosh 2000). This approach is presumed to provide the most precise information as information asymmetries may exist within the household, particularly when plots are distant from the household and/or individual returns from farming may not be completely pooled with household resources. Though presumed to provide the highest data quality, the cost of this approach leads survey implementers to compromise between presumed higher data quality from self-reports and the higher cost of tracking each plot manager or land owner to survey. Proxy response might take a variety of forms across surveys. In many surveys, the head of household responds for the entire household, though they may not be directly implicated in the agricultural activities of all household members. Alternatively, another household member may be selected as the proxy if the household head is not available or the person who should self-report is absent. Due to the frequency of these three types of respondents in agricultural surveys, we designed the experiment to estimate the relative effects on agricultural statistics of proxy response in a randomized control trial in Burkina Faso. The design of our experiment compares alternative respondent criteria (self-reporting, proxy-head of household or randomly selected proxy household member) to estimate the relative bias between survey design choices.

We find no effects of respondent type on total landholdings reported for the household, but statistically significant effects of area cultivated by random proxy reports relative to self-reported land data (11% of the standard deviation). Effect sizes are much larger on land reported by household heads and random proxies relative to self-reports for field crops and pasture land. We do not find that biases in land reported influences estimates of the inverse land size relationship. Household heads also over-report production of cereals, cash crops and computed crop diversity scores relative to self-reports. Household heads (+ 18% of a standard deviation) and random proxies (- 37% of a standard deviation) also provide different biases relative to self-reported agricultural labor. Female proxies report lower levels of fertilizer for the household and higher frequencies of crops such as legumes and vegetables that women traditionally produce in Burkina Faso.

The second section of the paper describes our study design and data. The third section discusses our econometric approach, while the fourth section presents the study results. The last section concludes.

2. METHODS AND DATA

2.1 Study design and context

We first randomly selected seven rural provinces within Burkina Faso that spanned the three agroecological regions of the country including one province from the Sahelian region, two from the Sudanian region, and four from the larger Sudan-Sahelian region. In the Sahelian region, annual rainfall is less than 600 mm with rains occurring only three to four months of the year. In the Sudanian zone, rainfall averages over 900 mm during five to six months of the year (Somé et al. 2013). Agricultural production is more diverse in this region with perennial crops such as mangos, citrus and cashews, as well as yams, cotton, maize, and millets produced (Food and Agriculture Organization, 2001). In the Sudan-Sahelian zone, annual rainfall is between 600-900 mm through four or five months of the year. Herding and agro-pastoralism are practiced throughout the country, especially in the drier regions, with subsistence production of millet, sorghum, and cowpea common in most regions.

Study provinces were randomly selected within each agroecological stratum with probability proportional to size of the strata. Eight provinces were initially selected, though field work was implemented in only seven provinces (see Figure 1). Terrorist activities in the Soum province (Sahelian region) in the two-week period before the initiation of data collection in January 2017 precluded survey implementation in that province. Given the focus of the trial on rural villages, the Kadiogo province, home to the urban capital Ouagadougou, was also excluded from possible selection.

Using data from the 2006 Burkina Faso Population and Housing Census (National Institute of Statistics and Demography (Burkina Faso), 2006), the most recent census data at the time, we randomly selected 10 villages within each selected province for participation in the survey experiment. We carried out a household listing in each selected village collecting data on household location, composition, and two principal inclusion criteria: 1) at least one child aged 24-59 months at the time of initiation of data collection must have been a household member; and, 2) the household's primary income or subsistence must have been derived from crop production and/or animal husbandry. The first inclusion criterion was necessary as the study was designed to investigate both agricultural and nutrition statistics. This paper focuses exclusively on agricultural statistics. Excluding households that did not meet both criteria, we randomly selected 15 eligible households within each village for a total target sample of 1,050 households. Five households within each village were then randomly assigned to one of three treatments of the survey design experiment: 1) random proxy, household-level agricultural statistics; 2) household head reporting, household-level agricultural statistics; and 3) plot-level, farmer self-reporting treatment. Data collection was initiated in January 2017 and completed in early February 2017. This period was chosen as it represents the period after the main cereal harvest in Burkina Faso.

Households randomly allocated to the plot-level, farmer self-reporting treatment (treatment 3) were administered a comprehensive agricultural questionnaire that collected plot-level data on land area, crops raised and harvested, labor and productive inputs applied, use of crops post-harvest, earnings from agriculture and other sources, as well as control of management decisions and income derived from productive activities. These plot-level data were collected at an individual level, by plot and season, from the (most knowledgeable) household member that managed each plot. This approach most closely approximates national data collections from statistical agencies that collaborate with the LSMS-ISA surveys at the World Bank. We compare this approach of using self-reported plot-level data with two alternative variations of proxy reporting. In the first proxy treatment, a randomly selected adult household member was chosen as a proxy and was administered a questionnaire that collected data for the entire household (across all plots and seasons) on the same agricultural production and livelihood activities as described for households in the plot-level farmer self-reporting treatment. In the second proxy treatment, the household head was designated as the proxy reporter for the entire household's activities and was administered the same questionnaire as that of randomly assigned proxy in the first treatment. The proxy effects that we estimate relative to the self-reported treatment assignment can be interpreted as arising from asymmetric information between the proxy and other household members, and between the units of observation that are recalled by the proxy vis-à-vis other household members (plot level information versus household level information). As we wanted to estimate bias between real alternative survey design choices that are implemented in the field, we chose these alternatives to measure relative bias between survey design choices rather than the estimation of a pure proxy effect by type of proxy. We do investigate the effect of gender as a potentially important difference between proxies in reporting bias, as the intrahousehold literature illustrates that asymmetric information may be particularly important between men and women within the household.

Households that were selected for participation in the experiment, but that either refused participation or were absent from their residence after three follow-up visits, were replaced with an alternative eligible household using a random replacement procedure. In total, 22 households across all villages were unable to be replaced because of an insufficient number of eligible replacement households in villages. The final analytic sample was 1,028 households (treatment 1: n = 336; treatment 2: n = 345; treatment 3: n = 347) (Figure 1).

2.2. Data description

Table 1A presents the descriptive statistics of the study sample and the tests of whether treatment groups are balanced on household head characteristics and housing and asset characteristics. Household heads in the study sample were mostly male (95%) and married (97%). The average age of the household head was 44 years. Fifteen percent (15%) of household heads were migrants—absent in their household for six months or more in the twelve months preceding the survey. Household head's level of education was low: seventy-six percent (76%) of household heads were neither informally (Koranic or French-Arabic school) nor formally educated; eight percent (8%) were informally educated; and sixteen percent (16%) were formally educated, mainly at the primary level (13%). The average household had 7 members, including 2 children aged 0-5 years, 3 children aged 6-17 years, and 2 adults aged 18-65 years. Most households owned their dwellings (97%), which were comprised of 4 buildings and 5 rooms, and various durable assets.

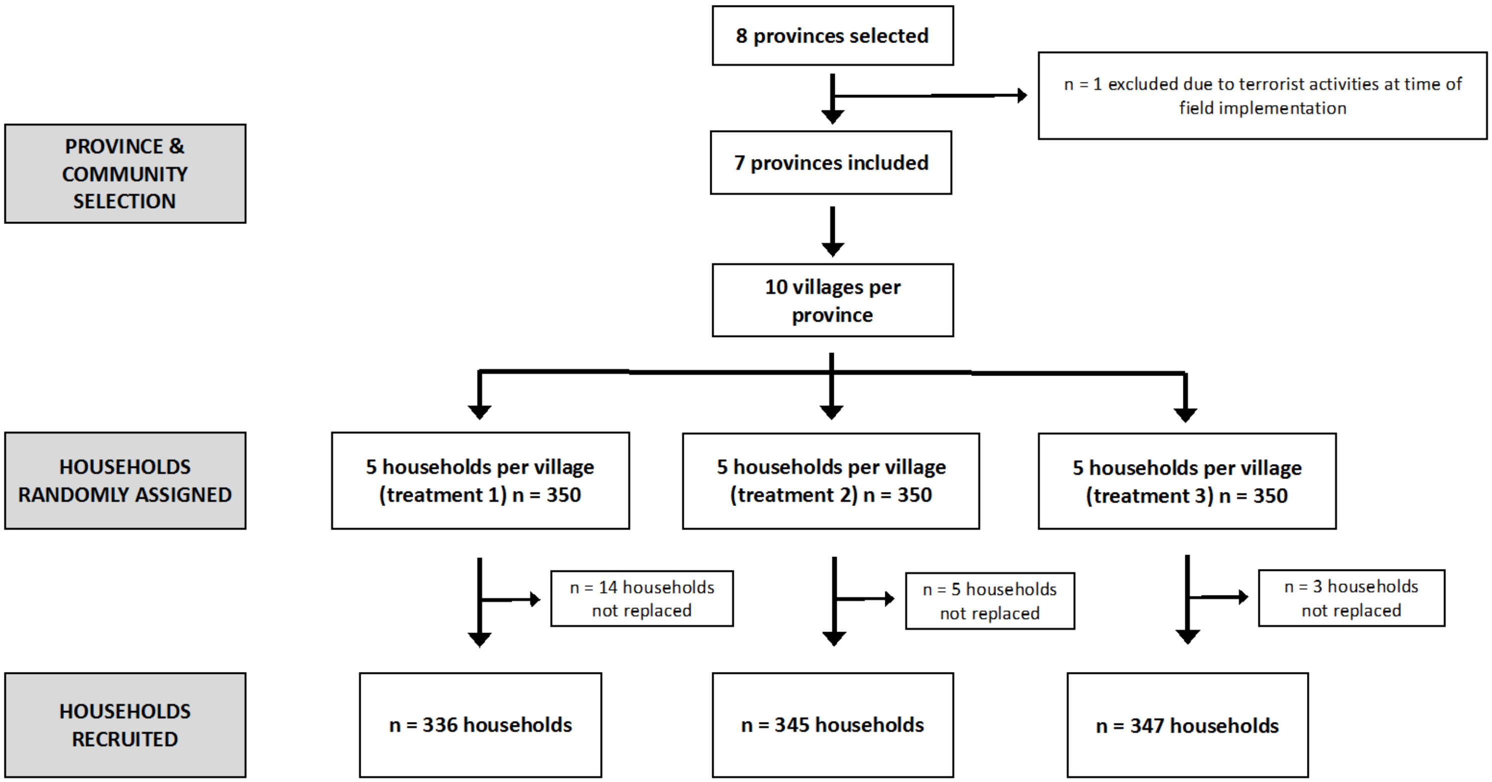

Figure 1.

Experimental design

Note: Treatment 1 is the random proxy treatment. Treatment 2 is the household head proxy treatment. Treatment 3 is the self-reported treatment.

To explore the balance between the treatment groups, we estimate the equation:

$$y_i = \beta_0 + \beta_1 T_{1i} + \beta_2 T_{2i} + \varepsilon_i \qquad (1)$$

where y_i is the socio-economic characteristic of household i, and T_{1i} and T_{2i} are indicators for the treatment survey designs used in the interview of household i. The self-reporting treatment (treatment 3) is the excluded survey design. In all estimations, standard errors are clustered at the village level, consistently with the sample design (Abadie et al. 2017). We are interested in testing two null hypotheses, (i) $\beta_1 = 0$ and $\beta_2 = 0$ which is the joint balance of both treatment 1 and treatment 2 to the self-reporting treatment; and (ii) $\beta_1 = \beta_2$ which is the balance between treatment 1 and treatment 2.

Balance tests in Tables 1A, 1B, and 1C, reveal that households interviewed using the household head reporting or the random proxy reporting survey designs compare well to the self-reporting households, except on the migration status of the household head, the household head's level of education, and the endowments in household's durable assets. No balance test on the household size and composition variables rejects the null hypothesis at the 5% level of significance (Table 1B). The joint test of the significance of treatment 1 and treatment 2 on household head's demographics (Table 1A) indicates the rejection of the balance of the treatment households to the self-reporting households, regarding the migration status of the household head (at the 1% level of significance) and the household head's level of education (at the 5% level of significance). While in the self-reporting households, 23% of household heads are migrants, the incidence of migration among household heads in the treatment households is lowered by 12 to 13 percentage points.

