Title

Gender matters in farm investment:

Implications for land tenure security and household welfare

Abstract

The gender gap in rural development has received attention from researchers and practitioners, and for women's empowerment it is necessary to better understand how gender intersects with land tenure and farm investments. However, there is a lack of research on the relationship between women's managerial rights, farm investment, and household welfare. This study examines the nexus among land tenure security, farm investment, household welfare, and their interactions with gender in Zambia, one of the most ethnically diverse countries in sub-Saharan Africa. To this end, we use datasets from a new and nationally representative panel survey in Zambia and take advantage of two distinct societies in the country: matrilineal and patrilineal. We find that land tenure is positively associated with farm investment and that women with land tenure are more likely to invest in tree planting to protect harvests from weather shocks. Furthermore, tree planting enhances farm income and alleviates food insecurity. Dividing households into matrilineal and patrilineal societies reveals that households led by women benefit from land tenure security and farm investment only in patrilineal societies. This heterogeneity suggests that the gender gap in rural areas stems from the male dominance in land stewardship. Therefore, these findings provide insights into the underpinnings of policies that empower women and increase their bargaining power within households through land reform.

1. Introduction

Agriculture has long been a critical component of Sub-Saharan Africa's (SSA) economies in terms of economic value and labor structure, and Zambia is no exception. The share of employment in agriculture was still over 50% in 2019, as shown in Figure 1 and the share of agriculture, forestry, and fishing value-added to the GDP remained at 2.7% in 2020 (Mulenga, 2021). In the agrarian sector, women play a crucial role in increasing food security; however, social norms would force women to say that they work at home, even when they are heavily involved in agriculture (Deere, 2005). Moreover, when new opportunities are created through changes in markets or technologies, women's labor burden in household work and food production may limit their ability to exploit these opportunities (Doss, Meinzen-Dick, Quisumbing, & Theis, 2018). Therefore, we need to build women's access to the resources needed for productive agriculture to attain gender equality and empowerment of all women and girls, as declared in Sustainable Development Goal (SDGs) number 5

[Figure 1 here]

Despite the consensus on the role of women in agriculture, studies have consistently found a gender gap in agricultural productivity in SSA. Ali, Bowen, Deininger, and Duponchel (2016) and United Nations Women (2019) identified the drivers of the gender gap in agricultural productivity. These include the fact that women have less access to male family labor and land, have lower use of contemporary farm technologies, plant fewer high-value crops, and have a high burden of unpaid household care and domestic work. One significant cause of this gender gap is women's lack of access to land rights, which has received increasing attention from development practitioners and activists (Doss, 2018). As such, narrowing gender inequality in land rights can be one way to narrow the gender gap in agricultural productivity and, consequently, improve household welfare.

Women's land rights (WLR) have several definitions; 1) land ownership; 2) right to make

planting decisions; and 3) the right to make output decisions (Kang, Schwab, & Yu, 2020). For example, ownership is linked to farmers' investment in soil quality improvement, terracing, bun walls, creating irrigation channels, purchasing irrigation equipment, and fallowing (Agarwal & Mahesh, 2023). However, empirical studies on the right to make planting decisions and farm investment are scarce. Taking advantage of the traits of our dataset, we identified planting decision makers on plots (women vs. men) and households' decision-making processes (sole vs. joint decision-making). This information is more reliable than the information such as gender of household head or plot holders to represent WLR (de la O Campos, Covarrubias, & Prieto Patron, 2016).

In this paper, we answer three research questions; First, we investigate whether land tenure security increases farm investment. Second, we examine whether there are any gender differences in the association between land tenure and farm investment. Finally, we examined whether there are any heterogeneous associations among land tenure, farm investment, farm income, and food insecurity across kinship systems. To this end, we use a new panel data designed to obtain a comprehensive picture of Zambia's small- and medium-scale farming sector using the 2010 Census sampling frame followed by the 2022 Census (Indaba Agricultural Policy Research Institute, 2016). Furthermore, we exploit the facts that Zambia has both patrilineal and matrilineal societies to examine whether the gender gaps in agricultural productivity stem from inequality in land tenure and agricultural decision-making due to differences in the societal system.

