Adoption of land restoration activities in Ethiopia: Understanding gender-labor dimensions

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Abstract

The role of labor in the adoption of land restoration activities (LRA) that reduce soil degradation in smallholder agricultural systems has received inadequate attention. We examine the gender-labor dimensions of the adoption of LRAs by smallholder agricultural households in rural Ethiopia, using three panels of LSMS—ISA data and employing panel data estimators to provide a correlational understanding of the role of male and female labor in the adoption of LRA. We also estimate these relationships for four different sub-samples of households—male-headed, female-headed, Orthodox, and non-Orthodox households—to examine heterogeneity in these gender-labor dimensions. The probability of adopting LRA is significantly higher when agricultural households have greater person-days of female household and female non-household labor. This holds for all four sub-samples of households. The area of land under LRA is positively and significantly most responsive to person-days of female non-household labor in all four types of households as well. Female non-household labor has been critical for increasing the adoption of LRA on private lands of rural households in Ethiopia in recent years. The results make a case for continued support towards LRA adoption with a specific focus on reducing labor shortages and drudgery.

***Keywords*:** Land restoration practices, adoption, gender, inclusion, Ethiopia

***JEL codes*:** Q12; Q15; Q24

1. Introduction

Land degradation is a serious concern for agriculture around the world. While the estimated magnitude of global economic costs of land degradation is uncertain, scholars agree that it is large (Nkonya, Mirzabaev and Von Braun 2016; Sartori et al. 2019). In Sub-Saharan Africa (SSA), around 180 million people are estimated to be adversely affected, with an annual economic loss of US$ 68 billion (Abera et al. 2020). Given its adverse impacts on food security and climate resilience, land restoration is a public priority in the sub-continent. Governments aim to reduce erosion, improve soil moisture, and increase organic and inorganic soil nutrient content on both public lands and private agricultural lands through a variety of physical (e.g., bunds, terraces, contours, ridges) and agronomic (e.g., crop choice/rotation, tree-planting, pasturing, exclosures/fallowing) approaches, collectively termed as land restoration activities (LRA).

LRAs on public lands are typically implemented through food-for-work, or cash-for-work programs, which typically provide payments pegged to local wage rates, or food baskets, as incentives for providing labor. In contrast, incentives for adopting LRAs on private agricultural land, even when 'catalyzed' through a publicly-funded and coordinated program, are affected by intra-household, household, and institutional characteristics[1] (Abera, Assen and Budds 2020; Bekele, Mirzabaev and Mekonnen 2021; Kassie et al. 2008; Arslan et al. 2014; Knowler and Bradshaw 2007). Among these, the importance of tenure has been highlighted (e.g., see Legesse, Jefferson-Moore and Thomas 2018; Moreda 2018; Nkomoki, Bavorová and Banout 2018; Lovo 2016)[2]; as has been that of larger farm size; fewer

[1] Agroclimatic conditions are important as well. However, these are not heterogeneous at the household level. Ensuring that the LRA selected for promotion are appropriate to local agroclimatic conditions is an important component for motivating its adoption (Kassie et al. 2010)

[2] The literature uses alternative metrics for measuring tenure (e.g., registration, title, certification, and security are different metrics), and varying analytical methods ranging from correlational to causal (Fenske 2011; Bambio and Agha 2018).

fragmented plots; and unfettered access to capital, credit, and extension (e.g. see Bekele et al. 2021; Wondwosen Abera et al. 2020; Anley, Bogale and Haile-Gabriel 2007).[3]

The role of labor in the adoption of LRA on private agricultural land has been less examined (Crossland et al. 2021). This is an important oversight given that most LRA is labor-intensive; returns to LRA are not immediate; rural households are often labor-constrained (Arslan et al. 2014; Ojha et al. 2022); the labor composition of the agricultural workforce in SSA has been 'feminizing' over the last two decades (Bryceson 2019; Crossland et al. 2021)[4]; and smallholder households often use female labor in activities where returns are not immediate (Doss 2013; Doss and Quisumbing, 2020).

In this paper, we employ panel data from Ethiopia's Living Standards Measurement Study—Integrated Surveys in Agriculture (LSMS—ISA) to examine the gender-labor dimensions of LRA in rural areas for both agricultural[5] and non-agricultural rural households.[6] LRA in Ethiopia is mostly practiced in the *Meher* season, the main agricultural season between the months of May to September; the LSMS—ISA consequently elicits data on LRA for the *Meher* season. We also examine these relationships for male-headed, female-headed, Orthodox, and non-Orthodox households, to examine inclusion in the creation of LRA.

We consider the sub-sample of agricultural households to examine whether the likelihood of their implementing LRA on their land, as well as the areas of their land that they implement LRA on, is mediated by the gender-disaggregated person-days of household labor[7], and non-household labor[8] for

[3] Considerable heterogeneity about these characteristics, and the interactions between heterogeneous characteristics, limits how universal any of these factors can be for increasing adoption of LRA (Knowler and Bradshaw 2007).
[4] Rural males from agricultural households are increasingly diversifying into wage labor, especially off-farm (Bryceson 2019); while households' own labor that is used on the farm is increasingly female (Crossland et al. 2021).
[5] Households whose dwellings are in rural areas or small towns, and who cultivated at least one crop or maintained at least one head of any livestock at any time in the last 12 months since the date of interview are considered as agricultural households.
[6] Households whose dwellings are in rural areas, or small towns, and who did not cultivate any crop or maintain any livestock of any kind in the last 12 months since the date of the interview are considered non-agricultural households.
[7] Household members who work on their own land
[8] Individuals who are not household members, but work on another household's land, either in return of cash/grain (called hired labor), or in exchange of reciprocal labor (called exchange labor).

performing land preparation activities. We also examine these relationships for male-headed, female-headed, Orthodox, and non-Orthodox households, since government-led land restoration programs on private land have made specific efforts to improve inclusion in the implementation of LRA among agricultural households, especially female-headed ones.[9]

This paper contributes to the literature on land degradation and restoration in several ways. First, much of the analyses of LRA adoption on private lands are often based on studies that have small samples and are cross-sectional (Arslan et al. 2014; Umar et al. 2011). We use LSMS—ISA data from Ethiopia, which employs a study design and sampling strategy that is nationally and regionally representative, and adequately powered to examine these correlations in the presence of considerable household and geographic heterogeneity. The LSMS—ISA dataset is a true panel, allowing us to control time-invariant confounders. Second, we examine the probability of adoption by using both a binary variable and the areas of households' private agricultural land under LRA to understand intensities. Agricultural households often don't adopt LRA on all plots or land (Peter Nkala, et al. 2011; Umar et al. 2011); and the area of land under LRA can vary within households across time, and between households across both space and time (Bekele et al. 2021; Arslan et al. 2014; Kassie et al. 2008). By examining both the probability of adoption and the areas under LRA, we gain richer insights into the relationships between labor and LRA adoption and its intensities. Third, existing studies typically link the number of individuals in an agricultural household to an adoption decision regarding LRA, without considering whether these individuals were involved in cultivation on private lands (Crossland et al. 2021; Doss and Quisumbing 2020). The LSMS—ISA data allows us to disaggregate male and female person-days of household labor, and non-household labor, of those who were involved in land-preparation activities (when LRA are implemented). Using these data, we can reduce the noisy measurement of a key variable and have a richer perspective on the gender-labor dimensions of LRA (Baudron et al. 2007; Nyanga, Johnsen, and Kalinda 2012; Njuki et al. 2014). Finally, we examine the relationships between labor and LRA for all

[9] See https://www.weadapt.org/solutions-portal/sustainable-land-management-project-i-ethiopia-slmp-1

households, male-headed households, female-headed households, and Orthodox and non-Orthodox households. This enables us to characterize inclusion in LRA.

These improvements in conceptualization, data, and measurement allow us to understand who is more likely to adopt LRA in rural Ethiopia and whether gender-labor dimensions are important in LRA adoption. We find that the probability of adopting LRA is higher when agricultural households have greater person-days of female household and female non-household labor. This holds for male-headed, female-headed, Orthodox, and non-Orthodox households. The area of land under LRA is positively and significantly most responsive to person-days female non-household labor; this holds for male-headed, female-headed, and Orthodox households. These results suggest that LRAs can contribute to the generation of environmental amenities and the extent to which LRAs can do so is significantly dependent on female labor.