Likewise, 19% of the self-reporting household heads are either formally or informally educated, but the treatment household heads in groups 1 and 2 are 7 to 8 percentage-point more educated.

Self-reporting households are also wealthier than those in the treatment groups (Table 1C): 31.7% of self-reporting households are in the top fourth wealth quartile versus 18.3% of household-head-reporting households; 20.2% of self-reporting households are in the bottom first wealth quartile versus 28.6% of random-proxy-reporting households. The estimation of the treatment effects thus controls for whether the household head is a migrant, whether the household head is formally or informally educated, and whether the household is in any wealth quartile, to obtain more precise estimates.

Self-reporting households have several respondents per household while treatment 1 and 2 households have a single respondent per household. To further validate the difference between treatment 1 and treatment 2 in their respondent's characteristics, we use the treatment sample and estimate the equation:

$$y_i = \alpha_0 + \alpha_2 T_{2i} + \varepsilon_i \qquad (2)$$

which excludes the household-head-reporting survey design as an independent variable. In equation (2), y_i is the respondent's characteristic of household i, and we expect the significance of α_2 on the respondent's relationship to the head of household and all other respondent's characteristics.

Consistently with the treatment assignment, the test of treatment 2 in Table 2 results in significant differences in the respondent's relationship to the head of household between treatment households. While 99.7% of respondents in the household-head-reporting group are household heads, respondents in the random-proxy-reporting group are less likely to be the household heads: the latter are sons and daughters of the household head (50.3%), household heads (33.7%), and other household members.

Table 1A

Balance tests on household head's demographics.

Dependent variable	(1) Female HH head	(2) Age of HH head	(3) HH head migrant	(4) Received formal or informal education	(5) Received formal education	(6) Level of formal education: none	(7) Level of formal education: primary	(8) Level of formal education: junior secondary	(9) Level of formal education: senior secondary	(10) Level of formal education: university
Treatment 1: Household head reporting	0.018 (0.014)	-0.319 (1.134)	-0.123*** (0.035)	0.068* (0.034)	0.036 (0.026)	-0.038 (0.027)	0.029 (0.025)	0.012 (0.012)	0.000 (0.004)	-0.003 (0.003)
Treatment 2: Random proxy reporting	0.013 (0.013)	-0.524 (1.029)	-0.132*** (0.032)	0.075** (0.033)	0.052* (0.028)	-0.052* (0.028)	0.045* (0.023)	0.013 (0.012)	-0.003 (0.003)	-0.003 (0.003)
p-value: test of treatment 1 = treatment 2	0.767	0.854	0.667	0.880	0.691	0.739	0.654	0.951	0.322	
p-value: joint test of treatment 1 and treatment 2	0.400	0.878	0.001	0.024	0.067	0.058	0.079	0.473	0.366	0.325
N	1,028	1,025	1,028	1,028	1,028	1,026	1,026	1,026	1,026	1,026
Mean of dependent variable in control households	0.035	44.641	0.231	0.193	0.127	0.876	0.101	0.017	0.003	0.003
S.D. of dependent variable in control households	0.183	13.057	0.422	0.395	0.333	0.330	0.302	0.131	0.054	0.054

Notes: OLS estimates. All standard errors are clustered at the village level. *** p<0.01; ** p<0.05; *p<0.1
The omitted category is the control survey design (self-reporting).
No treatment 1 and treatment 2 households have their household head educated at the university level.

Table 1B

Balance tests on household size and composition.

Dependent variable	(1) HH head married	(2) HH size	(3) Number of male children 0-5	(4) Number of female children 0-5	(5) Number of male children 6-17	(6) Number of female children 6-17	(7) Number of male adults 18-65	(8) Number of female adults 18-65	(9) Number of male seniors 66+	(10) Number of female seniors 66+
Treatment 1: Household head reporting	-0.006 (0.013)	0.146 (0.370)	0.152** (0.069)	-0.016 (0.063)	0.081 (0.125)	-0.050 (0.100)	-0.031 (0.083)	-0.018 (0.099)	0.018 (0.023)	0.012 (0.020)
Treatment 2: Random proxy reporting	0.004 (0.010)	0.211 (0.484)	0.141* (0.082)	-0.048 (0.058)	0.062 (0.135)	-0.094 (0.135)	0.043 (0.078)	0.099 (0.114)	-0.006 (0.021)	0.013 (0.029)
p-value: test of treatment 1 = treatment 2	0.486	0.856	0.899	0.643	0.882	0.654	0.316	0.211	0.301	0.986
p-value: joint test of treatment 1 and treatment 2	0.780	0.902	0.078	0.710	0.804	0.788	0.593	0.443	0.570	0.806
N	880	1,028	1,028	1,028	1,028	1,028	1,028	1,028	1,028	1,028
Mean of dependent variable in control households	0.970	6.620	0.683	0.726	1.441	1.406	1.213	0.945	0.081	0.118
S.D. of dependent variable in control households	0.171	4.703	0.908	0.852	1.503	1.444	1.133	1.209	0.273	0.341

Notes: OLS estimates. All standard errors are clustered at the village level. *** p<0.01; ** p<0.05; *p<0.1
The omitted category is the control survey design (self-reporting).

Table 1C

Balance tests on housing and asset index.

Dependent variable	(1) HH head owns the HH dwelling	(2) Number of buildings in the dwelling	(3) Number of rooms in the dwelling	(4) HH asset index	(5) HH asset index quartile: 1st	(6) HH asset index quartile: 2nd	(7) HH asset index quartile: 3rd	(8) HH asset index quartile: 4th
Treatment 1: Household	-0.003	-0.267	-0.280	-0.719***	0.053	0.051	0.031	-0.134***
head reporting	(0.011)	(0.165)	(0.277)	(0.171)	(0.036)	(0.035)	(0.044)	(0.036)
Treatment 2: Random	-0.010	-0.201	-0.161	-0.541**	0.084**	0.049	-0.075	-0.058
proxy reporting	(0.017)	(0.201)	(0.294)	(0.244)	(0.035)	(0.035)	(0.048)	(0.042)
p-value: test of treatment 1 = treatment 2	0.561	0.677	0.619	0.539	0.390	0.966	0.015	0.119
p-value: joint test of treatment 1 and treatment 2	0.820	0.283	0.596	0.000	0.071	0.221	0.049	0.003
N	1,027	1,028	1,028	1,028	1,028	1,028	1,028	1,028
Mean of dependent variable in control households	0.977	3.873	5.161	0.446	0.202	0.216	0.265	0.317
S.D. of dependent variable in control households	0.150	2.685	3.611	2.597	0.402	0.412	0.442	0.466

Notes: OLS estimates. All standard errors are clustered at the village level. *** p<0.01; ** p<0.05; *p<0.1
The omitted category is the control survey design (self-reporting).

Table 2

Between treated balance tests on respondent characteristics.

Panel A: Respondent's gender and relationship to the head of household

Dependent variable	(1) Relationship to the head of HH: household head	(2) Relationship to the head of HH: son /daughter	(3) Relationship to the head of HH: grandson /granddaughter	(4) Relationship to the head of HH: mother /father	(5) Relationship to the head of HH: sister /brother	(6) Relationship to the head of HH: other relative	(7) Female respondent
Treatment 2: Random proxy reporting	-0.643***	0.521***	0.028***	0.016**	0.022**	0.056***	0.283***
	(0.058)	(0.057)	(0.009)	(0.007)	(0.010)	(0.010)	(0.036)
p-value: test of treatment 2	0.000	0.000	0.005	0.027	0.032	0.000	0.000
N	664	664	664	664	664	664	664
Mean of dep. var. in treatment 1 HHs	0.997	0.003	0.000	0.000	0.000	0.000	0.052
S.D. of dep. var. in treatment 1 HHs	0.054	0.054	0.000	0.000	0.000	0.000	0.223

Panel B: Respondent's gender and relationship to the head of household

Dependent variable	(8) Age of respondent	(9) Respondent is a migrant	(10) Received formal or informal education	(11) Received formal education	(12) Formal education level: none	(13) Formal education level: primary	(14) Formal education level: jun. secondary	(15) Formal education level: sen. secondary
Treatment 2: Random proxy reporting	-7.393***	0.055**	0.004	0.055*	-0.052	0.057*	-0.002	-0.003
	(1.873)	(0.026)	(0.033)	(0.031)	(0.032)	(0.030)	(0.012)	(0.003)
p-value: test of treatment 2	0.000	0.038	0.902	0.092	0.107	0.064	0.884	0.322
N	512	677	677	677	676	676	676	676
Mean of dep. var. in treatment 1 HHs	44.255	0.107	0.258	0.162	0.838	0.130	0.029	0.003
S.D. of dep. var. in treatment 1 HHs	13.016	0.310	0.438	0.369	0.369	0.337	0.168	0.054

Notes: OLS estimates. All standard errors are clustered at the village level. *** p<0.01; ** p<0.05; *p<0.1
The omitted category is Treatment 1 (household head reporting).

Moreover, at the 5% level of significance, compared to household head respondents, there are significantly more females among random proxy respondents (33.5% versus 5.2 %) and more migrants (16.2% versus 10.7%); random proxy respondents are also 7 years younger than household head respondents. These differences in respondent characteristics can drive the observed differences in agricultural outcomes between the treatment survey designs.

Treatment groups are balanced on the respondent's level of education (Table 2), the household head's demographics (Table 1A), household size and composition variables (Table 1B), and housing and asset index (Table 1C).

Results

We use two econometric specifications for the results on land size, land characteristics, crop choices, inputs, labor, production, and productivity. The first specification is expressed in Equation (1), and the second specification is shown in Equation (3) which adds the vector of identified imbalanced covariates, represented by X_i, to the independent variables in Equation (1):

$$y_i = \beta_0 + \beta_1 T_{1i} + \beta_2 T_{2i} + \varphi' X_i + \varepsilon_i \tag{3}$$

Although we present the results from both Equations (1) and (3), we interpret and discuss only the estimated treatment effects from Equation (3) since they are more precise than those in Equation (1). Each of the proxy treatments (random proxy (treatment 1) and household head (treatment 2)) are interpreted relative to the omitted category of the self-reported respondent (treatment 3).

Results on land size, land characteristics, and crop choices

Table 3 presents the effects of the experimental survey designs on the first set of agricultural outcomes including landholdings (native forests, secondary forests, pasture, field edges, field crops, garden crops, and orchard crops), total landholdings, the total area cultivated, and the share of landholding cultivated.

Columns one through eight in Panel B of Table 2 indicate that the treatment survey designs have no significant change in the total landholdings relative to the self-reporting treatment but influence the reported distribution over the landholdings at the 1% of level of significance. With the household head reporting treatment, there is an over-reporting of landholding in native forests (+0.98 ha), secondary forests (+0.31 ha), pasture (+0.19 ha), field edges (+0.24 ha), and garden crops (+0.06 ha), which is offset by an under-reporting of landholding in field crops (-1.39 ha). With the random proxy reporting treatment, there is an over-reporting of landholding in native forests (+0.43 ha), secondary forests (+0.21 ha), pasture (+0.27 ha), and field edges (+0.36 ha), which is offset by an under-reporting of landholding in field crops (-1.75 ha).

Columns nine and ten in Panel B of Table 2 show that, interviewing the household head does not influence the total size of land cultivated but does reduce at the 1% level of significance the share of landholding cultivated by 8.2 percentage points; interviewing a random proxy household member reduces the total size of land cultivated by 0.64 ha at the 10% level of significance, and the share of landholding cultivated by 2.1 percentage points at the 5% level of significance.

Overall, our results on land size suggest that the total land size owned by a household is of common knowledge by the household members, the aggregate cultivated land size is also known by the household head, and it is the size of the specific landholdings which requires the knowledge of the manager of that specific landholding. Strikingly, under any treatment survey design, the size of the landholding in field crops (the largest landholding cultivated) is underestimated while the size of the other landholdings (the smallest landholdings cultivated) is overestimated. This result aligns with the finding from Carletto et al. (2014) in Uganda and Dillon et al (2017) from Nigeria which suggests that farmer estimates of large plots are under-reported while their estimates of small plots are over-reported.