Section 2 provides a background in land degradation and land restoration programs in Ethiopia. Section 3 describes the LSMS-ISA data and section 4 discusses analytical methods. Results are presented in section 5 and section 6 concludes.

2. Background

Ethiopia has experienced land degradation, and extensive efforts have been made to stem losses. Countrywide, recent estimates pegged annual land degradation costs at US$ 4.3 billion (Gebreselassie, Kirui and Mirzabaev 2016), with 14.3 million hectares estimated to be severely degraded (Gashaw 2015). In response, Ethiopia has invested around US$ 1.2 billion a year over the last ten years for land restoration on public and private lands, especially in the regions of Amhara, Oromia, Tigray and SNNPR; making it the largest land restoration effort in the world; with investments to further reduce degradation continuing (Wuletawu Abera et al. 2020).

Early efforts towards land restoration on public lands began in the 1960s, morphing into the Food for Work program, and the ongoing Productive Safety Net Program (Wuletawu Abera et al. 2020; Bezu

and Holden 2008; Kozicka et al. 2023). LRA on private lands was introduced in the early 2000s with the MERET program (which also financed the restoration of public lands; (Nedessa and Wickrema 2010). In 2008, the first phase of the Sustainable Land Management Program (SLMP) was implemented; with a second phase between 2013—2018 (Schmidt and Tadesse 2019; Wuletawu Abera et al. 2020); this program rapidly expanded LRA on private agricultural lands, giving explicit consideration to improving inclusion in the implementation of LRA, especially for female-headed households (World Bank 2019; World Bank 2020). Baring the Somali, Afar and Benishangul regions (where LRA has not been implemented in any committed manner), most regions of Ethiopia have experienced a mix of LRA on both public and private lands, with the incidence of LRA on public lands higher in low drylands of eastern and northern Ethiopia (where rangelands are numerous) and incidence of LRA on private lands higher in the highlands (where agricultural land is abundant) (Wuletawu Abera et al. 2020).[10] A variety of interventions have been implemented. On public lands, soil and/or stone bunds, exclosures and afforestation are common approaches. On private lands, efforts consist of soil and stone bunds, fallowing, various types of conservation agriculture practices (such as low tillage, ridge tillage, mulching, green manure, retaining stubble), crop rotation, crop cover, pasturing, and tree cultivation.

Statistics from the LSMS—ISA dataset show that the prevalence of adoption of LRA on private land increased from 5% of agricultural households in 2011 to 65% in 2015-16.[11] Benefits from LRA take time to materialize and are larger when adopted consistently across space and time (Shiferaw and Holden 1998; Shiferaw and Holden 1999; Beyene 2015; Gebregziabher and Soltani 2019). Since the availability of labor towards LRA on private land can be an important constraint due to the increasing diversification of agricultural labor (especially male) into off-farm wage employment (Bryceson 2019); the increase in the prevalence of LRA over time allows us to examine the relationships between LRA adoption and labor in a dynamic setting.

[10] Therefore, our analysis includes dummies for regions.
[11] Program design and implementation modalities were identified as factors for low, slow and non-persistent adoption in the early years (Wondwosen Abera, Assen and Budds 2020).

3. Data

Data come from the integrated household and agricultural survey, called the Living Standard Measurement Study – Integrated Surveys in Agriculture (LSMS-ISA), which is conducted by the Government of Ethiopia's Central Statistical Agency with technical support from the World Bank. The LSMS-ISA is a panel dataset (referred to as the survey, hereafter), and collects data at the community, household, and agricultural plot levels for three different periods – 2011/12, 2013/14, and 2015/16. It is a nationally and regionally representative sample of households in Ethiopia.

--Table 1 here--

Table 1 provides a summary of the sample sizes of the three panels of the survey.[12] The 2011/12 panel collected data from 3,544 households, all located in rural areas or small towns (100%), of which 2,993 (85% of all households) were agricultural households.[13] The 2012/14 and 2015/16 panels covered urban areas as well, expanding their sample sizes to 5,262 and 4,951 households, respectively. Of these, 3,776 (72%) and 3,697 (75%) households were in rural areas and small towns, and 3,500 (66% of all households) and 3,368 (68% of all households) were agricultural households, respectively.

We use agricultural households from rural and small towns only; urban households are excluded due to negligible agricultural activity in urban areas, and because urban areas were not part of the 2011/12 panel. The area under LRA and the labor involved in land preparation (when LRAs are implemented) are for the *Meher* season, the main agricultural season in Ethiopia.[14]

3.1. Gender-labor days and land restoration activities for agricultural households

The survey collects person-days of labor used in the pre-harvesting[15] period at the plot level, by gender, and by whether the labor was of household members or non-household individuals. We aggregate

[12] As mentioned in the introduction, households that cultivate at least one crop or maintain at least one head of any livestock at any time in the last 12 months since the date of interview are considered as agricultural households.
[13] The 2011/12 survey did not cover urban areas and is nationally representative of rural and small towns.
[14] Cultivation in the *Belg* season is only possible if an agricultural household has access to irrigation, which is around 6-8% of agricultural households. LRA are not practiced in the *Belg* season on private agricultural lands, since cultivation scarcely takes place.
[15] The survey does not distinguish between the different activities in the pre-harvesting period; this variable cannot be decomposed into its constituent activities.

plot-level data to calculate person-days of male household, female household, male non-household, and female non-household labor used by each agricultural household in each of the three survey years.[16] We also construct two dummy variables to indicate whether the household has any member who is wage-employed in that year; and whether any member of the household has provided labor (in exchange for wages or food) to the PSNP program on public lands in that year.[17]

Each panel of the survey records the area of every plot under the various types of LRA. We aggregate the area across plots across all types of LRA in each panel to calculate the total area of the households' agricultural land under LRA in each panel.[18,19,20] We also construct a dummy variable to indicate whether the household practices LRA for each panel (at the household level).[21]

Data on characteristics of agricultural land of the household are also included in the analyses, consisting of the following: whether the household has any land use certificates for any plot; whether any plot was granted by village leaders; whether any plot was inherited; whether any plot is rented in; the number of sloped plots[22]; area of land irrigated; whether the household used inorganic fertilizers; and whether the household used organic fertilizers.

[16] Non-household labor consists of the sum of person-days of hired and exchange labor (defined in footnote 10). A very small share of households hired a small number of person-days of labor, while a significant share exchanged a reasonable number of person-days of labor. We combine hired and exchange labor and refer to it as non-household labor. We also replicated the analyses throughout the paper by explicitly differentiating between hired and exchange labor; the results are similar and comparable.

[17] Our analysis for agricultural households controls for whether the household contributed labor towards the PSNP program, which is the publicly funded land restoration program on public lands. While participating in LRA to restore public lands may constrain labor availability for LRA on private lands (Adimassu and Kessler 2015; Woolf et al. 2018; Kozicka et al. 2023); LRA on public land provide food or cash which can reduce capital constraints that often impede adoption of LRA activities on private land (Barrett 2002; Bezu and Holden 2008). The LSMS—ISA dataset distinguishes between households' participation in LRA on public lands (through the Productive Safety Net Program (PSNP), the flagship program for LRA on public lands which focuses on terracing and exclosures), allowing us to use the data to control for LRA on public lands.

[18] Plots that were rented out were excluded from this calculation; while plots rented in were included.

[19] The area of the plots under multiple LRAs is counted only once to avoid over estimation of area under all LRA.

[20] The survey records whether the household practices crop rotation or not (as a dummy) at the household-level. Consequently, the area under LRA is likely underestimated for all households that did practice crop-rotation.

[21] We also aggregate the areas across plots *by* LRA, to calculate the area under each LRA implemented by the household in each panel, and use this for supplemental analysis, in section 5.4.

[22] The LSMS—ISA agricultural module collects land tenure/land security information and information of self-reported soil-type and self-reported slope at the plot level.

We also use data on household demographics, consisting of the following: household size, dependency ratio, a dummy for whether the household's dwelling is rural[23]; a dummy variable for whether the household received private transfers (including remittances); dummy variables related to the whether the household head is married, or divorced; and dummy variables related to whether household head has completed primary and secondary schooling. When analyzing the full sample, we also use a dummy variable for whether the household head is female; and dummy variables for whether the household head is Orthodox Christian, Other Christian, or Muslim.[24] We do not use the dummy for the household head being female when we examine male and female-headed households, and we do not use the dummy for the religion of the household head when examining Orthodox and non-Orthodox households.

3.2. Land restoration activities

The total area of land under LRA for agricultural households in each panel, as calculated in the section above, is used as key right-hand-side covariates. As control covariates, we include person-days of household labor and non-household labor that households employed in land preparation, disaggregated by gender; data on characteristics of agricultural land (as described in section 3.1), and data on household demographics (as described in section 3.1). We examine the full sample, male-headed, female-headed, Orthodox, and non-Orthodox households.

The key covariates for this analysis are private land area that agricultural households implement LRA on. We construct them by aggregating the total areas of private land that agricultural households implemented LRA on in that year, which we calculated in section 3.1, within an enumeration area.

We also use data on distance to the nearest input and output markets, distance to the nearest paved road, whether agriculture is the primary occupation in the enumeration area, land use pattern in the enumeration area, the slope of the land in the enumeration area, the share of large farms in the

[23] If the dwelling is not located in a rural area, then it is located in a small town; households whose dwellings are located in urban areas are not included in this paper.
[24] Marriage between individuals of different religions/faiths is uncommon in Ethiopia.

enumeration area, presence of any community irrigation projects in the enumeration area, a dummy for low rainfall in the previous *Belg* season,[25] and a dummy for whether the community has a micro-enterprise. We examine this relationship for the full sample of non-agricultural households as well as the four sub-samples of non-agricultural households: male-headed, female-headed, Orthodox, and non-Orthodox households.

4. Methods

We use a two-way fixed effects (TWFE) regression estimator to examine whether the adoption of LRA on private lands of agricultural households is mediated by male and female person-days of household labor and non-household labor involved in land-preparation activities (when the bulk of the effort for LRA is deployed). Considering the need to control time-invariant factors that are related to the adoption of LRA, we verify the TWFE results using a pooled ordinary least squares regression at the household level. Equation 1 provides the TWFE estimating equation where i indicates an agricultural household and t indicates the survey year.

$$LRA_{it} = \propto_0 + \Pi \boldsymbol{Labor}_{it} + \Phi \boldsymbol{Land}_{it} + \Theta \boldsymbol{Demo}_{it} + household_i + + Time_t + u_{it} \quad (1)$$

$Labor_{it}$ is a set of six variables. Four of them consist of the person-days that household i employed in land preparation in time t of: male household labor; female household labor; male non-household labor; and female non-household labor. The other two are dummy variables to indicate whether the household has any member who is wage-employed in that year; and whether any member of the household has provided labor (in exchange for wages or food) to the PSNP program on public lands in that year.

$Land_{it}$ is a set of eight variables denoting whether in time t, household i has: any plot of land with a land-use certificate (dummy); any plot granted by leaders (dummy); any plot inherited (dummy);

[25] *Belg* is the shorter agriculture season from February to April.

any plot that is rented (dummy); the number of sloped plots; areas irrigated; used inorganic fertilizer (dummy); used organic fertilizer (dummy).

$Demo_{it}$ is a set of several variables for household i in time t pertaining to the following*:* household size; dependency ratio; rural location of the dwelling (dummy); receipt of private transfers (including remittances; dummy); household head's attainment of primary education (dummy); household head's attainment of secondary education (dummy); gender of household head (dummy); marital status of household head (married or divorced); religion of the household head (Orthodox Christian, Other Christian, Muslim). When examining the sub-sample of male-headed and female-headed households, we exclude the gender of the household head; for the sub-sample of Orthodox and non-Orthodox households, we exclude dummies on the religion of the household head. Likewise, $household_i$ is household fixed effects, $Time_t$ is a dummy for the survey year t, and u_{it} is the idiosyncratic error term.

We implement equation 1 using two (different) dependent variables. In the first specification, the dependent variable is a dummy variable on whether agricultural household i practices LRA in time t; this estimates the probability of adopting LRA (Table 4, column 1). We run this specification for the subsample of male-headed, female-headed, Orthodox, and non-Orthodox agricultural households (Table 4, columns 2-5). In the second specification, we use the logged total area of land under LRA for agricultural household i in time t as another dependent variable; this estimates semi-elasticities – the percentage increase in area under LRA from an additional labor day (Table 5, column 1). We also estimate the second specification for the subsample of male-headed, female-headed, Orthodox, and non-Orthodox agricultural households (Table 5, columns 2-5). In all regressions, robust standard errors are used, with clustering at the enumeration areas.

5. Results

5.1. Descriptive statistics

Table 2 provides summary statistics for all variables used in the regressions, for agricultural households. The first panel provides summary statistics for household and non-household person-days of labor involved in the land-preparation stage of cultivation for the *Meher* cultivation season, disaggregated

by gender. The mean person-days of male household labor decreased slightly from 2011/12 to 2015/16, from nine person-days to seven. The mean female household labor days also decreased, but less than that for male-household labor days, from almost five days to four. The mean person-days of male non-household and female non-household labor remained around the same over the three panels. The share of agricultural households engaged in supplying labor to the PSNP program slightly fell, from 11% in 2011/12 to 8% in 2015/16. The share of households engaged in wage employment also slightly fell, from around 10% in 2011/12 to 8.4% in 2015/16.

--Table 2 here--

The second panel of Table 2 provides summary statistics related to land characteristics for agricultural households. Around 48% of households in the 2011/12 panel had at least one plot of land that had been granted by kebele leaders, and this share remained constant over 2013/14 and 2015/16. The share of households with at least one plot gained through inheritance increased (as expected) from 50% in 2011/12 to almost 60% in 2015/16. The share of households with at least one rented plot remained the same, around 29% over the three panels. The share of households with at least one plot that had a land certificate also increased over time from 46% to 60%, reflecting the land certification reforms that were happening throughout this time. The mean total land-holding areas remained more-or-less the same across the three panels (around 1.4 acres), as did the area cultivated in the *Mehr* season (around 1.08 acres), and the number of plots (around 11 per agricultural household). The mean number of sloped plots per agricultural household increased slightly, from 3.7 plots to 4.8 plots. Mean irrigated areas in the *Meher* season remained the same over the three panels, around 0.01 acres, consistent with predominantly rainfed cultivation practices. Around 54% of households used inorganic fertilizers in 2011/12, this remained unchanged across the three panels. Application of organic fertilizer also remained constant; around 64% of households did so in each of the three panels.

The third panel of Table 2 provides summary statistics related to the demographics of agricultural households. In 2011/12 and 2013/14, almost all agricultural households were in rural areas; in 2015/16, 95% of agricultural households were in rural areas, with the remaining 5% located in small towns. Mean

household size slightly increased, from around five persons in 2011/12 to 6.5 persons in 2015/16. The mean dependency ratio also slightly increased, from 1.65 in 2011/12 to 2.11 in 2015/16 indicating that non-earning members increased. Per-capita monthly consumption expenditures (food and non-food) are reported in 2009/10 Ethiopian Birrs (ETB). Mean per-capita consumption expenditures were around ETB 476 per month in 2011/12, decreasing to ETB 457 per month in 2013/15, and then increasing again to ETB 478 per month in 2015/16. Around 16% of households received private transfers in 2011/12 (including remittances); this reduced slightly to 14% in 2013/15 and 13.8% in 2015/16.

The last panel in Table 2 presents the household head's characteristics. Around 19% of households in 2011/12 were female-headed, this increased to 21% in 2015/16. The marital status of household heads changed slightly; in 2011/12, 82% of heads were married and 16% divorced; this changed to 79% heads married and 19% divorced by 2015/16. The mean age of the household head increased over time (as expected in panel data) from almost 45 years in 2011/12 to almost 48 years in 2015/16. In 2011/12 around 37% of household heads and 3% of household heads had completed primary and secondary education respectively, which increased to 40% and almost 5% in 2015/16. The share of household heads whose religion was Orthodox Christian, other Christian, Muslim, and other religions remained the same for each religious category across the three panels; with the share of household heads reporting their religion to be Orthodox Christianity the highest, reflecting the underlying religious demographics of Ethiopia.[26]

--Table 3 here--

Table 3 provides summary statistics for all outcome variables used in the regressions. The first panel provides mean areas under LRAs. In 2011/12, hardly any land was under any type of activity; this steadily increased to 0.74 acres per agricultural household in 2013/15 and 0.86 acres in 2015/16. The mean area under terracing, the most labor-intensive of all LRA, increased from 0.001 acres in 2011/12 to

[26] Supplementary Table S1 reports the differences between households that adopted LRA and did not adopt any LRA for each of the three panels. Adopters and non-adopter households are statistically significantly different on most model variables including household and non-household labor days employed in land preparation.