The results about the effects of the experimental survey designs on the second set of agricultural outcomes including the main mode of acquisition of the cultivated plots and the main type of soil on the cultivated plots are showed in Table 4. In both treatment survey designs, an over-reporting of the inheritance mode of acquisition of cultivated plots is observed by 22 percentage points, as opposed to the donation mode (columns one through three); and an under-reporting of clayey soils by 14 percentage points, as opposed to sandy soils (columns four through eight). Since sandy soils have a lower fertility than clayey soils, the latter result suggests an under-reporting of soil fertility by treatment respondents.

Another set of agricultural outcomes includes crop choices. The results on crop choices are presented in Tables 5A and 5B and relate to cereal crops, legume crops, vegetable crops, cash crops, and the crop diversity score. Columns one through five in Panel B of Table 5A indicate no significant effect of the random proxy reporting on cereal crop choices, while there is an under-reporting of the main cereal crop (sorghum) and an over-reporting of the other cereal crops with the household head reporting treatment. Households in the household head reporting group report less cultivation of sorghum (-16 percentage points) and more cultivation of millet (+17 percentage points), corn (+11 percentage points), and rice (+7 percentage points) relative to self-reporting households, resulting in an increase in the reporting of the cultivation of cereals by 3.6 percentage points. Columns six through ten in Panel B of Table 5A show an over-reporting of bean crop choice by 8.7 percentage points with the household head reporting treatment and an under-reporting of peanut crop choice by 11.2 percentage points with the random proxy reporting treatment. These biases in reporting, however, do not influence the aggregate reporting of the cultivation of legumes. There is no evidence of bias in the reporting of vegetable crop choices by any treatment respondent (Table 5B, columns one through four). Columns five and six in Panel B of Table 5B show that, with the household head reporting treatment, there is an over-reporting of cotton crop choice by 4.8 percentage points, which translates into an aggregate over-reporting of cash crop cultivation by 5.7 percentage points. With the random proxy reporting treatment, there is an under-reporting of cotton crop choice by 10 percentage points. This under-reporting does not influence the aggregate reporting of cash crop cultivation because households not producing cotton produce other cash crops. We also estimate a marginal increase in the crop diversity score at the 10% level of significance, under household head reporting treatment. However, there is no evidence of bias in the total number of crops produced by the households surveyed under random proxy reporting treatment (Table 5B, column seven).

In summary for the reporting of crop choices, our results suggest that interviewing the household head does not give a good indicator of crop diversification particularly because the household head over-reports the cultivation of cereal and cash crops. This finding adds an important element to the crop diversification literature in the sense that, agricultural shocks and risk (Reardon et al., 1992) and household's wealth (Zimmerman and Carter, 2003; Stoeffler, 2016), which are known as the determinants of crop portfolios, can be questionable with the survey designs employed to measure crop choices.

Table 3

Treatment effects on land size.

Dependent variable	(1) Native forest (ha)	(2) Secondary forest (ha)	(3) Pasture (ha)	(4) Edge (ha)	(5) Field crops (ha)	(6) Garden crops (ha)	(7) Orchard crops (ha)	(8) Total land-holdings (ha)	(9) Total area cultivated (ha)	(10) Percent area cultivated
Panel A: Estimates without the imbalanced covariates										
Treatment 1: HH head reporting	0.861***	0.277***	0.179**	0.234**	-1.824***	0.050*	-0.170	-0.394	-1.057***	-0.079***
	(0.304)	(0.091)	(0.074)	(0.095)	(0.513)	(0.026)	(0.105)	(0.431)	(0.384)	(0.018)
Treatment 2: Random proxy reporting	0.325*	0.171***	0.256***	0.373***	-2.037***	0.059	-0.097	-0.950**	-1.020**	-0.018**
	(0.166)	(0.058)	(0.063)	(0.122)	(0.332)	(0.038)	(0.095)	(0.442)	(0.403)	(0.007)
p-value: test of treat. 1 = treat. 2	0.117	0.245	0.438	0.406	0.622	0.800	0.164	0.215	0.921	0.003
p-value: joint test of treat. 1 and treat. 2	0.009	0.003	0.000	0.001	0.000	0.126	0.212	0.114	0.018	0.000
Panel B: Estimates with the imbalanced covariates										
Treatment 1: HH head reporting	0.979***	0.311***	0.188**	0.241***	-1.385***	0.062**	-0.164	0.231	-0.484	-0.082***
	(0.339)	(0.094)	(0.077)	(0.088)	(0.463)	(0.028)	(0.109)	(0.371)	(0.316)	(0.019)
Treatment 2: Random proxy reporting	0.428**	0.209***	0.266***	0.359***	-1.750***	0.065	-0.101	-0.525	-0.640*	-0.021**
	(0.189)	(0.061)	(0.068)	(0.115)	(0.316)	(0.040)	(0.108)	(0.418)	(0.375)	(0.008)
p-value: test of treat. 1 = treat. 2	0.126	0.230	0.459	0.467	0.280	0.934	0.165	0.074	0.649	0.003
p-value: joint test of treat. 1 and treat. 2	0.008	0.002	0.000	0.000	0.000	0.090	0.191	0.195	0.191	0.000
N	1,028	1,028	1,028	1,028	1,028	1,028	1,028	1,028	1,028	1,028
Mean of dep. var. in control HHs	0.242	0.051	0.027	0.056	4.889	0.052	0.187	5.505	5.359	0.990
S.D. of dep. var. in control HHs	1.172	0.565	0.197	0.636	4.892	0.456	1.636	5.797	5.609	0.070

Notes: OLS estimates. All standard errors are clustered at the village level. *** p<0.01; ** p<0.05; *p<0.1
The omitted category is the control survey design (self-reporting).

Table 4

Treatment effects on land characteristics.

Dependent variable	(1) Main mode of acquisition of cultivated plots: inherited	(2) Main mode of acquisition of cultivated plots: gift/donation	(3) Main mode of acquisition of cultivated plots: other	(4) Main type of soil on cultivated plots: clayey	(5) Main type of soil on cultivated plots: sandy and clayey	(6) Main type of soil on cultivated plots: sandy	(7) Main type of soil on cultivated plots: sandy and stony	(8) Main type of soil on cultivated plots: other
Panel A: Estimates without the imbalanced covariates								
Treatment 1: HH head reporting	0.244***	-0.232***	-0.011	-0.134***	-0.014	0.253***	-0.028	-0.077***
	(0.049)	(0.048)	(0.009)	(0.044)	(0.037)	(0.047)	(0.022)	(0.026)
Treatment 2: Random proxy reporting	0.231***	-0.285***	0.054**	-0.140**	0.029	0.128**	0.043	-0.060*
	(0.051)	(0.047)	(0.024)	(0.058)	(0.043)	(0.056)	(0.037)	(0.031)
p-value: test of treat. 1 = treat. 2	0.696	0.061	0.005	0.909	0.365	0.057	0.093	0.425
p-value: joint test of treat. 1 and treat. 2	0.000	0.000	0.011	0.014	0.657	0.000	0.207	0.020
Panel B: Estimates with the imbalanced covariates								
Treatment 1: HH head reporting	0.224***	-0.218***	-0.006	-0.138***	-0.016	0.263***	-0.029	-0.080***
	(0.049)	(0.048)	(0.011)	(0.044)	(0.039)	(0.049)	(0.022)	(0.026)
Treatment 2: Random proxy reporting	0.215***	-0.272***	0.057**	-0.145**	0.031	0.134**	0.042	-0.063*
	(0.050)	(0.047)	(0.025)	(0.059)	(0.045)	(0.057)	(0.039)	(0.031)
p-value: test of treat. 1 = treat. 2	0.781	0.061	0.003	0.893	0.320	0.052	0.098	0.434
p-value: joint test of treat. 1 and treat. 2	0.000	0.000	0.005	0.011	0.604	0.000	0.193	0.014
N	1,028	1,028	1,028	1,028	1,028	1,028	1,028	1,028
Mean of dep. var. in control HHs	0.510	0.464	0.026	0.372	0.161	0.176	0.124	0.167
S.D. of dep. var. in control HHs	0.501	0.499	0.159	0.484	0.368	0.381	0.330	0.374

Notes: OLS estimates. All standard errors are clustered at the village level. *** p<0.01; ** p<0.05; *p<0.1
The omitted category is the control survey design (self-reporting).

Table 5A

Treatment effects on cereal and legume crop choice.

Dependent variable	(1) Rice	(2) Millet	(3) Sorghum	(4) Corn	(5) Cereals	(6) Bean	(7) Peanut	(8) Bambaranut	(9) Sesame	(10) Legumes
Panel A: Estimates without the imbalanced covariates										
Treatment 1: HH head reporting	0.053**	0.189***	-0.156**	0.058	0.036***	0.088**	-0.070*	-0.012	0.014	-0.020
	(0.024)	(0.043)	(0.061)	(0.040)	(0.012)	(0.040)	(0.036)	(0.024)	(0.029)	(0.043)
Treatment 2: Random proxy reporting	-0.040	-0.003	-0.064	-0.023	-0.014	0.043	-0.129**	-0.014	0.018	-0.092
	(0.026)	(0.065)	(0.076)	(0.042)	(0.018)	(0.035)	(0.048)	(0.025)	(0.039)	(0.059)
p-value: test of treat. 1 = treat. 2	0.000	0.017	0.340	0.076	0.013	0.189	0.096	0.946	0.900	0.109
p-value: joint test of treat. 1 and treat. 2	0.000	0.001	0.038	0.169	0.007	0.098	0.039	0.834	0.870	0.231
Panel B: Estimates with the imbalanced covariates										
Treatment 1: HH head reporting	0.067***	0.168***	-0.163**	0.113***	0.036**	0.087**	-0.057	-0.012	0.029	-0.012
	(0.021)	(0.047)	(0.061)	(0.040)	(0.014)	(0.039)	(0.037)	(0.027)	(0.028)	(0.045)
Treatment 2: Random proxy reporting	-0.029	-0.024	-0.064	0.032	-0.014	0.043	-0.112**	-0.012	0.038	-0.075
	(0.025)	(0.064)	(0.079)	(0.046)	(0.020)	(0.034)	(0.052)	(0.025)	(0.037)	(0.062)
p-value: test of treat. 1 = treat. 2	0.000	0.018	0.309	0.096	0.011	0.200	0.134	0.995	0.763	0.144
p-value: joint test of treat. 1 and treat. 2	0.000	0.004	0.034	0.028	0.009	0.100	0.115	0.872	0.526	0.328
N	993	993	993	993	993	993	993	993	993	993
Mean of dep. var. in control HHs	0.146	0.432	0.649	0.598	0.961	0.301	0.598	0.101	0.176	0.729
S.D. of dep. var. in control HHs	0.353	0.496	0.478	0.491	0.193	0.459	0.491	0.302	0.381	0.445

Notes: OLS estimates. All standard errors are clustered at the village level. *** p<0.01; ** p<0.05; *p<0.1
The omitted category is the control survey design (self-reporting). Crop choice variable takes value 1 if the household produced it. A household is considered producing cereal crops if it produced at least one of the following crops: rice, millet, sorghum, corn, and fonio; legume crops if it produced at least one of the following crops: bean, peanut, bambaranut, sesame, and soybean.

Table 5B

Treatment effects on vegetable and cash crop choice.