0.10 acres in 2013/15 and in 2015/16. Mean area under contouring fared better, this increased from 0.002 acres in 2011/12 to 0.19 acres and 0.33 acres in 2013/14 and 2015/16. Around 11% of agricultural households practiced crop rotation in 2011/12, this decreased slightly to 8.6% in 2013/14 and then increased to 9.7% in 2015/16. Mean areas under crop cover remained low; none in 2011/12, increasing to 0.10 acres in 2013/15, and then decreasing to 0.02 acres in 2015/16. Mean areas under the following changed from none in 2011/12 to 0.10 acres in 2013/14 to 0.02 acres in 2015/15, reflective of the cyclic nature of this practice. Mean areas under pasturing steadily increased over time, from none in 2011/12 to 0.12 acres in 2015/16.

5.2. Likelihood of land restoration activities

Correlates of the adoption of LRA are presented in Table 4. Column 1 presents results for all sample households. Household size is positively correlated with LRA adoption, but dependency ratio is negatively correlated. An increase in household size by one member increases the adoption of LRA by 0.5%, but a one-unit increase in dependency ratio decreases it by 0.4%. This reflects the fact that LRAs are labor-intensive. Households that are Orthodox Christians are 5.4% more likely to adopt LRA than other religions, while female-headed households are 3.8% less likely to adopt LRA than male-headed ones. The education of the head of the household is negatively correlated with LRA; households with heads who completed primary school are 2% less likely and heads who completed secondary school are 9.7% less likely to adopt LRA than households with not educated heads. This reflects the fact that households whose heads have higher levels of education are less likely to be agricultural households.

--Table 4 here—

Land characteristics are also correlated with LRA adoption. The likelihood of LRA adoption is higher for the plots with user right certificate (by 3.7%), inherited plots (by 9.2%), plots granted by local leaders (by 6%), and rented plots (by 2.3%) as compared to the likelihood of adoption on rented land. Households are more likely to adopt LRA on irrigated plots, sloped plots, and plots on which fertilizers (organic and inorganic) are used, suggesting that such activities may be complementary. For agricultural labor, households that use non-household labor are 4.4% more likely to adopt LRA than those who do not

use such labor, again reflecting the importance of access to labor in LRA. The same results hold for all sub-sample of households examined – male-headed, female-headed, Orthodox, and non-Orthodox households (Table 4, columns 2-5).

Next, we break down household and hired labor into male and female labor days and estimate the relationship between labor days and the probability of LRA adoption.

5.3. Gender-labor days and land restoration activities

Table 5, column 1 presents the probability of adopting LRA by all agricultural households.[27] The probability of adopting LRA is higher for female labor than for male labor; this is true for household and non-household labor. An increase in female household labor use by one person-day increases the probability of practicing any LRA by 0.4 %, but female non-household labor does not affect LRA adoption. A similar increase in male household (and non-household) labor use is not statistically significantly correlated with the probability of adopting any LRA. Having a member working in the PSNP program on public land reduces the probability of adopting LRA by 7.7%, but wage employment is positively correlated with LRA adoption.[28]

--Table 5 here--

In columns 2-5 of Table 5, we examine subsamples of male-headed (2), female-headed (3), Orthodox (4), and non-Orthodox households (5) and find similar relationships. Female household labor days increase the probability of male-headed households (column 2) adopting LRA by 0.4%, but there is no significant relationship between LRA adoption and male labor days. In female-headed households (column 3), both male and female household labor days are positively correlated with LRA adoption, but female household labor days are more strongly correlated (0.4%) than male household labor days (0.3%).

[27] The probability of LRA adoption using pooled OLS can be found in Appendix Table A1.
[28] Other coefficients in column 1, which control for covariates (but are not included in the table for the sake of brevity), have signs as expected. For example, all coefficients pertaining to variables that indicate households feel secure about the land they cultivate have a positive and significant relationship with the probability of adopting LRA.

In Orthodox households (column 4), male labor days do not affect LRA adoption but an increase in female household labor days increases LRA by 0.37%. For non-Orthodox households (column 5), female household labor days are an important determinant of LRA as it is significantly positively correlated with LRA adoption.

Table 6 presents the correlations between gender-labor days and areas of private agricultural land under LRA for agricultural households.[29] One labor-day increase in male household labor use corresponds to 0.09% smaller area under LRA (column 1) and a similar increase in male non-household labor corresponds to 0.22% greater areas under LRA. While a one-labor-day increase in female household labor increases LRA area by 0.15%, female non-household labor has no effects on LRA. Having a household member work in the PSNP program though, reduces the area of private land under LRA by 3.8%. Having one or more members working on wage employment does not affect the LRA area.

Columns 2-5 of Table 6 present the relationship between gender-labor days and LRA area for subsamples of male-headed, female-headed, Orthodox, and non-Orthodox households and find similar results. For male-headed households (column 2), an additional day of female household labor is associated with 0.19% greater area under LRA. For female-headed households (column 3), male non-household labor is associated with 0.37% greater area under LRA. For Orthodox households, male non-household labor is the most important, with an additional day associated with 0.4% greater areas under LRA. For non-orthodox households, female household labor days are associated with 0.24% greater area under LRA.

As a check, we also examined the probability of adopting LRA, and the adoption of acres of land under LRA using a pooled OLS rather than a fixed-effects regression (Appendix Table A2). The results are similar to those in Table 6. We also used the share of household labor that is female, and the share of non-household labor that is female, instead of the four categories of labor, and replicated the analyses in Table 6 (see Appendix Table A3). Results in Table A3 indicate that an increase in the share of female

[29] The dependent variables (land area under LRAs) are log-transformed; thus, the coefficient estimates are partial elasticities; and must be multiplied by 100 to interpret them as percentages change.

non-household labor is significantly positively correlated with LRA adoption suggesting that female non-household labor may be more important for LRA adoption than male non-household labor.

--Table 6 here--

The results in Tables 5 and 6 and appendix Tables A2 and A3 indicate that both adoption of and areas under LRA are most dependent on female household labor and male non-household labor. Female household labor is more correlated with higher probabilities of adopting LRA than female non-household labor, including for the subsamples analyzed. However, the share of female household and non-household labor is not important in determining LRA.

5.4. Additional analyses on types of land restoration activities

In Table 7, we examine how the probability of adopting different types of LRA is correlated with gender-labor days. We distinguish between terracing and contouring, where the former is more labor-intensive than the latter, but neither generates any output by itself. We also examine crop rotation (rotating a staple with a legume, typically, for nitrogen fixing); crop covering (fast-growing crops to reduce erosion, which are typically vegetables in Ethiopia); fallowing (leaving land uncultivated for a season to 'recover'); and pasturing (planting fodder plants on agricultural land); where crop-rotation, crop covering and pasturing also produce economically important outputs. The probability of adopting terracing (Table 7, column 1) is most correlated with an additional day of female household labor (0.3%). The probability of adopting contouring (Table 7, column 2) is most correlated with an additional person-day of female non-household labor (0.83%), in contrast to that with male household and non-household labor (0.2%). Similarly, crop rotation (Table 7, column 3) is most sensitive to female household labor, an additional day of which increases the probability of its adoption by 0.21%. The adoption of crop covering (Table 7, column 4) and fallowing (column 5) is not correlated with male and female labor days. Pasturing (Table 7, column 6) is most significantly correlated with female non-household labor (1.1%) followed by female household labor (0.26%) and male household labor (-0.23%).

--Table 7 here—

The relationship between gender-labor days and areas under LRA is examined in Table A4 in the appendix. The area under terracing is most sensitive to female household labor days. One additional day of female household labor increases the area under terracing by 0.07%; a similar increase in male household labor days decreases the terracing area by 0.04%. Likewise, contour is most sensitive to female non-household labor (0.61%), and crop rotation and pasturing are most sensitive to female household labor days. Results in Table 7 and Table A4 indicate that female labor is most important in adopting LRA. While male household and male non-household labor have a role to pay, their relationship with the probabilities of adopting different types of LRA is weaker than that with female household and female non-household labor.

6. Conclusion

Ongoing land restoration efforts on private lands such as the Sustainable Land Management Program explicitly target female-headed households to promote socially inclusive development (World Bank 2020); the results in this paper suggest that such explicit targeting may have paid off for female-headed households. However, LRAs involve manual labor, and sustaining them over time requires households to continue deploying household and non-household labor; access to female labor is likely to be critical for sustaining these activities. Reducing constraints in access to non-household labor and reducing drudgery in LRA are likely to be effective strategies for maintaining LRA and its benefits. These results suggest scope to further improve inclusiveness in the benefits from LRA, especially for female-headed and non-Orthodox households.

Bibliography

Abera, Wondwosen, M. Assen, and J. Budds. 2020. "Determinants of agricultural land management practices among smallholder farmers in the Wanka watershed, northwestern highlands of Ethiopia." *Land Use Policy* 99:104841.

Abera, Wuletawu, L. Tamene, D. Tibebe, Z. Adimassu, H. Kassa, H. Hailu, K. Mekonnen, G. Desta, R. Sommer, and L. Verchot. 2020. "Characterizing and evaluating the impacts of national land restoration initiatives on ecosystem services in Ethiopia." *Land Degradation & Development* 31(1):37–52.

Anley, Y., A. Bogale, and A. Haile-Gabriel. 2007. "Adoption decision and use intensity of soil and water conservation measures by smallholder subsistence farmers in Dedo District, Western Ethiopia." *Land Degradation & Development* 18(3):289–302.

Arslan, A., N. McCarthy, L. Lipper, S. Asfaw, and A. Cattaneo. 2014. "Adoption and intensity of adoption of conservation farming practices in Zambia." *Agriculture, Ecosystems & Environment* 187:72–86.

Bambio, Y., and S.B. Agha. 2018. "Land tenure security and investment: Does strength of land right really matter in rural Burkina Faso?" *World Development* 111:130–147.

Baudron, F., H.M. Mwanza, B. Triomphe, and M. Bwalya. 2007. *Conservation agriculture in Zambia : a case study of southern province*. African Conservation Tillage Network. Available at: https://agritrop.cirad.fr/541137/ [Accessed August 7, 2023].

Bekele, R.D., A. Mirzabaev, and D. Mekonnen. 2021. "Adoption of multiple sustainable land management practices among irrigator rural farm households of Ethiopia." *Land Degradation & Development* 32(17):5052–5068.

Beyene, F. 2015. "Incentives and Challenges in Community-Based Rangeland Management: Evidence from Eastern Ethiopia." *Land Degradation & Development* 26(5):502–509.

Bezu, S., and S. Holden. 2008. "Can food-for-work encourage agricultural production?" *Food Policy* 33(6):541–549.

Bryceson, D.F. 2019. "Gender and generational patterns of African deagrarianization: Evolving labour and land allocation in smallholder peasant household farming, 1980–2015." *World Development* 113:60–72.

Crossland, M., A.M. Paez Valencia, T. Pagella, C. Magaju, E. Kiura, L. Winoweicki, and F. Sinclair. 2021. "Onto the Farm, into the Home: How Intrahousehold Gender Dynamics Shape Land Restoration in Eastern Kenya." *Ecological Restoration* 39(1–2):90–107.

Doss, C.R., and A.R. Quisumbing. 2020. "Understanding rural household behavior: Beyond Boserup and Becker." *Agricultural Economics* 51(1):47–58.

Fenske, J. 2011. “Land tenure and investment incentives: Evidence from West Africa.” *Journal of Development Economics* 95(2):137–156.

Gashaw, T. 2015. “The implications of watershed management for reversing land degradation in Ethiopia.” *Research Journal of Agriculture and Environmental Management* 4:5–12.

Gebregziabher, D., and A. Soltani. 2019. “Exclosures in people’s minds: perceptions and attitudes in the Tigray region, Ethiopia.” *Forest Policy and Economics* 101:1–14.

Gebreselassie, S., O.K. Kirui, and A. Mirzabaev. 2016. “Economics of Land Degradation and Improvement in Ethiopia.” In E. Nkonya, A. Mirzabaev, and J. von Braun, eds. *Economics of Land Degradation and Improvement – A Global Assessment for Sustainable Development*. Cham: Springer International Publishing, pp. 401–430. Available at: https://doi.org/10.1007/978-3-319-19168-3_14 [Accessed August 7, 2023].

Kassie, M., J. Pender, M. Yesuf, G. Kohlin, R. Bluffstone, and E. Mulugeta. 2008. “Estimating returns to soil conservation adoption in the northern Ethiopian highlands.” *Agricultural Economics* 38(2):213–232.

Kassie, M., P. Zikhali, J. Pender, and G. Köhlin. 2010. “The Economics of Sustainable Land Management Practices in the Ethiopian Highlands.” *Journal of Agricultural Economics* 61(3):605–627.

Knowler, D., and B. Bradshaw. 2007. “Farmers’ adoption of conservation agriculture: A review and synthesis of recent research.” *Food Policy* 32(1):25–48.

Kozicka, M., E. Gotor, T. Pagnani, M. Occelli, and F. Caracciolo. 2023. “Examining linkages among multiple sustainable development outcomes: does the productive safety net program increase on-farm agrobiodiversity?” *Environment, Development and Sustainability*. Available at: https://link.springer.com/10.1007/s10668-023-03257-2 [Accessed August 7, 2023].

Legesse, B.A., K. Jefferson-Moore, and T. Thomas. 2018. “Impacts of land tenure and property rights on reforestation intervention in Ethiopia.” *Land Use Policy* 70:494–499.

Lovo, S. 2016. “Tenure Insecurity and Investment in Soil Conservation. Evidence from Malawi.” *World Development* 78:219–229.

Moreda, T. 2018. “Contesting conventional wisdom on the links between land tenure security and land degradation: Evidence from Ethiopia.” *Land Use Policy* 77:75–83.

Nedessa, B., and S. Wickrema. 2010. “Disaster risk reduction: Experience from the MERET project in Ethiopia.” Revolution from Food Aid to Food Assistance: Innovations in Overcoming Hunger. Available at: https://docustore.wfp.org/stellent/groups/public/documents/newsroom/wfp225961.pdf.

Njuki, J., E. Waithanji, B. Sakwa, J. Kariuki, E. Mukewa, and J. Ngige. 2014. "A Qualitative Assessment of Gender and Irrigation Technology in Kenya and Tanzania." *Gender, Technology and Development* 18(3):303–340.

Nkomoki, W., M. Bavorová, and J. Banout. 2018. "Adoption of sustainable agricultural practices and food security threats: Effects of land tenure in Zambia." *Land Use Policy* 78:532–538.

Nkonya, E., A. Mirzabaev, and J. Von Braun eds. 2016. *Economics of Land Degradation and Improvement – A Global Assessment for Sustainable Development*. Cham: Springer International Publishing. Available at: http://link.springer.com/10.1007/978-3-319-19168-3 [Accessed July 29, 2023].

Nyanga, P.H., F.H. Johnsen, and T.H. Kalinda. 2012. "Gendered impacts of conservation agriculture and paradox of herbicide use among smallholder farmers." *International Journal of Technology and Development Studies* (3):1–24.

Ojha, R.B., K. Atreya, P. Kristiansen, D. Devkota, and B. Wilson. 2022. "A systematic review and gap analysis of drivers, impacts, and restoration options for abandoned croplands in Nepal." *Land Use Policy* 120:106237.

Peter Nkala, N. Mango, M. Corbeels, G.J. Veldwisch, and J. Huising. 2011. "The conundrum of conservation agriculture and livelihoods in Southern Africa." *African Journal of Agricultural Research* 6(24). Available at: http://www.academicjournals.org/ajar/abstracts/abstracts/abstracts2011/26%20Oct/Nkala%20et%20al.htm [Accessed August 7, 2023].

Sartori, M., G. Philippidis, E. Ferrari, P. Borrelli, E. Lugato, L. Montanarella, and P. Panagos. 2019. "A linkage between the biophysical and the economic: Assessing the global market impacts of soil erosion." *Land Use Policy* 86:299–312.

Schmidt, E., and F. Tadesse. 2019. "The impact of sustainable land management on household crop production in the Blue Nile Basin, Ethiopia." *Land Degradation & Development* 30(7):777–787.

Shiferaw, B., and S. Holden. 1999. "Soil Erosion and Smallholders' Conservation Decisions in the Highlands of Ethiopia." *World Development* 27(4):739–752.

Shiferaw, B., and S.T. Holden. 1998. "Resource degradation and adoption of land conservation technologies in the Ethiopian Highlands: A case study in Andit Tid, North Shewa." *Agricultural Economics* 18(3):233–247.