Dependent variable	(1) Tomato	(2) Okra	(3) Sorrel	(4) Vegetables	(5) Cotton	(6) Cash crops	(7) Crop diversity score
Panel A: Estimates without the imbalanced covariates							
Treatment 1: HH head	0.018	-0.003	-0.018	-0.036	0.038	0.027	0.221
reporting	(0.021)	(0.015)	(0.020)	(0.025)	(0.028)	(0.026)	(0.147)
Treatment 2: Random	-0.010	0.017	-0.006	0.011	-0.110***	-0.010	-0.313
proxy reporting	(0.016)	(0.033)	(0.020)	(0.038)	(0.040)	(0.029)	(0.210)
p-value: test of treat. 1 = treat. 2	0.195	0.561	0.565	0.171	0.001	0.137	0.013
p-value: joint test of treat. 1 and treat. 2	0.421	0.842	0.671	0.201	0.002	0.283	0.034
Panel B: Estimates with the imbalanced covariates							
Treatment 1: HH head	0.024	-0.009	-0.017	-0.042	0.048*	0.057**	0.304*
reporting	(0.024)	(0.018)	(0.021)	(0.028)	(0.027)	(0.026)	(0.159)
Treatment 2: Random	-0.003	0.015	-0.000	0.010	-0.098**	0.023	-0.199
proxy reporting	(0.016)	(0.033)	(0.021)	(0.040)	(0.040)	(0.032)	(0.237)
p-value: test of treat. 1 = treat. 2	0.197	0.504	0.473	0.151	0.001	0.179	0.022
p-value: joint test of treat. 1 and treat. 2	0.429	0.769	0.698	0.184	0.003	0.079	0.027
N	993	993	993	993	993	993	993
Mean of dep. var. in control HHs	0.042	0.149	0.125	0.217	0.229	0.866	3.625
S.D. of dep. var. in control HHs	0.200	0.356	0.331	0.413	0.421	0.341	1.754

Notes: OLS estimates. All standard errors are clustered at the village level. *** p<0.01; ** p<0.05; *p<0.1
The omitted category is the control survey design (self-reporting).
Crop choice variable takes value 1 if the household produced it. A household is considered producing vegetable crops if it produced at least one of the following crops: tomato, onion, okra, sorrel, eggplant, lettuce, cabbage, bell pepper, pepper, cucumber, and squash; cash crops if it produced at least one of the following crops: cotton, sesame, peanut, and corn. Fruit crops and root and tuber crops were produced by only three households in the sample. Crop diversity score is the total number of crops produced.

Results on the use of agricultural inputs

Estimations of the ownership of machinery in Table 6A show an over-reporting of the ownership of straw choppers (+10 percentage points) with the random proxy reporting treatment relative to the self-reporting treatment; and an under-reporting of the ownership of plowing animals (-8 percentage points), sowing machines (-22 percentage points), and straw choppers (-10 percentage points) with the household head reporting treatment relative to the self-reporting treatment. This result suggests that interviewing the household head leads to underestimating the level of ownership of machinery, especially by counting plowing animals as household's livestock assets but not as machinery and by under-reporting machinery used by the other household members such as the sowing machines and straw choppers.

Table 6B presents the results on the use of inorganic fertilizer and chemicals. On the one hand, no evidence of bias is observed in the reporting of the use of inorganic fertilizer and chemicals by the household head, probably because these inputs are purchased and controlled by the household head within the household. On the other hand, a random proxy respondent under-reports the use of inorganic fertilizer by 10 percentage points relative to the control reporting, followed by a lower monetary value of inorganic fertilizer used by the random proxy reporting households. Similarly, there is an under-reporting of the use of chemicals by 12 percentage points with the random proxy reporting treatment, followed by a lower monetary value of chemicals used by the random proxy reporting households.

The two treatment survey designs are associated with an over-reporting of the use or cow-based and goat-based manure and an under-reporting of the quantity of other manure (chicken-based) relative to the self-reporting treatment (Table 6C, columns one through six). There is an increase in the use of cow-based manure by 13 percentage points, as compared to the control households which have a 28% rate of use of cow-based manure. While self-reporting households have a 10% rate of use of goat-based manure, treated households have a 100% rate of use of goat-based manure, indicating an increase in the use of goat-based manure by 90 percentage points, followed by a higher quantity of goat-based manure used by treated households. The last column of Table 6C shows no change in the reporting of the use of irrigation across the survey design methods, probably because agricultural water sources are well-known by the household and whether a crop is irrigated is of common knowledge within the household.

Table 6A

Treatment effects on ownership of machinery.

Dependent variable	(1) Plow	(2) Cart	(3) Plowing animals	(4) Seeder	(5) Watering can	(6) Sprayer	(7) Straw chopper
Panel A: Estimates without the imbalanced covariates							
Treatment 1: HH head reporting	-0.037	-0.064*	-0.130***	-0.236***	-0.028	-0.042	-0.135***
	(0.039)	(0.034)	(0.035)	(0.055)	(0.018)	(0.043)	(0.029)
Treatment 2: Random proxy reporting	-0.070**	-0.100**	-0.060*	0.002	-0.043	0.016	0.076
	(0.034)	(0.038)	(0.033)	(0.057)	(0.030)	(0.056)	(0.048)
p-value: test of treatment 1 = treatment 2	0.377	0.336	0.088	0.000	0.640	0.254	0.001
p-value: joint test of treatment 1 and treatment 2	0.140	0.036	0.003	0.000	0.187	0.420	0.000
Panel B: Estimates with the imbalanced covariates							
Treatment 1: HH head reporting	0.015	0.002	-0.079**	-0.221***	0.010	0.005	-0.100***
	(0.029)	(0.028)	(0.034)	(0.056)	(0.018)	(0.040)	(0.022)
Treatment 2: Random proxy reporting	-0.009	-0.035	-0.001	0.013	-0.016	0.056	0.102**
	(0.029)	(0.035)	(0.027)	(0.056)	(0.029)	(0.046)	(0.043)
p-value: test of treatment 1 = treatment 2	0.431	0.235	0.040	0.000	0.302	0.235	0.001
p-value: joint test of treatment 1 and treatment 2	0.726	0.470	0.067	0.000	0.526	0.414	0.000
N	1,028	1,028	1,028	1,028	1,028	1,028	1,028
Mean of dep. var. in control HHs	0.680	0.484	0.637	0.254	0.153	0.225	0.144
S.D. of dep. var. in control HHs	0.467	0.500	0.482	0.436	0.360	0.418	0.352

Notes: OLS estimates. All standard errors are clustered at the village level. *** p<0.01; ** p<0.05; *p<0.1
The omitted category is the control survey design (self-reporting).

Table 6B

Treatment effects on use of inorganic fertilizer and chemicals.

Dependent variable	(1) HH used fertilizer	(2) Log quantity of fertilizer (Kg/ha)	(3) Log value of fertilizer (USD/ha)	(4) HH used chemicals	(5) Log quantity of chemicals (L/ha)	(6) Log value of chemicals (USD/ha)
Panel A: Estimates without the imbalanced covariates						
Treatment 1: HH head reporting	-0.057* (0.029)	-0.053 (0.133)	-0.141 (0.122)	0.007 (0.041)	-0.037 (0.066)	-0.061 (0.101)
Treatment 2: Random proxy reporting	-0.137*** (0.039)	-0.140 (0.127)	-0.369** (0.135)	-0.154*** (0.042)	-0.078 (0.086)	-0.317** (0.117)
p-value: test of treatment 1 = treatment 2	0.057	0.313	0.146	0.005	0.545	0.039
p-value: joint test of treatment 1 and treatment 2	0.004	0.414	0.033	0.003	0.668	0.033
Panel B: Estimates with the imbalanced covariates						
Treatment 1: HH head reporting	-0.014 (0.032)	0.013 (0.128)	0.007 (0.132)	0.040 (0.044)	0.024 (0.070)	0.028 (0.111)
Treatment 2: Random proxy reporting	-0.097** (0.038)	-0.079 (0.132)	-0.228* (0.128)	-0.119*** (0.040)	-0.029 (0.087)	-0.225* (0.114)
p-value: test of treatment 1 = treatment 2	0.034	0.297	0.122	0.005	0.442	0.039
p-value: joint test of treatment 1 and treatment 2	0.043	0.563	0.172	0.007	0.728	0.076
N	1,028	1,028	1,028	1,028	1,028	1,028
Mean of dep. var. in control HHs	0.738	1.110	2.215	0.744	0.595	1.658
S.D. of dep. var. in control HHs	0.440	1.311	1.603	0.437	0.795	1.315

Notes: OLS estimates. All standard errors are clustered at the village level. *** p<0.01; ** p<0.05; *p<0.1
The omitted category is the control survey design (self-reporting).
Chemicals include pesticides, insecticides, and herbicides.

Table 6C

Treatment effects on use of manure and irrigation.

Dependent variable	(1) HH used cow manure	(2) Log quantity of cow manure (Kg/ha)	(3) HH used goat manure	(4) Log quantity of goat manure (Kg/ha)	(5) HH used other manure	(6) Log quantity of other manure (Kg/ha)	(7) HH used irrigation
Panel A: Estimates without the imbalanced covariates							
Treatment 1: HH head reporting	0.089*	0.097	0.902***	0.280***	-0.216***	-0.569***	-0.020
	(0.051)	(0.125)	(0.020)	(0.082)	(0.053)	(0.159)	(0.023)
Treatment 2: Random proxy reporting	0.101*	0.086	0.902***	0.204**	-0.002	-0.285**	-0.019
	(0.057)	(0.142)	(0.020)	(0.092)	(0.045)	(0.133)	(0.020)
p-value: test of treat. 1 = treat. 2	0.758	0.923	.	0.342	0.001	0.022	0.944
p-value: joint test of treat. 1 and treat. 2	0.176	0.738	0.000	0.006	0.001	0.004	0.626
Panel B: Estimates with the imbalanced covariates							
Treatment 1: HH head reporting	0.125**	0.133	0.900***	0.263***	-0.202***	-0.567***	-0.010
	(0.051)	(0.125)	(0.020)	(0.082)	(0.055)	(0.171)	(0.021)
Treatment 2: Random proxy reporting	0.126**	0.105	0.899***	0.193**	0.013	-0.274*	-0.011
	(0.055)	(0.143)	(0.020)	(0.089)	(0.044)	(0.138)	(0.017)
p-value: test of treat. 1 = treat. 2	0.962	0.777	0.733	0.382	0.000	0.019	0.956
p-value: joint test of treat. 1 and treat. 2	0.054	0.568	0.000	0.011	0.001	0.007	0.813
N	1,028	1,028	1,028	1,028	1,028	1,028	1,028
Mean of dep. var. in control HHs	0.280	0.611	0.098	0.167	0.308	0.736	0.069
S.D. of dep. var. in control HHs	0.449	1.313	0.298	0.717	0.462	1.359	0.254

Notes: OLS estimates. All standard errors are clustered at the village level. *** p<0.01; ** p<0.05; *p<0.1
The omitted category is the control survey design (self-reporting).

Results on the use of labor

Table 7A illustrates the effects of the treatment survey designs on unpaid household labor (columns one through four) and unpaid non-household labor (columns five through seven). Estimations of the use of unpaid household labor show a 0.39 log-increase in the number of person-days per year for the unpaid household male labor under household head reporting, translating into a 0.26 log-increase in the number of person-days per year for the total unpaid household labor. Under the random proxy reporting treatment, there is a marginal decrease in the number of person-days per year for the unpaid household female labor by 0.45 log-units.

Unpaid non-household labor is under-reported by proxy reporting households. The household head reporting treatment is associated with a 0.51 log-decrease in the number of person-days per year for the unpaid non-household labor of relatives, followed by a 0.37 log-decrease in the number of person-days per year for the total unpaid non-household labor. The random proxy reporting treatment is associated with a smaller number of person-days per year for the unpaid non-household labor of relatives (0.78 log-decrease) and non-relatives (0.62 log-decrease), followed by a 0.96 log-decrease in the number of person-days per year for the total unpaid non-household labor. Additional results on the use of labor relate to salaried labor (Table 7B) and total labor (Table 7C). There is no evidence of bias in the reporting of salaried labor by the household labor, probably because salaried labor decisions are made by the household head. Conversely, as shown in the first column of Table 7B, there is an under-reporting of the use of salaried labor by 10 percentage points, after interviewing a random proxy household member. Column one of Table 7C indicates that child labor reporting is not affected by any treatment survey design.

Column two of Table 7C indicates a marginal over-reporting of total labor with the household head reporting treatment (resulting from the over-reporting of unpaid household male labor) and a marginal under-reporting of total labor with the random proxy reporting treatment (resulting from the under-reporting of unpaid household female labor and unpaid non-household labor). Columns three through five of Table 7C show that the random proxy reporting treatment is associated with a 0.34 log-decrease in the total payment of labor and a 0.18 log-decrease in the total payment of labor per hectare. However, after restricting the sample to households who use salaried labor, we find no significant effect of the random proxy reporting treatment on the total payment of labor per hectare. Rather, we do find a marginal positive effect of the household head reporting treatment on the total payment of labor per hectare (Table 7C, last column).

Table 7A

Treatment effects on unpaid labor.