Umar, Bridget., Jens. Aune, Fred. Johnsen, and Obed. Lungu. 2011. "Options for Improving Smallholder Conservation Agriculture in Zambia." *Journal of Agricultural Science* 3(3):p50.

World Bank. 2019. "Implementation completion and results report: Sustainable Land Management Project." No. ICR00004449, World Bank.

World Bank. 2020. “Project Performamance Assessment Report. Ethiopia Sustainable Land Management Project I and II.” No. 153559, Independent Evaluation Group, World Bank. Available at: https://ieg.worldbankgroup.org/sites/default/files/Data/reports/ppar_ethiopiasustainableland.pdf.

Tables

Table 1. LSMS-ISA sample size

Survey year	2011/12	2013/14	2015/16
All households	3,544	5,262	4,951
Rural/Small towns	3,544	3,776	3,697
Agricultural households	2,993	3,500	3,368
Urban	0	1,486	1,254

Source: Living Standard Study-Integrated Surveys in Agriculture (LSMS-ISA).

Table 2. Summary statistics of model variables

	Survey years		
	2011/12	**2013/14**	**2015/16**
Labor *(land preparation, planting, weeding, ridging etc.)*			
Male household labor (person-days)	9.165	7.878	7.204
	(9.904)	8.228)	7.806)
Female household labor (person-days)	4.984	4.433	3.723
	(6.140)	5.853)	4.634)
Male non-household labor (person-days)	1.265	1.121	1.259
	(3.777)	3.314)	4.248)
Female non-household labor (person-days)	0.117	0.191	0.085
	(0.582)	0.851)	0.484)
PSNP labor (dummy)	0.107	0.072	0.083
	(0.309)	(0.258)	(0.276)
Wage employment (dummy)	0.097	0.084	0.084
	(0.296)	0.277)	0.277)
Land characteristics			
At least one plot granted by leaders (dummy)	0.478	0.498	0.491
	(0.500)	(0.500)	(0.500)
At least one plot inherited (dummy)	0.504	0.601	0.592
	(0.500)	(0.490)	(0.492)
At least one plot Rented (dummy)	0.291	0.284	0.296
	(0.454)	(0.451)	(0.457)
At least one plot Moved-in (dummy)	0.054	0.044	0.044
	(0.226)	(0.206)	(0.206)
At least one plot has land use certificate (dummy)	0.464	0.560	0.600
	(0.499)	(0.496)	(0.490)
Total land area (acres)	1.347	1.460	1.441
	(1.387)	(1.351)	(1.574)
Area cultivated (acres)	1.084	1.069	1.098
	(1.188)	(1.039)	(1.216)
Number of plots (#)	11.734	11.164	11.316
	(7.333)	(6.731)	(7.542)
Number of slope plots (#)	3.697	4.603	4.787
	(5.748)	(5.522)	(6.048)
Irrigated area (acres)	0.055	0.013	0.010
	(2.906)	(0.083)	(0.098)
Applied inorganic fertilizer (dummy)	0.540	0.590	0.547
	(0.498)	(0.492)	(0.498)
Applied organic fertilizer (dummy)	0.643	0.658	0.642
	(0.479)	(0.474)	(0.479)
Household demographics			

Rural household (dummy)	0.99	0.99	0.95
	(0.066)	(0.075)	(0.226)
Household size	5.2	5.9	6.5
	(2.20)	(2.33)	(2.44)
Dependency ratio	1.65	1.50	2.11
	(2.511)	(2.186)	(2.615)
Consumption expenditure (per-capita monthly, ETB)	475.98	457.54	478.13
	(442.167)	(335.272)	(302.643)
Received private transfers (dummy)	0.161	0.144	0.138
	(0.368)	(0.351)	(0.345)
Female head (dummy)	0.19	0.20	0.21
	(0.388)	(0.402)	(0.407)
Currently married head (dummy)	0.82	0.80	0.79
	(0.382)	(0.400)	(0.404)
Divorced head (dummy)	0.16	0.18	0.19
	(0.362)	(0.380)	(0.391)
Head's age (years)	44.8	46.5	47.8
	(15.43)	(15.35)	(15.01)
Head completed prim. educ. or lower (dummy)	0.37	0.38	0.40
	(0.484)	(0.485)	(0.489)
Head completed sec. educ. or higher (dummy)	0.033	0.033	0.046
	(0.178)	(0.178)	(0.209)
Head is Orthodox (dummy)	0.473	0.480	0.483
	(0.499)	(0.500)	(0.500)
Head is other Christian (dummy)	0.254	0.237	0.242
	(0.435)	(0.425)	(0.429)
Head is Muslim (dummy)	0.258	0.276	0.279
	(0.438)	(0.447)	(0.449)
Head is other religion (dummy)	0.032	0.027	0.019
	(0.175)	(0.161)	(0.136)
Number of households	**2,993**	**3,500**	**3,368**

Notes: Point estimates are weighted means, representative of agricultural households in rural and small towns across the country. Standard deviations are in parentheses.

Table 3. Summary statistics of outcome variables

	Survey years		
	2011/12	**2013/14**	**2015/16**
Land restoration activities (LRA)			
Any LRA (acres)	0.006	0.743	0.863
	(0.038)	(0.886)	(1.098)
Terracing (acres)	0.001	0.101	0.105
	(0.013)	(0.219)	(0.224)
Contouring (acres)	0.002	0.191	0.335
	(0.020)	(0.471)	(0.767)
Cover crop (acres)	0.116	0.086	0.097
	(0.198)	(0.146)	(0.198)
Crop rotation (1=yes, 0=no)	0.781	0.807	0.783
	(0.414)	(0.395)	(0.412)
Fallowing (acres)	0.000	0.104	0.026
	(0.001)	(0.316)	(0.084)
Pasturing (acres)	0.002	0.097	0.118
	(0.013)	(0.179)	(0.246)
Number of households	**2,993**	**3,500**	**3,368**

Notes: Point estimates are weighted means, representative of agricultural households in rural and small towns across the country. Standard deviations are in parentheses.

Table 4. Correlates of land restoration activities (LRA) –Pooled OLS results

Variables (1=yes, 0= no, unless otherwise noted)	LRA adoption (1=yes, 0=no)				
	All households	*Male-headed households*	*Female-headed households*	*Orthodox households*	*Non-Orthodox households*
Household demographics					
Household size (#)	0.0047***	0.0033*	0.0092**	-0.00036	0.0080***
	(0.0017)	(0.0020)	(0.0039)	(0.0028)	(0.0022)
Dependency ratio (ratio)	-0.0040**	-0.0058**	-0.00064	-0.0056**	-0.0022
	(0.0016)	(0.0025)	(0.0021)	(0.0024)	(0.0022)
Orthodox	0.054***	0.050**	0.070*	-	-
	(0.020)	(0.022)	(0.042)		
Other Christian	0.0034	-0.0054	0.042	-0.030	0.034
	(0.020)	(0.022)	(0.041)	(0.032)	(0.026)
Muslim	0.022	0.0084	0.063	-0.20**	0.061**
	(0.021)	(0.024)	(0.044)	(0.10)	(0.026)
Female head	-0.038***	-	-	-0.030	-0.044**
	(0.014)			(0.022)	(0.017)
Married head	-0.0010	-0.0073	-0.012	0.027	-0.024
	(0.014)	(0.019)	(0.020)	(0.022)	(0.018)
Head education: primary or lower	-0.020**	-0.016*	-0.028	-0.0063	-0.030***
	(0.0083)	(0.0088)	(0.028)	(0.012)	(0.012)
Head education: secondary or greater	-0.097***	-0.11***	-0.0060	-0.12***	-0.094***
	(0.019)	(0.021)	(0.056)	(0.030)	(0.025)
Land ownership					
User right certificate	0.037***	0.041***	0.015	0.010	0.061***
	(0.0094)	(0.010)	(0.021)	(0.014)	(0.013)
Inherited	0.092***	0.099***	0.058***	0.051***	0.12***
	(0.0097)	(0.011)	(0.022)	(0.014)	(0.013)
Granted by local leaders	0.060***	0.067***	0.037	0.046***	0.073***
	(0.010)	(0.011)	(0.023)	(0.016)	(0.013)
Rented	0.023***	0.029***	0.0021	0.0044	0.039***
	(0.0086)	(0.0093)	(0.023)	(0.012)	(0.013)
Land irrigated	0.0011***	0.0011***	0.17	-0.0013	0.0011***