Dependent variable	(1) Log unpaid household male labor (person-days/year)	(2) Log unpaid household female labor (person-days/year)	(3) Log unpaid household child labor (person-days/year)	(4) Log total unpaid household labor (person-days/year)	(5) Log unpaid non-household labor of relatives (person-days/year)	(6) Log unpaid non-household labor of non-relatives (pers.-days/year)	(7) Log total unpaid non-household labor (person-days/year)
Panel A: Estimates without the imbalanced covariates							
Treatment 1: HH head reporting	0.298*	-0.009	0.057	0.181	-0.515***	-0.194	-0.373**
	(0.154)	(0.115)	(0.192)	(0.110)	(0.150)	(0.127)	(0.155)
Treatment 2: Random proxy reporting	-0.367	-0.514*	-0.271	-0.493*	-0.773***	-0.605***	-0.938***
	(0.297)	(0.264)	(0.210)	(0.267)	(0.206)	(0.161)	(0.227)
p-value: test of T1=T2	0.019	0.068	0.189	0.017	0.122	0.002	0.004
p-value: joint test of T1 T2	0.019	0.159	0.362	0.032	0.001	0.002	0.001
Panel B: Estimates with the imbalanced covariates							
Treatment 1: HH head reporting	0.395**	0.075	0.170	0.260**	-0.509***	-0.198	-0.372**
	(0.147)	(0.123)	(0.200)	(0.116)	(0.152)	(0.128)	(0.151)
Treatment 2: Random proxy reporting	-0.281	-0.450*	-0.164	-0.431	-0.783***	-0.616***	-0.955***
	(0.295)	(0.259)	(0.210)	(0.267)	(0.201)	(0.157)	(0.219)
p-value: test of T1=T2	0.015	0.055	0.173	0.013	0.089	0.002	0.002
p-value: joint test of T1 T2	0.004	0.154	0.389	0.013	0.001	0.001	0.001
N	1,025	1,025	1,025	1,025	1,025	1,025	1,025
Mean of dep. var. in control HHs	4.605	4.989	3.282	5.873	1.536	0.745	1.789
S.D. of dep. var. in control HHs	1.517	1.190	2.245	1.108	1.822	1.468	1.963

Notes: OLS estimates. All standard errors are clustered at the village level. *** p<0.01; ** p<0.05; *p<0.1
The omitted category is the control survey design (self-reporting).

Table 7B

Treatment effects on salaried labor.

Dependent variable	(1) HH used salaried labor	(2) Log paid non-hh male labor (person-days/year)	(3) Log paid non-hh female labor (pers.-days/year)	(4) Log paid non-hh child labor (person-days/year)	(5) Log total paid non-hh labor (person-days/year)	(6) Log payment of non-hh male labor (USD/year)	(7) Log paymt. of non-hh female labor (USD/year)	(8) Log payment of non-hh child labor (USD/year)	(9) Log total payment of labor – conditional (USD/year)
Panel A: Estimates without the imbalanced covariates									
Treatment 1:	-0.093**	0.167	-0.250	0.017	-0.165	0.329	-0.245	0.154	0.120
HH head reporting	(0.044)	(0.216)	(0.240)	(0.168)	(0.150)	(0.241)	(0.237)	(0.129)	(0.155)
Treatment 2:	-0.120**	-0.134	0.136	-0.106	0.064	-0.437	0.146	-0.018	-0.112
Random proxy reporting	(0.044)	(0.297)	(0.280)	(0.197)	(0.218)	(0.276)	(0.278)	(0.166)	(0.227)
p-value: test of T1=T2	0.513	0.206	0.285	0.538	0.296	0.001	0.287	0.386	0.227
p-value: joint test of T1 T2	0.029	0.371	0.503	0.812	0.426	0.003	0.511	0.483	0.401
Panel B: Estimates with the imbalanced covariates									
Treatment 1:	-0.068	0.219	-0.105	-0.086	-0.141	0.387	-0.075	0.084	0.210
HH head reporting	(0.044)	(0.241)	(0.241)	(0.190)	(0.155)	(0.253)	(0.240)	(0.134)	(0.149)
Treatment 2:	-0.102**	-0.138	0.314	-0.179	0.088	-0.406	0.357	-0.066	0.009
Random proxy reporting	(0.045)	(0.334)	(0.269)	(0.198)	(0.212)	(0.308)	(0.251)	(0.152)	(0.212)
p-value: test of T1=T2	0.387	0.172	0.212	0.640	0.276	0.001	0.194	0.430	0.262
p-value: joint test of T1 T2	0.095	0.291	0.420	0.669	0.468	0.004	0.336	0.716	0.254
N	1,025	329	329	329	329	329	329	329	329
Mean of dep. var. in control HHs	0.391	1.995	1.606	0.658	3.233	2.198	1.540	0.521	3.256
S.D. of dep.	0.489	1.679	1.874	1.199	1.305	1.668	1.761	0.993	1.159

var. in control HHs

Notes: OLS estimates. All standard errors are clustered at the village level. *** p<0.01; ** p<0.05; *p<0.1

The omitted category is the control survey design (self-reporting).

Table 7C

Treatment effects on total labor.

Dependent variable	(1) Log total child labor (person-days/year)	(2) Log total labor (person-days/year	(3) Log total payment of labor – unconditional (USD/year)	(4) Log total labor per hectare (person-days/year/ha)	(5) Log total payment of labor per hectare – unconditional (USD/year/ha)	(6) Log total payment of labor per hectare – conditional (USD/year/ha)
Panel A: Estimates without the imbalanced covariates						
Treatment 1: HH head reporting	0.021	0.119	-0.266*	0.178	-0.097	0.264**
	(0.175)	(0.107)	(0.147)	(0.118)	(0.093)	(0.127)
Treatment 2: Random proxy reporting	-0.301	-0.461*	-0.420***	-0.271	-0.212**	0.052
	(0.206)	(0.239)	(0.133)	(0.221)	(0.093)	(0.163)
p-value: test of T1=T2	0.190	0.020	0.332	0.042	0.271	0.112
p-value: joint test of T1 T2	0.324	0.055	0.011	0.073	0.085	0.068
Panel B: Estimates with the imbalanced covariates						
Treatment 1: HH head reporting	0.126	0.193*	-0.150	0.120	-0.048	0.254*
	(0.184)	(0.113)	(0.144)	(0.120)	(0.094)	(0.137)
Treatment 2: Random proxy reporting	-0.196	-0.405*	-0.341**	-0.328	-0.181*	0.031
	(0.209)	(0.238)	(0.130)	(0.223)	(0.095)	(0.181)
p-value: test of T1=T2	0.183	0.015	0.200	0.049	0.188	0.109
p-value: joint test of T1 T2	0.406	0.028	0.044	0.124	0.166	0.077
N	1,025	1,025	1,025	1,025	1,025	329
Mean of dep. var. in control HHs	3.371	6.002	1.274	4.812	0.740	1.892
S.D. of dep. var. in control HHs	2.182	1.081	1.748	1.042	1.116	1.000

Notes: OLS estimates. All standard errors are clustered at the village level. *** p<0.01; ** p<0.05; *p<0.1
The omitted category is the control survey design (self-reporting).

Results on agricultural output and agricultural productivity

Table 8A illustrates the treatment effects on output and yield of food crops. An increase in cereal output by 1.05 log-units is observed translating in a higher output of food crops with the household head reporting treatment (columns one and four). The household head reporting treatment is also associated with an increase in cereal yield by 0.97 log-units and an increase in food crop yield by 0.4 log-units (columns five and eight). The positive household head reporting effects on yield in cereals is not surprising since this treatment leads to no significant change in cultivated area (Table 3, column nine) while it leads to an over-reporting in cereal crop choices (Table 5A, column five) and an increase in cereal output (Table 8A, column one).

The increase in cereal output and food crop output with the household head reporting treatment also reflects on the quantity sold of cereals and food crops, leading to no significant change in the commercialization index of cereals and food crops with this treatment (Appendix Tables 1A and 1B). Results also show a decrease in legume output by 0.75 log-units with the random proxy reporting treatment, which does not translate into a significantly lower yield in legumes (Table 8A, columns two and six). The missing random proxy reporting effects on yield in legumes can be explained by the simultaneous drop in the cultivated area (Table 3, column nine) and in the legume output (Table 8, column two) with this treatment.

Additional results relate to the treatment effects on the value of output (Table 8B) and on the value of output per hectare (Table 8C) for cereals, legumes, vegetables, all food crops, all cash crops, and the total output. Consistently with the over-reporting of cereal and cash crop choices with the household head treatment (Tables 4A and 4B), an increase in the value of cereal output by 0.89 log-units is observed and in the value of cash crop output by 0.44 log units (Table 8B, columns one and five). Since there is no effect on cultivated area (Table 3) with the household head treatment, the positive effects on the value of output from cereal and cash crops translate into higher cereal productivity (+0.75 log units) and higher cash crop productivity (+0.38 log units) as evidenced for this treatment in columns one and five of Table 8C.

Table 8A

Treatment effects on output and yield of food crops.

Dependent variable	(1) Log cereal output (kg)	(2) Log legume output (kg)	(3) Log vegetable output (kg)	(4) Log food crop output (kg)	(5) Log cereal yield (kg/ha)	(6) Log legume yield (kg/ha)	(7) Log vegetable yield (kg/ha)	(8) Log food crop yield (kg/ha)
Panel A: Estimates without the imbalanced covariates								
Treatment 1: HH head reporting	0.837***	-0.414	-0.135	0.316**	0.883***	-0.224	-0.107	0.370***
	(0.227)	(0.285)	(0.123)	(0.152)	(0.207)	(0.227)	(0.104)	(0.129)
Treatment 2: Random proxy reporting	-0.487**	-0.940**	-0.080	-0.537***	-0.236	-0.554*	-0.054	-0.329*
	(0.227)	(0.375)	(0.158)	(0.195)	(0.199)	(0.310)	(0.136)	(0.177)
p-value: test of treat. 1 = treat. 2	0.000	0.049	0.681	0.000	0.000	0.153	0.657	0.000
p-value: joint test of treat. 1 and treat. 2	0.000	0.049	0.549	0.000	0.000	0.207	0.585	0.001
Panel B: Estimates with the imbalanced covariates								
Treatment 1: HH head reporting	1.048***	-0.279	-0.102	0.501***	0.970***	-0.174	-0.091	0.422***
	(0.230)	(0.284)	(0.153)	(0.147)	(0.216)	(0.235)	(0.126)	(0.133)
Treatment 2: Random proxy reporting	-0.287	-0.748*	-0.027	-0.353	-0.147	-0.447	-0.020	-0.265
	(0.239)	(0.389)	(0.171)	(0.215)	(0.209)	(0.316)	(0.144)	(0.190)
p-value: test of treat. 1 = treat. 2	0.000	0.082	0.579	0.000	0.000	0.229	0.547	0.000
p-value: joint test of treat. 1 and treat. 2	0.000	0.143	0.747	0.000	0.000	0.354	0.709	0.000
N	993	993	993	993	993	993	993	993
Mean of dep. var. in control HHs	6.245	4.364	0.774	7.138	5.050	3.388	0.598	5.925
S.D. of dep. var. in control HHs	2.585	3.233	1.992	1.990	2.253	2.607	1.620	1.721

Notes: OLS estimates. All standard errors are clustered at the village level. *** p<0.01; ** p<0.05; *p<0.1
The omitted category is the control survey design (self-reporting).
Food crops include cereals (rice, millet, sorghum, corn, and fonio), legumes (bean, peanut, bambaranut, sesame, and soybean), and vegetables (tomato, onion, okra, sorrel, eggplant, lettuce, cabbage, bell pepper, pepper, cucumber, and squash).

Table 8B

Treatment effects on value of output.