	(0.00028)	(0.00030)	(0.13)	(0.081)	(0.00023)
Used inorganic fertilizer	0.12***	0.0093***	0.013***	0.012***	0.0090***
	(0.0088)	(0.00076)	(0.0020)	(0.0012)	(0.00092)
Used organic fertilizer	0.086***	0.067***	0.13***	0.10***	0.069***
	(0.0088)	(0.0098)	(0.019)	(0.013)	(0.012)
Labor					
Household labor	-0.20***	-0.31***	-0.094	0.037	-0.21***
	(0.065)	(0.069)	(0.11)	(0.024)	(0.070)
Hired labor	0.044***	0.030***	0.078***	0.042***	0.045***
	(0.0077)	(0.0086)	(0.017)	(0.011)	(0.011)
PSNP labor	0.018	0.021	-0.012	0.030	0.011
	(0.012)	(0.013)	(0.026)	(0.018)	(0.015)
Wage employed	-0.0031	-0.0066	-0.0079	0.012	-0.013
	(0.013)	(0.014)	(0.032)	(0.020)	(0.017)
Regional fixed effects	Yes	Yes	Yes	Yes	Yes
Constant	-0.034	0.097	-0.23*	0.11	-0.044
	(0.072)	(0.078)	(0.12)	(0.11)	(0.078)
Observations	**9,749**	**7,516**	**2,233**	**4,108**	**5,641**

Notes: Point estimates are coefficient estimates from panel fixed effects. Standard errors are in parentheses. Level of significance * $p < .10$, ** $p < .05$, *** $p < .01$.

Table 5. Gender-labor days and the probability of land restoration activities (LRA) –Panel Fixed effects results

Labor *(land preparation, planting, weeding, ridging etc.)*	All households	Male-headed households	Female-headed households	Orthodox households	Non-Orthodox households
	(1)	*(2)*	*(3)*	*(4)*	*(5)*
Male household labor days	0.000042	-0.00038	0.0032*	0.0010	-0.00066
	(0.00056)	(0.00060)	(0.0017)	(0.00086)	(0.00074)
Female household labor days	0.0039***	0.0043***	0.0044**	0.0037***	0.0049***
	(0.00090)	(0.0010)	(0.0020)	(0.0012)	(0.0013)
Male non-household labor days	0.0015	0.0013	0.0031	0.0013	0.0014
	(0.0010)	(0.0012)	(0.0024)	(0.0015)	(0.0014)
Female non-household labor days	0.0048	0.0062	-0.0056	0.0054	0.011
	(0.0040)	(0.0045)	(0.011)	(0.0047)	(0.0073)
PSNP labor (dummy)	-0.077***	-0.077***	-0.098**	-0.033	-0.087***
	(0.018)	(0.020)	(0.046)	(0.027)	(0.023)
Wage employed (dummy)	0.034*	0.047**	-0.015	0.071**	0.021
	(0.020)	(0.022)	(0.046)	(0.029)	(0.027)
Control covariates	Yes	Yes	Yes	Yes	Yes
Constant	-0.048	-0.034	0.016	-0.062	-0.12
	(0.065)	(0.075)	(0.14)	(0.078)	(0.10)
Observations	**9,749**	**7,516**	**2,233**	**4,108**	**5,641**

Notes: Point estimates are coefficient estimates from panel fixed effects. Standard errors are in parentheses. Level of significance * $p < .10$, ** $p < .05$, *** $p < .01$. Control covariates include land characteristics (user certificate, land granted, land inherited, land rented, and number of slope plots, irrigated area, organic fertilizer application, inorganic fertilizer application), household demographics (household size, dependency ratio, rural dummy, dummy for received private transfers, head's education, female head, married head, and divorced head), and survey year dummies.

Table 6. Gender-labor days and area under land restoration activities (LRA) –Panel Fixed effects results

Labor *(land preparation, planting, weeding, ridging etc.)*	All households	Male-headed households	Female-headed households	Orthodox households	Non-Orthodox households
	(1)	*(2)*	*(3)*	*(4)*	*(5)*
Male household labor days	-0.00089*	-0.00086	-0.00050	-0.0012	-0.00089
	(0.00054)	(0.00060)	(0.0013)	(0.00092)	(0.00063)
Female household labor days	0.0015*	0.0019*	0.0010	0.0011	0.0024**
	(0.00081)	(0.00098)	(0.0013)	(0.0013)	(0.00098)
Male non-household labor days	0.0022*	0.0018	0.0037*	0.0040*	0.0012
	(0.0012)	(0.0013)	(0.0021)	(0.0021)	(0.0013)
Female non-household labor days	0.0024	0.0021	0.0043	0.0040	0.011
	(0.0048)	(0.0053)	(0.0099)	(0.0059)	(0.0080)
PSNP labor (dummy)	-0.038***	-0.033*	-0.045*	0.010	-0.051***
	(0.014)	(0.017)	(0.027)	(0.025)	(0.017)
Wage employed (dummy)	0.016	0.026	-0.0045	0.038	0.016
	(0.016)	(0.019)	(0.032)	(0.027)	(0.018)
Control covariates	Yes	Yes	Yes	Yes	Yes
Constant	-0.18***	-0.18***	-0.061	-0.33***	-0.15**
	(0.056)	(0.071)	(0.081)	(0.076)	(0.071)
Observations	**9,749**	**7,516**	**2,233**	**4,108**	**5,641**

Notes: Point estimates are coefficient estimates from panel fixed effects. Standard errors are in parentheses. Level of significance * $p < .10$, ** $p < .05$, *** $p < .01$. Control covariates include land characteristics (user certificate, land granted, land inherited, land rented, and number of slope plots, irrigated area, organic fertilizer application, inorganic fertilizer application), household demographics (household size, dependency ratio, rural dummy, dummy for received private transfers, head's education, female head, married head, divorced head, and dummies for religion categories), regional dummies, and survey year dummies.

Table 7. Probability of different types of land restoration activities (LRAs) - Panel fixed effects results

	Terracing	Contour	Crop rotation	Cover cropping	Fallowing	Pasturing
Labor *(land preparation, planting, weeding, ridging etc.)*	(1)	(2)	(3)	(4)	(5)	(6)
Male household labor days	-0.0015***	0.0019***	0.00061	0.00089	-0.00030	-0.0023***
	(0.00058)	(0.00059)	(0.00046)	(0.00058)	(0.00050)	(0.00060)
Female household labor days	0.0033***	0.00027	0.0021***	0.00032	-0.00040	0.0026***
	(0.00086)	(0.00093)	(0.00073)	(0.00091)	(0.00082)	(0.00093)
Male non-household labor days	-0.00052	0.0018*	0.000033	0.0012	0.00096	-0.0011
	(0.0010)	(0.0011)	(0.00081)	(0.00095)	(0.0010)	(0.0010)
Female non-household labor days	0.0016	0.0083*	0.0019	0.0028	-0.0047	0.011**
	(0.0045)	(0.0048)	(0.0030)	(0.0045)	(0.0046)	(0.0047)
PSNP labor (dummy)	-0.088***	-0.029	0.015	-0.025	0.016	-0.013
	(0.020)	(0.019)	(0.016)	(0.019)	(0.016)	(0.019)
Wage employed (dummy)	0.026	0.020	0.030*	0.017	0.022	0.047**
	(0.019)	(0.018)	(0.016)	(0.019)	(0.017)	(0.020)
Control covariates	Yes	Yes	Yes	Yes	Yes	Yes
Constant	-0.33***	-0.19***	-0.31***	-0.045	-0.087**	-0.33***
	(0.036)	(0.038)	(0.043)	(0.048)	(0.037)	(0.041)
Observations	**9,749**	**9,749**	**9,749**	**9,749**	**9,749**	**9,749**

Notes: Point estimates are coefficient estimates from pooled probit regression. Standard errors are in parentheses. Level of significance * $p < .10$, ** $p < .05$, *** $p < .01$. Control covariates include land characteristics (user certificate, land granted, land inherited, land rented, and number of slope plots, irrigated area, organic fertilizer application, inorganic fertilizer application), household demographics (household size, dependency ratio, rural dummy, dummy for received private transfers, head's education, female head, married head, divorced head, and dummies for religion categories), and survey year dummies.

APPENDIX

Table A1. Probability of land restoration activities (LRA) –Pooled OLS results

Labor *(land preparation, planting, weeding, ridging etc.)*	All households	Male-headed households	Female-headed households	Orthodox households	Non-Orthodox households
	(1)	(2)	(3)	(4)	(5)
Male household labor days	0.0019***	0.0017***	0.0030***	0.0022***	0.0014***
	(0.00040)	(0.00045)	(0.00092)	(0.00073)	(0.00046)
Female household labor days	0.00095	0.0010	0.00025	-0.00013	0.0012
	(0.00062)	(0.00076)	(0.00093)	(0.00096)	(0.00078)
Male non-household labor days	0.0035***	0.0031***	0.0040***	0.0045***	0.0029***
	(0.00087)	(0.00100)	(0.0015)	(0.0015)	(0.00099)
Female non-household labor days	0.012***	0.0098**	0.019**	0.015***	0.0092
	(0.0037)	(0.0040)	(0.0086)	(0.0046)	(0.0059)
PSNP labor (dummy)	-0.027***	-0.018*	-0.033**	-0.065***	0.0055
	(0.0090)	(0.011)	(0.013)	(0.015)	(0.011)
Wage employed (dummy)	-0.036***	-0.039***	-0.010	-0.049***	-0.017
	(0.010)	(0.012)	(0.019)	(0.016)	(0.012)
Control covariates	Yes	Yes	Yes	Yes	Yes
Constant	-0.43***	-0.48***	-0.27***	-0.54***	-0.37***
	(0.031)	(0.038)	(0.048)	(0.17)	(0.035)
Observations	**9,749**	**7,516**	**2,233**	**4,108**	**5,641**

Notes: Point estimates are coefficient estimates from pooled OLS regression. Standard errors are in parentheses. Level of significance * $p < .10$, ** $p < .05$, *** $p < .01$. Control covariates include land characteristics (user certificate, land granted, land inherited, land rented, and number of slope plots, irrigated area, organic fertilizer application, inorganic fertilizer application), household demographics (household size, dependency ratio, rural dummy, dummy for received private transfers, head's education, female head, married head, divorced head, and dummies for religion categories), regional dummies, and survey year dummies.

Table A2. Correlates of area under land restoration activities (LRA) –Pooled OLS results

Labor *(land preparation, planting, weeding, ridging etc.)*	All households	Male-headed households	Female-headed households	Orthodox households	Non-Orthodox households
	(1)	(2)	(3)	(4)	(5)
Male household labor days	0.0019***	0.0017***	0.0030***	0.0022***	0.0014***
	(0.00040)	(0.00045)	(0.00092)	(0.00073)	(0.00046)
Female household labor days	0.00095	0.0010	0.00025	-0.00013	0.0012
	(0.00062)	(0.00076)	(0.00093)	(0.00096)	(0.00078)
Male non-household labor days	0.0035***	0.0031***	0.0040***	0.0045***	0.0029***
	(0.00087)	(0.00100)	(0.0015)	(0.0015)	(0.00099)
Female non-household labor days	0.012***	0.0098**	0.019**	0.015***	0.0092
	(0.0037)	(0.0040)	(0.0086)	(0.0046)	(0.0059)
PSNP labor (dummy)	-0.027***	-0.018*	-0.033**	-0.065***	0.0055
	(0.0090)	(0.011)	(0.013)	(0.015)	(0.011)
Wage employed (dummy)	-0.036***	-0.039***	-0.010	-0.049***	-0.017
	(0.010)	(0.012)	(0.019)	(0.016)	(0.012)
Control covariates	Yes	Yes	Yes	Yes	Yes
Constant	-0.43***	-0.48***	-0.27***	-0.54***	-0.37***
	(0.031)	(0.038)	(0.048)	(0.17)	(0.035)
Observations	**9,749**	**7,516**	**2,233**	**4,108**	**5,641**

Notes: Point estimates are coefficient estimates from pooled OLS regression. Standard errors are in parentheses. Level of significance * $p < .10$, ** $p < .05$, *** $p < .01$. Control covariates include land characteristics (user certificate, land granted, land inherited, land rented, and number of slope plots, irrigated area, organic fertilizer application, inorganic fertilizer application), household demographics (household size, dependency ratio, rural dummy, dummy for received private transfers, head's education, female head, married head, divorced head, and dummies for religion categories), regional dummies, and survey year dummies.

Table A3. Share of female labor days and area under land restoration activities (LRA) – Panel fixed effects

Labor *(land preparation, planting, weeding, ridging etc.)*	All households	Male-headed households	Female-headed households	Orthodox households	Non-Orthodox households
	(1)	*(2)*	*(3)*	*(4)*	*(5)*
Share of female household labor days	0.0034	0.0037	0.0068	0.0035	0.0048
	(0.0048)	(0.0057)	(0.0082)	(0.0069)	(0.0062)
Share of female non-household labor days	-0.0030	-0.020	0.016	-0.021	0.069*
	(0.023)	(0.030)	(0.045)	(0.027)	(0.038)
PSNP labor (dummy)	-0.039***	-0.034**	-0.046*	0.0082	-0.051***
	(0.014)	(0.017)	(0.027)	(0.026)	(0.017)
Wage employed (dummy)	0.015	0.025	-0.0037	0.036	0.017
	(0.016)	(0.019)	(0.032)	(0.027)	(0.018)
Control covariates	Yes	Yes	Yes	Yes	Yes
Constant	-0.18***	-0.19***	-0.062	-0.32***	-0.15**
	(0.057)	(0.072)	(0.082)	(0.077)	(0.071)
Observations	**9,749**	**7,516**	**2,233**	**4,108**	**5,641**

Notes: Point estimates are coefficient estimates from pooled OLS regression. Standard errors are in parentheses. Level of significance * $p < .10$, ** $p < .05$, *** $p < .01$. Control covariates include land characteristics (user certificate, land granted, land inherited, land rented, and number of slope plots, irrigated area, organic fertilizer application, inorganic fertilizer application), household demographics (household size, dependency ratio, rural dummy, dummy for received private transfers, head's education, female head, married head, divorced head, and dummies for religion categories), regional dummies, and survey year dummies.

Table A4. Gender-labor days and area under different types of land restoration activities (LRAs) – Panel fixed effects

	Terracing	Contour	Crop rotation	Cover cropping	Fallowing	Pasturing
Labor *(land preparation, planting, weeding, ridging etc.)*	(1)	(2)	(3)	(4)	(5)	(6)
Male household labor days	-0.00038*	0.00083*	0.00061	0.00017	0.00024	-0.00043**
	(0.00022)	(0.00043)	(0.00046)	(0.00021)	(0.00021)	(0.00018)
Female household labor days	0.00072**	0.00016	0.0021***	-0.0000056	-0.00037	0.00056**
	(0.00032)	(0.00063)	(0.00073)	(0.00029)	(0.00031)	(0.00027)
Male non-household labor days	0.00042	0.0024**	0.000033	0.00048	-0.00054	0.00036
	(0.00037)	(0.0010)	(0.00081)	(0.00045)	(0.00038)	(0.00032)
Female non-household labor days	-0.00021	0.0061*	0.0019	-0.00040	-0.0019	-0.0019
	(0.0016)	(0.0035)	(0.0030)	(0.0014)	(0.0020)	(0.0014)
PSNP labor (dummy)	-0.010	-0.012	0.015	-0.018***	0.0021	-0.0016
	(0.0086)	(0.011)	(0.016)	(0.0069)	(0.0046)	(0.0056)
Wage employed (dummy)	-0.0050	-0.0030	0.030*	0.0058	0.0098	0.0025
	(0.0067)	(0.012)	(0.016)	(0.0053)	(0.0063)	(0.0052)
Control covariates	Yes	Yes	Yes	Yes	Yes	Yes
Constant	0.013	-0.12**	0.49***	0.060***	-0.0095	-0.0089
	(0.021)	(0.048)	(0.054)	(0.022)	(0.016)	(0.019)
Observations	**9,749**	**9,749**	**9,749**	**9,749**	**9,749**	**9,749**

Notes: Point estimates are coefficient estimates from pooled probit regression. Standard errors are in parentheses. Level of significance * $p < .10$, ** $p < .05$, *** $p < .01$. Control covariates include land characteristics (user certificate, land granted, land inherited, land rented, and number of slope plots, irrigated area, organic fertilizer application, inorganic fertilizer application), household demographics (household size, dependency ratio, rural dummy, dummy for received private transfers, head's education, female head, married head, divorced head, and dummies for religion categories), regional dummies, and survey year dummies.