Dependent variable	(1) Log value of cereal output (USD)	(2) Log value of legume output (USD)	(3) Log value of vegetable output (USD)	(4) Log value of food crop output (USD)	(5) Log value of cash crop output (USD)	(6) Log total value of output (USD)
Panel A: Estimates without the imbalanced covariates						
Treatment 1: HH head reporting	0.717***	-0.438	-0.291	-0.096	0.145	-0.105
	(0.206)	(0.289)	(0.231)	(0.184)	(0.203)	(0.174)
Treatment 2: Random proxy reporting	-0.344*	-0.686*	-0.016	-0.498*	-0.280	-0.448*
	(0.202)	(0.368)	(0.323)	(0.292)	(0.219)	(0.250)
p-value: test of treat. 1 = treat. 2	0.000	0.366	0.378	0.169	0.062	0.171
p-value: joint test of treat. 1 and treat. 2	0.001	0.182	0.403	0.247	0.167	0.216
Panel B: Estimates with the imbalanced covariates						
Treatment 1: HH head reporting	0.886***	-0.349	-0.263	0.046	0.438**	0.064
	(0.205)	(0.300)	(0.271)	(0.190)	(0.195)	(0.181)
Treatment 2: Random proxy reporting	-0.198	-0.522	0.066	-0.329	0.036	-0.250
	(0.212)	(0.385)	(0.344)	(0.313)	(0.234)	(0.265)
p-value: test of treat. 1 = treat. 2	0.000	0.531	0.304	0.208	0.120	0.228
p-value: joint test of treat. 1 and treat. 2	0.000	0.393	0.471	0.447	0.082	0.479
N	993	993	993	993	993	993
Mean of dep. var. in control HHs	4.994	4.228	1.601	6.979	4.633	7.194
S.D. of dep. var. in control HHs	2.556	3.733	3.660	3.079	2.908	3.021

Notes: OLS estimates. All standard errors are clustered at the village level. *** p<0.01; ** p<0.05; *p<0.1

The omitted category is the control survey design (self-reporting).

Food crops include cereals (rice, millet, sorghum, corn, and fonio), legumes (bean, peanut, bambaranut, sesame, and soybean), and vegetables (tomato, onion, okra, sorrel, eggplant, lettuce, cabbage, bell pepper, pepper, cucumber, and squash). Cash crops include cotton, sesame, peanut, and corn. Total value of output is the sum of values of individual crop output, not the sum of values of food crop output and cash crop output.

Table 8C

Treatment effects on productivity.

Dependent variable	(1) Log cereal productivity (USD/ha)	(2) Log legume productivity (USD/ha)	(3) Log vegetable productivity (USD/ha)	(4) Log food crop productivity (USD/ha)	(5) Log cash crop productivity (USD/ha)	(6) Log total productivity (USD/ha)
Panel A: Estimates without the imbalanced covariates						
Treatment 1: HH head reporting	0.709***	-0.249	-0.257	-0.058	0.221	-0.062
	(0.198)	(0.233)	(0.209)	(0.180)	(0.168)	(0.173)
Treatment 2: Random proxy reporting	-0.105	-0.343	-0.001	-0.297	-0.108	-0.293
	(0.171)	(0.313)	(0.295)	(0.276)	(0.192)	(0.246)
p-value: test of treat. 1 = treat. 2	0.003	0.700	0.390	0.426	0.098	0.399
p-value: joint test of treat. 1 and treat. 2	0.004	0.497	0.431	0.564	0.208	0.498
Panel B: Estimates with the imbalanced covariates						
Treatment 1: HH head reporting	0.752***	-0.248	-0.247	-0.052	0.383**	-0.035
	(0.201)	(0.246)	(0.245)	(0.181)	(0.174)	(0.177)
Treatment 2: Random proxy reporting	-0.075	-0.268	0.060	-0.253	0.086	-0.224
	(0.182)	(0.318)	(0.310)	(0.285)	(0.197)	(0.253)
p-value: test of treat. 1 = treat. 2	0.003	0.935	0.306	0.487	0.172	0.477
p-value: joint test of treat. 1 and treat. 2	0.002	0.591	0.469	0.676	0.099	0.677
N	993	993	993	993	993	993
Mean of dep. var. in control HHs	3.866	3.251	1.374	5.789	3.484	5.993
S.D. of dep. var. in control HHs	2.342	3.297	3.236	2.998	2.485	2.914

Notes: OLS estimates. All standard errors are clustered at the village level. *** p<0.01; ** p<0.05; *p<0.1
The omitted category is the control survey design (self-reporting).
Productivity is value of output per hectare cultivated. Food crops include cereals (rice, millet, sorghum, corn, and fonio), legumes (bean, peanut, bambaranut, sesame, and soybean), and vegetables (tomato, onion, okra, sorrel, eggplant, lettuce, cabbage, bell pepper, pepper, cucumber, and squash). Cash crops include cotton, sesame, peanut, and corn. Aggregate value of output is the sum of values of individual crop output.

Results on the relationship between land size and agricultural productivity

A growing literature has investigated the effects of mismeasurement on the inverse land size relationship (Carletto et al. 2013, Dillon et al. 2016, Bevis and Barrett 2017, Desiere and Jolliffe 2017, Dillon and Rao 2017). As we estimate the effects of proxy response relative to self-reported responses on land size, it is possible that mismeasurement due to proxy response may bias the inverse land size relationship which we investigate using four econometric specifications:

$$y_i = \delta_0 + \delta_1 T_{1i} + \delta_2 T_{2i} + \gamma_0 A_i + u_i \quad (4)$$

$$y_i = \delta_0 + \delta_1 T_{1i} + \delta_2 T_{2i} + \gamma_0 A_i + \varphi' X_i + u_i \quad (5)$$

$$y_i = \delta_0 + \delta_1 T_{1i} + \delta_2 T_{2i} + \gamma_0 A_i + \gamma_1 T_{1i} * A_i + \gamma_2 T_{2i} * A_i + u_i \quad (6)$$

$$y_i = \delta_0 + \delta_1 T_{1i} + \delta_2 T_{2i} + \gamma_0 A_i + \gamma_1 T_{1i} * A_i + \gamma_2 T_{2i} * A_i + \varphi' X_i + u_i \quad (7)$$

In Equations 4-7, the outcome y_i of household i represents any of the three following variables log-transformed: total value of output per hectare, value of food crop output per hectare, and value of cash crop output per hectare; the variable A_i represents the log of the total area cultivated by household i; the error component is denoted u_i; and all other variables keep their previous definitions.

In Equations 4-5, we expect the coefficient γ_0 to be negative as hypothesized by the theory. The coefficients δ_1 and δ_2 are naturally interpreted as the treatment effects after controlling for land size in Equation 4, and after controlling for land size and the imbalanced covariates in Equation 5. We are interested in testing two null hypotheses, (i) $\delta_1 = 0$ and $\delta_2 = 0$ which states that only land size matters on the outcome; and (ii) $\delta_1 = \delta_2$ which states that the individual effects of treatment 1 and treatment 2 are the same.

In Equations 6-7, the effects of land size on the outcome are $(\gamma_0 + \gamma_1)$ under the household head reporting treatment, and $(\gamma_0 + \gamma_2)$ under the random proxy reporting treatment. We expect these two effects to be negative, implying the inverse relationship is maintained under any treatment. We then test two null hypotheses (i) $\gamma_0 + \gamma_1 = 0$ and (ii) $\gamma_0 + \gamma_2 = 0$. We also test the null hypotheses (iii) $\gamma_1 = \gamma_2$ which states that the interaction effects are the same, and (iv) $\delta_1 = \delta_2 = \gamma_1 = \gamma_2 = 0$ which states that only the individual effect of land size matters on the outcome.

Results on the land size-productivity relationship are presented in the regressions of the value of total output per hectare (Table 9), the value of food crop output per hectare (Table 10), and the value of cash crop output per hectare (Table 11). Columns one and two of Table 9 show that, in the econometric specifications without interaction terms, the effect of land size on total crop productivity is negative: 1% increase in the total area cultivated leads to a 0.4 to 0.6% decrease in the value of total output per hectare. In these specifications, the individual effects of the treatment survey designs are statistically insignificant. However, in the econometric specifications without interaction terms (columns three and four of Table 9), we find that the treatment survey designs matter. While we fail to reject the null hypothesis that the effect of land size on total crop productivity under household head reporting treatment is insignificant (columns three and four), we reject that the effect under random proxy reporting treatment is insignificant at the 10% level of significance in column three and at the 5% level of significance in column four.

These results suggest that the expected inverse relationship is significantly maintained under the random proxy reporting treatment the control reporting, but not under the household head reporting treatment. Under the control reporting method, 1% increase in the total area cultivated leads to a 0.4 to 0.6% decrease in the value of total output per hectare (Table 9, all columns). Under the random proxy reporting treatment, a 1% increase in the total area cultivated leads to a 0.7 to 0.8% decrease in the value of total output per hectare (Table 9, columns three and four). However, under the household head reporting treatment, the effect of the total area cultivated on the value of total output per hectare is insignificant, albeit negative (Table 9, columns three and four).

Table 9
Effects of land size on total productivity.

	(1) coef/se	(2) coef/se	(3) coef/se	(4) coef/se
Dependent variable: Log total productivity (USD/ha)				
Treatment 1: HH head reporting	-0.106	-0.040	-0.555	-0.516
	(0.170)	(0.176)	(0.512)	(0.504)
Treatment 2: Random proxy reporting	-0.349	-0.253	0.049	0.148
	(0.238)	(0.248)	(0.583)	(0.566)
Log total area cultivated (ha)	-0.420**	-0.555**	-0.419*	-0.560**
	(0.194)	(0.207)	(0.215)	(0.245)
Treatment 1 * Log total area cultivated (ha)			0.300	0.319
			(0.341)	(0.345)
Treatment 2 * Log total area cultivated (ha)			-0.272	-0.273
			(0.324)	(0.315)
Includes imbalanced covariates	no	yes	no	yes
Includes interaction between treat. and land size	no	no	yes	yes
p-value: test of treatment 1 = treatment 2	0.356	0.413		
p-value: joint test of treatment 1 and treatment 2	0.337	0.598		
p-value: test of Log total area cultivated (ha) + Interaction with treatment 1			0.675	0.383
p-value: test of Log total area cultivated (ha) + Interaction with treatment 2			0.056	0.024
p-value: test of Interaction with treatment 1 = Interaction with treatment 2			0.173	0.166
p-value: joint test of treatment 1, treatment 2, Interaction with treatment 1, and Interaction with treatment 2			0.305	0.467
N	993	993	993	993

Notes: OLS estimates.
All standard errors are clustered at the village level. *** p<0.01; ** p<0.05; *p<0.1
The omitted category is the control survey design (self-reporting).
Total productivity is total value of output per hectare cultivated.

The results about the effect of land size on cereal crop productivity in Table 10 are similar to the results in Table 9. We reject that the effect under random proxy reporting treatment is insignificant at the 5% level of significance in column three and at the 1% level of significance in column four. Under the random proxy reporting treatment, a 1% increase in the total area cultivated results in a 0.9 to 1.1% decrease in the value of cereal crop output per hectare (Table 10, columns three and four). Under the control reporting, a 1% increase in the total area cultivated results in a 0.6 to 0.7% decrease in the value of cereal output per hectare (Table 10, all columns). However, under the household head reporting treatment, the effect of the total area cultivated on the value of cereal output per hectare is insignificant, albeit negative (Table 10, columns three and four).

Table 10
Effects of land size on cereal productivity.

	(1) coef/se	(2) coef/se	(3) coef/se	(4) coef/se
Dependent variable: Log cereal productivity (USD/ha)				
Treatment 1: HH head reporting	-0.122	-0.058	-0.532	-0.496
	(0.177)	(0.182)	(0.519)	(0.513)
Treatment 2: Random proxy reporting	-0.381	-0.292	0.163	0.254
	(0.268)	(0.281)	(0.593)	(0.576)
Log total area cultivated (ha)	-0.617***	-0.745***	-0.580**	-0.714***
	(0.202)	(0.212)	(0.217)	(0.248)
Treatment 1 * Log total area cultivated (ha)			0.277	0.296
			(0.347)	(0.351)
Treatment 2 * Log total area cultivated (ha)			-0.368	-0.369
			(0.338)	(0.333)
Includes imbalanced covariates	no	yes	no	yes
Includes interaction between treat. and land size	no	no	yes	yes
p-value: test of treatment 1 = treatment 2	0.370	0.412		
p-value: joint test of treatment 1 and treatment 2	0.351	0.589		
p-value: test of Log total area cultivated (ha) + Interaction with treatment 1			0.298	0.149
p-value: test of Log total area cultivated (ha) + Interaction with treatment 2			0.018	0.007
p-value: test of Interaction with treatment 1 = Interaction with treatment 2			0.166	0.160
p-value: joint test of treatment 1, treatment 2, Interaction with treatment 1, and Interaction with treatment 2			0.361	0.515
N	993	993	993	993

Notes: OLS estimates.
All standard errors are clustered at the village level. *** p<0.01; ** p<0.05; *p<0.1
The omitted category is the control survey design (self-reporting).
Cereal productivity is value of cereal output per hectare cultivated.

We do not find a similar pattern of results when we estimate the effect of land size on cash crop productivity in Table 11 as in Tables 9 and 10. Under the self-reported treatment, a 1% increase in the total area cultivated results in a 0.4 to 0.7% increase in the value of cash crop output (Table 11, all columns). The unexpected positive effect remains significant at the 10% level of significance under household head reporting treatment and at the 1% level of significance under random proxy reporting treatment. Under the household head reporting treatment, 1% increase in the total area cultivated results in a 0.6 to 0.8% increase in the value of cash crop output (Table 11, columns three and four). Under the random proxy reporting treatment, 1% increase in the total area cultivated results in a 0.4 to 0.6% increase in the value of cash crop output (Table 11, columns three and four).

The positive land size - cash crop productivity could be due to increasing returns to scale technologies of cash crop production—especially cotton. The large adoption of sustainable cotton production technologies in Burkina Faso generates not only environmental benefits (Vitale et al., 2011), but also productivity benefits. Vitale et al (2016) find that large GM cotton farms intensify household labor and obtain higher productivity than conventional cotton farms. Savadogo et al. (1998) also emphasize the higher intensity of use of variable inputs on cash crops, but not on subsistence crops.

Table 11
Effects of land size on cash crop productivity.

	(1) coef/se	(2) coef/se	(3) coef/se	(4) coef/se
Dependent variable: Log cash crop productivity (USD/ha)				
Treatment 1: HH head reporting	0.293*	0.386**	0.027	0.094
	(0.164)	(0.173)	(0.464)	(0.447)
Treatment 2: Random proxy reporting	-0.015	0.110	0.010	0.135
	(0.203)	(0.199)	(0.625)	(0.600)
Log total area cultivated (ha)	0.691***	0.465***	0.649***	0.418*
	(0.160)	(0.164)	(0.237)	(0.246)
Treatment 1 * Log total area cultivated (ha)			0.175	0.193
			(0.258)	(0.259)
Treatment 2 * Log total area cultivated (ha)			-0.021	-0.021
			(0.367)	(0.363)
Includes imbalanced covariates	no	yes	no	yes
Includes interaction between treat. and land size	no	no	yes	yes
p-value: test of treatment 1 = treatment 2	0.132	0.199		
p-value: joint test of treatment 1 and treatment 2	0.148	0.095		
p-value: test of Log total area cultivated (ha) + Interaction with treatment 1			0.070	0.070
p-value: test of Log total area cultivated (ha) + Interaction with treatment 2			0.000	0.000

p-value: test of Interaction with treatment 1 = Interaction with treatment 2			0.555	0.526
p-value: joint test of treatment 1, treatment 2, Interaction with treatment 1, and Interaction with treatment 2			0.277	0.239
N	993	993	993	993

Notes: OLS estimates.
All standard errors are clustered at the village level. *** p<0.01; ** p<0.05; *p<0.1
The omitted category is the control survey design (self-reporting).
Cash crop productivity is value of cash crop output per hectare cultivated.

Gender heterogeneity in agricultural outcomes with proxy reporting

To investigate further any gender-based differences in agricultural outcomes among proxy respondents, we conduct the regressions of a set of agricultural outcomes (land size, land characteristics, use of inorganic fertilizer, use of salaried labor, crop choices, and value of output) on the gender of the random proxy respondent i denoted by G_i, with and without a vector of additional respondent characteristics (migration status and formal education) denoted by Z_i and a vector of household characteristics (household size and asset quartiles) denoted by H_i. Equations 8-9 express these first two gender-related specifications, where the binary variable G_i takes the value one if the random proxy respondent i is female. We are interested in the coefficient θ_1 indicating gender differences in the specified outcomes.

$$y_i = \theta_0 + \theta_1 G_i + \nu_i \quad (8)$$

$$y_i = \theta_0 + \theta_1 G_i + \psi' Z_i + \rho' H_i + \nu_i \quad (9)$$

We also investigate any differences in the effect of land size on value of output per hectare due to the gender of the random proxy respondent by estimating two equations:

$$y_i = \tau_0 + \tau_1 G_i + \sigma_0 A_i + \sigma_1 G_i * A_i + \epsilon_i \quad (10)$$

$$y_i = \tau_0 + \tau_1 G_i + \sigma_0 A_i + \sigma_1 G_i * A_i + \psi' Z_i + \rho' H_i + \epsilon_i \quad (11)$$

In Equations 10-11, we are interested in the coefficient σ_1 indicating an interaction between the gender of the respondent and land size on the specified outcomes. The effect of gender on the outcome is $(\tau_1 + \sigma_1)$, and the effect of land size on the outcome is $(\sigma_0 + \sigma_1)$. We expect the latter to be negative, consistently with the inverse land size-productivity relationship.

Table 12 presents heterogeneous results on random proxy reporting with respect to land size, land characteristics, use of inorganic fertilizer, and use of labor. Columns one through three indicate that, relative to male proxy respondents, female proxy respondents over-report edge landholding (+0.3 ha), the total landholding (+1.1 to 1.5 ha), and the total area cultivated (+1.2 to 1.6 ha). This suggests that the under-reporting in the total area cultivated, earlier found with the pooled random proxy respondents, is driven by the male proxy respondents. Interviewing female proxy respondents on the total area cultivated yields more accurate land sizes than male proxy respondents. Columns four through six point out an under-reporting of the inheritance mode of acquisition of cultivated plots by 10 to 12 percentage points and an over-reporting of the donation mode by 12 percentage points by female proxy respondents, as opposed to male proxy respondents.

The last columns of Table 12 show no change in the reporting of salaried labor but an under-reporting of the intensity of fertilizer use by female proxy respondents. There is a drop in the quantity of fertilizer used per hectare by 27 to 29 log units and a drop in the monetary value of fertilizer used per hectare by 31 to 37 log units relative to male proxy reporting. One possible reason could be that males are those purchasing fertilizers and thus have better knowledge on the intensity of fertilizer used by the household. Another possible reason could be that female proxy respondents might be referring to female-managed plots as a benchmark in their reporting of fertilizer use at the household level. This could lead to an under-reporting of fertilizer use, which is consistent with findings from Udry (1996) that indicate, in households controlled by males, there is a lower intensity of input use on female-managed plots than on male-managed plots.

Table 13 relates to the heterogeneous results on random proxy reporting with respect to crop choices. It reveals that female proxy respondents under-report rice (-7 percentage points), sorghum (-16 to -14 percentage points), over-report bean (+13 to 14 percentage points), sesame (+9 to 10 percentage points), and okra (+9 to 10 percentage points) relative to male proxy respondents. Rice and sorghum are male-dominated crops while bean, sesame, and okra are female-dominated crops, suggesting that the crop diversification patterns reported by the proxy respondents depend on the gender of the proxy respondents.

In line with the over-reporting in bean and sesame choices relative to male proxy respondents (Table 13), a higher value of legume output is associated to female proxy respondents (Table 14).

Table 15 summarizes the investigation of gender heterogeneity in crop productivity with random proxy reporting. We fail to reject the null hypotheses that the effect of gender on crop productivity is insignificant. However, we reject at the 5% level of significance that the effect of land size is insignificant on cereal productivity (column one) and on cash crop productivity (column five). Hence, interviewing female instead of male proxy respondents leads to a negative association between land size and cereal productivity, and a positive association between land size and cash crop productivity. The inverse relationship between land size and cereal productivity is not surprising since female proxy reporting leads to no significant change in the value of cereal output at a 5% level of significance (Table 14) but to an increase in land size (Table 12). The over-reporting of sesame crop choice (Table 13) coupled with the marginal increase in the value of cash crop output (Table 14) dominates the over-reporting of land size (Table 12) and explains the positive relationship between land size and cash crop productivity under female proxy reporting.

Table 12

Gender effects on inputs among random proxy responding households.

Dependent variable	(1) Edge land area (ha)	(2) Total landholdings (ha)	(3) Total area cultivated (ha)	(4) Main mode of acquisition of cultivated plots: inherited	(5) Main mode of acquisition of cultivated plots: gift /donation	(6) Main mode of acquisition of cultivated plots: other	(7) HH used fertilizer	(8) Log quantity of fertilizer (Kg/ha)	(9) Log value of fertilizer (USD/ha)	(10) HH used salaried labor
Panel A: Estimates without the imbalanced covariates										
Female proxy respondent	0.300*	1.480**	1.550***	-0.119**	0.120***	-0.001	-0.057	-0.274**	-0.307*	0.076
	(0.158)	(0.594)	(0.563)	(0.056)	(0.044)	(0.024)	(0.045)	(0.108)	(0.168)	(0.058)
p-value: test of female proxy respondent	0.067	0.018	0.009	0.040	0.009	0.974	0.214	0.016	0.077	0.201
Panel B: Estimates with the imbalanced covariates										
Female proxy respondent	0.274*	1.148**	1.210**	-0.102*	0.124***	-0.022	-0.077*	-0.291***	-0.370**	0.072
	(0.154)	(0.488)	(0.460)	(0.054)	(0.041)	(0.027)	(0.040)	(0.101)	(0.150)	(0.058)
p-value: test of female proxy respondent	0.084	0.025	0.013	0.065	0.005	0.427	0.063	0.007	0.019	0.224
N	319	319	319	319	319	319	319	319	319	318
Mean of dep. var. in male proxy responding HHs	0.301	4.007	3.761	0.774	0.142	0.085	0.618	1.062	1.958	0.242
S.D. of dep. var. in male proxy responding HHs	0.888	3.619	2.974	0.420	0.349	0.279	0.487	1.261	1.746	0.429

Notes: OLS estimates. All standard errors are clustered at the village level. *** p<0.01; ** p<0.05; *p<0.1

Table 13

Gender effects on crop choice among random proxy responding households.

Dependent variable	(1) Rice	(2) Sorghum	(3) Cereals	(4) Bean	(5) Sesame	(6) Legumes	(7) Okra	(8) Vegetables	(9) Cash crops	(10) Crop diversity score
Panel A: Estimates without the imbalanced covariates										
Female proxy	-0.070**	-0.158**	-0.063	0.129*	0.087*	0.068	0.087*	0.136**	-0.018	0.229
respondent	(0.034)	(0.072)	(0.046)	(0.073)	(0.045)	(0.059)	(0.045)	(0.064)	(0.046)	(0.308)
p-value: test of female proxy resp.	0.049	0.036	0.181	0.084	0.063	0.263	0.060	0.041	0.691	0.463
Panel B: Estimates with the imbalanced covariates										
Female proxy	-0.065*	-0.139*	-0.055	0.140**	0.104**	0.092*	0.096**	0.152**	-0.021	0.327
respondent	(0.035)	(0.072)	(0.045)	(0.068)	(0.043)	(0.054)	(0.043)	(0.060)	(0.047)	(0.308)
p-value: test of female proxy resp.	0.069	0.060	0.230	0.047	0.022	0.096	0.032	0.016	0.658	0.296
N	304	304	304	304	304	304	304	304	304	304
Mean of dep. var. in male proxy responding HHs	0.129	0.629	0.965	0.292	0.158	0.609	0.129	0.168	0.861	3.173
S.D. of dep. var. in male proxy responding HHs	0.336	0.484	0.183	0.456	0.366	0.489	0.336	0.375	0.346	1.723

Notes: OLS estimates. All standard errors are clustered at the village level. *** p<0.01; ** p<0.05; *p<0.1
Crop choice variable takes value 1 if the household produced it. A household is considered producing cereal crops if it produced at least one of the following crops: rice, millet, sorghum, corn, and fonio; legume crops if it produced at least one of the following crops: bean, peanut, bambaranut, sesame, and soybean; vegetable crops if it produced at least one of the following crops: tomato, onion, okra, sorrel, eggplant, lettuce, cabbage, bell pepper, pepper, cucumber, and squash; cash crops if it produced at least one of the following crops: cotton, sesame, peanut, and corn. Crop diversity score is the total number of crops produced.

Table 14

Gender effects on value of output among random proxy responding households.

Dependent variable	(1) Log value of cereal output (USD)	(2) Log value of legume output (USD)	(3) Log value of vegetable output (USD)	(4) Log value of food crop output (USD)	(5) Log value of cash crop output (USD)	(6) Log total value of output (USD)
Panel A: Estimates without the imbalanced covariates						
Female proxy respondent	-0.567*	1.152**	0.652	0.525	0.716*	0.568
	(0.320)	(0.522)	(0.449)	(0.417)	(0.373)	(0.383)
p-value: test of female proxy respondent	0.086	0.034	0.156	0.216	0.063	0.147
Panel B: Estimates with the imbalanced covariates						
Female proxy respondent	-0.509	1.295**	0.771*	0.627	0.715*	0.646
	(0.330)	(0.510)	(0.439)	(0.433)	(0.388)	(0.399)
p-value: test of female proxy respondent	0.132	0.016	0.088	0.157	0.074	0.115
N	304	304	304	304	304	304
Mean of dep. var. in male proxy responding HHs	4.895	3.111	1.233	6.244	4.113	6.508
S.D. of dep. var. in male proxy responding HHs	2.739	3.298	3.221	3.109	2.653	2.908

Notes: OLS estimates. All standard errors are clustered at the village level. *** p<0.01; ** p<0.05; *p<0.1
Food crops include cereals (rice, millet, sorghum, corn, and fonio), legumes (bean, peanut, bambaranut, sesame, and soybean), and vegetables (tomato, onion, okra, sorrel, eggplant, lettuce, cabbage, bell pepper, pepper, cucumber, and squash). Cash crops include cotton, sesame, peanut, and corn. Total value of output is the sum of values of individual crop output, not the sum of values of food crop output and cash crop output.

Table 15

Gender effects on productivity among random proxy responding households.

Dependent variable	(1) Log cereal productivity (USD/ha)	(2) Log legume productivity (USD/ha)	(3) Log vegetable productivity (USD/ha)	(4) Log food crop productivity (USD/ha)	(5) Log cash crop productivity (USD/ha)	(6) Log total productivity (USD/ha)
Panel A: Estimates without the imbalanced covariates						
Gender: Female proxy respondent	-0.475	-0.220	0.499	-0.436	-0.112	-0.340
	(0.783)	(0.957)	(1.219)	(0.922)	(0.891)	(0.901)
Land size: Log total area cultivated (ha)	-0.858*	-0.764**	-0.304	-1.242***	0.528	-0.929**
	(0.459)	(0.375)	(0.449)	(0.436)	(0.361)	(0.390)
Interaction: Gender * Land size	-0.014	0.798	0.034	0.639	0.344	0.560
	(0.516)	(0.484)	(0.625)	(0.539)	(0.462)	(0.492)
p-value: test of Gender + Interaction	0.161	0.317	0.404	0.674	0.623	0.649
p-value: test of Land size + Interaction	0.037	0.949	0.552	0.265	0.034	0.460
Panel B: Estimates with the imbalanced covariates						
Gender: Female proxy respondent	-0.356	-0.224	0.464	-0.391	-0.135	-0.290
	(0.817)	(1.000)	(1.198)	(0.968)	(0.921)	(0.926)
Land size: Log total area cultivated (ha)	-0.938**	-0.565	-0.062	-1.084**	0.518	-0.820**
	(0.428)	(0.386)	(0.450)	(0.401)	(0.368)	(0.376)
Interaction: Gender * Land size	-0.053	0.881	0.117	0.677	0.412	0.593
	(0.532)	(0.525)	(0.643)	(0.585)	(0.477)	(0.518)
p-value: test of Gender + Interaction	0.271	0.257	0.343	0.566	0.572	0.541
p-value: test of Land size + Interaction	0.036	0.594	0.918	0.478	0.033	0.666
N	304	304	304	304	304	304
Mean of dep. var. in male proxy responding HHs	4.036	2.574	1.092	5.327	3.222	5.540
S.D. of dep. var. in male proxy responding HHs	2.538	2.975	2.981	3.083	2.303	2.919

Notes: OLS estimates. All standard errors are clustered at the village level. *** p<0.01; ** p<0.05; *p<0.1.
Productivity is value of output per hectare cultivated. Food crops include cereals (rice, millet, sorghum, corn, and fonio), legumes (bean, peanut, bambaranut, sesame, and soybean), and vegetables (tomato, onion, okra, sorrel, eggplant, lettuce, cabbage, bell pepper, pepper, cucumber, and squash). Cash crops include cotton, sesame, peanut, and corn. Aggregate value of output is the sum of values of individual crop output.

Conclusion

Data quality is heavily predicated on survey design choices that researchers make which can affect not only the bias in reported variables, but the relationships estimated with this data. The survey design literature has focused on several dimensions of questionnaire design that may affect data quality, but proxy, in comparison to self-reported responses, has been less rigorously studied in development economics.

In our study, we estimate the relative bias due to random proxy reporting and household head reporting, relative to self-reported information. While we can not assert that self-reported data is unbiased, it is a relevant reference as it is presumed that self-reporting may reduce biases associated with assymetric information between household members. We find no effects of respondent type on total landholdings reported for the household, but statistically significant effects of area cultivated by random proxy reports relative to self-reported land data (11% of the standard deviation). Effect sizes are much larger on land reported by household heads and random proxies relative to self-reports for field crops and pasture land. We do not find that biases in land reported influences estimates of the inverse land size relationship. Household heads also over-report production of cereals, cash crops and computed crop diversity scores relative to self-reports. Household heads (+ 18% of a standard deviation) and random proxies (- 37% of a standard deviation) also provide different biases relative to self-reported agricultural labor. Female proxies report lower levels of fertilizer for the household and higher frequencies of crops such as legumes and vegetables that women traditionally produce in Burkina Faso.

The results from this study present unbiased treatment effects of differing survey design choices, but leaves two research questions open in understanding about proxy response. First, the choice of proxy inherently alters the agricultural questionnaire design of the survey in the sense that the proxy is now reporting for the entire household, while comparisons to the self-reported data is often at the plot level of disaggregation. There may be heterogenous treatment effects of proxy response depending on data type as proxy education reporting will inherently use the same level of disaggregation whether it is proxy or self-reported. One can not aggregate the grade completed for a household, whereas one can aggregate the total landholdings. Future work on proxy reporting should attempt to estimate proxy response bias between differing types of questionnaire modules considering that proxy reporting results in not only a change in the respondent, but implicitly a change in the unit of analysis reported in the module. Second, while we have estimated proxy response bias from household heads relative to self-reports and a random proxy relative to a self-report, heterogenous treatment effects by proxy characteristics would provide better guidance to make survey design choices. We do investigate differential effects of proxy bias by gender, but there are often other relevant respondent characteristics such as age, education or the relationship of the proxy to the household head which may result in differing biases.

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Appendix Table 1A

Treatment effects on cereal and legume commercialization.

Dependent variable: commercialization index	(1) Rice	(2) Millet	(3) Sorghum	(4) Corn	(5) Cereals	(6) Bean	(7) Peanut	(8) Bambaranut	(9) Sesame	(10) Legumes
Panel A: Estimates without the imbalanced covariates										
Treatment 1: HH head reporting	0.080***	-0.015	0.067**	0.002	0.017	-0.015	0.076*	-0.018	0.166	0.076**
	(0.028)	(0.021)	(0.032)	(0.021)	(0.015)	(0.033)	(0.038)	(0.047)	(0.100)	(0.034)
Treatment 2: Random proxy reporting	-0.001	-0.010	-0.002	-0.010	-0.000	-0.019	0.050	-0.015	-0.047	0.046
	(0.032)	(0.026)	(0.017)	(0.014)	(0.012)	(0.029)	(0.046)	(0.047)	(0.087)	(0.036)
p-value: test of treatment 1 = treatment 2	0.054	0.831	0.029	0.428	0.179	0.913	0.539	0.954	0.022	0.459
p-value: joint test of treatment 1 and treatment 2	0.026	0.777	0.087	0.543	0.377	0.804	0.147	0.922	0.067	0.084
Panel B: Estimates with the imbalanced covariates										
Treatment 1: HH head reporting	0.076**	-0.005	0.071**	0.005	0.022	-0.013	0.077*	-0.015	0.165	0.082**
	(0.029)	(0.022)	(0.032)	(0.023)	(0.015)	(0.029)	(0.042)	(0.046)	(0.097)	(0.035)
Treatment 2: Random proxy reporting	-0.010	-0.005	0.004	-0.007	0.005	-0.017	0.049	-0.032	-0.051	0.057
	(0.036)	(0.026)	(0.017)	(0.015)	(0.012)	(0.029)	(0.046)	(0.058)	(0.096)	(0.037)
p-value: test of treatment 1 = treatment 2	0.039	0.997	0.034	0.433	0.197	0.875	0.508	0.754	0.024	0.526
p-value: joint test of treatment 1 and treatment 2	0.029	0.968	0.086	0.630	0.309	0.822	0.201	0.856	0.063	0.070
N	150	491	571	606	962	342	529	92	185	688
Mean of dep. var. in control HHs	0.074	0.058	0.057	0.053	0.052	0.140	0.180	0.055	0.521	0.214
S.D. of dep. var. in control HHs	0.181	0.190	0.164	0.153	0.132	0.272	0.274	0.195	0.443	0.305

Notes: OLS estimates. All standard errors are clustered at the village level. *** p<0.01; ** p<0.05; *p<0.1
The omitted category is the control survey design (self-reporting).
The commercialization index is computed as the share of the quantity produced (output) that is sold. It is defined if output quantity is not zero. Cereal crops include rice, millet, sorghum, corn, and fonio. Legume crops include bean, peanut, bambaranut, sesame, and soybean.

Appendix Table 1B

Treatment effects on commercialization of vegetables, food crops, and cotton.

Dependent variable: commercialization index	(1) Tomato	(2) Okra	(3) Sorrel	(4) Vegetables	(5) Food crops	(6) Cotton
Panel A: Estimates without the imbalanced covariates						
Treatment 1: HH head reporting	0.010	0.045	0.002	0.065	0.026	-0.007
	(0.169)	(0.042)	(0.018)	(0.072)	(0.020)	(0.091)
Treatment 2: Random proxy reporting	0.100	-0.053*	-0.012	-0.082	-0.002	0.075
	(0.187)	(0.029)	(0.013)	(0.075)	(0.017)	(0.074)
p-value: test of T1=T2	0.487	0.037	0.352	0.021	0.102	0.118
p-value: joint test of T1 and T2	0.759	0.071	0.468	0.067	0.237	0.177
Panel B: Estimates with the imbalanced covariates						
Treatment 1: HH head reporting	0.025	0.039	-0.003	0.089	0.032	0.014
	(0.173)	(0.039)	(0.021)	(0.071)	(0.021)	(0.106)
Treatment 2: Random proxy reporting	0.099	-0.083*	-0.008	-0.043	0.006	0.096
	(0.187)	(0.041)	(0.009)	(0.066)	(0.018)	(0.086)
p-value: test of T1=T2	0.536	0.029	0.736	0.029	0.119	0.145
p-value: joint test of T1 and T2	0.787	0.075	0.492	0.089	0.218	0.168
N	44	152	116	207	984	205
Mean of dep. var. in control HHs	0.668	0.066	0.012	0.237	0.109	0.841
S.D. of dep. var. in control HHs	0.342	0.192	0.077	0.369	0.187	0.365

Notes: OLS estimates. All standard errors are clustered at the village level. *** p<0.01; ** p<0.05; *p<0.1

The omitted category is the control survey design (self-reporting).

The commercialization index is computed as the share of the quantity produced (output) that is sold. It is defined if output quantity is not zero. Food crops include cereals (rice, millet, sorghum, corn, and fonio), legumes (bean, peanut, bambaranut, sesame, and soybean), and vegetables (tomato, onion, okra, sorrel, eggplant, lettuce, cabbage, bell pepper, pepper, cucumber, and squash).