There is substantial literature looking at the relationship between land tenure and farm investment in rural areas of developing economies (Hayes, Roth, & Zepeda, 1997; Bellemare et al., 2020). On the one hand, land is often the most important natural capital for supporting agricultural production and providing food security (FAO, 2018). On the other hand, Place (2009) argues that debates continue on whether land tenure security enhances agricultural

productivity. Although previous studies have found that increasing women's bargaining power in farming associates with increased household food consumption in SSA (Doss, 2006; Muchomba, 2017), Meinzen-Dick, Quisumbing, Doss, and Theis (2019) state that there is less agreement and insufficient evidence on the association between WLR and livelihoods including household food (in)security as opposed to bargaining power and decision-making on consumption and human capital investment. In addition, Kang et al., (2020) conclude that women supply more of their own labor to plots they control, and gender inequality in labor allocation varies with each structure-domain combination. However, little is known about whether this observed agricultural gender inequality is innate or derived from societal differences.

The main contribution of this paper is threefold. First, we provide novel evidence of a link among land tenure, farm investment decisions and household welfare in Zambia where matrilineal societies coexist with patrilineal societies. To the best of our knowledge, empirical studies have examined the relevance of sole and joint decision-making in the association between farm investment and WLR (Meinzen-Dick et al., 2019). This is because the linkage depends on local context and the overarching macro-and sectoral conditions (Place, 2009). Second, we examine the association between farm investment and not only farm income but also household food insecurity across the genders of decision-makers. Finally, we provide insights into the underpinnings of the observed gender differences in agricultural decision-making across men and women by comparing patrilineal and matrilineal households.

Our results revealed that land tenure security increases farm investment in soil and land management. Land tenure security increases investment in tree planting if the decision makers on farm plots are women. Tree planting also increases farm income and reduces food insecurity. We also found that women in patrilineal societies benefit proportionately from land tenure security and farm investments. Such insights may also be relevant to the policy community

where the gender gap in agriculture is poorly understood.

The remainder of this paper is organized as follows: In Section 2, we provide background on the Zambian agrarian sector. Section 3 presents the data and descriptive statistics. Section 4 presents the conceptual and empirical framework for answering our research questions. Section 5 discusses the estimation results. Finally, Section 6 concludes the paper and discusses policy implications.

2. Land tenure systems and matrilineal society in Zambia

2.1. Land tenure systems

Zambia has two land tenure systems. These are the customary statutory systems. Under the customary system, traditional establishments such as the chief and/or village headman allocate vacant land to families and individuals on the recommendation of village headmen or headwomen as the first persons of contact at the village level. However, according to Zambia's land laws, customary land does not have legal tenure security. This situation renders usufruct land users vulnerable to displacements by more powerful individuals and corporations (Chu, Young, & Phiri, 2015). Customary land is advantageous to many farmers at the village level. Under this system, for example, land is easy to acquire because the process is short and affordable for many users.

In 1995, Zambia government implemented the Lands Act to allow for individual ownership rights and other formal land rights transfer. If households want formal access to customary lands through the statutory system, they must be devolved from customary to statutory status (Chamberlin & Ricker-Gilbert, 2016). Moreover, once land is converted to statutory tenure, Moreover, once the land is converted to statutory tenure, it cannot be returned to its customary tenure (Hall, Murombedzi, Nkonkomalimba, Sambo, & Sommerville, 2017). Under the statutory system, landowners have rights to sell, rent, mortgage, or transfer their land (Chapoto, Jayne, & Mason, 2011). According to the statutory law, women in Zambia can apply for any

land in the country, as their male counterparts do. In the event of divorce or widowhood, if the husband dies without leaving a will and if he held state land, the Intestate Succession Act stipulates that the surviving spouse inherits 20% of the deceased's property, including land, and together with the children, the house (Kapihya, 2017) . However, this Act is not applied generally on customary land. If the deceased husband held customary land, the widow may be permitted to continue to utilize the land. However, the widow may also be ejected from the land by relatives of the deceased (Kapihya, 2017). Owing to data availability, we considered the land title tenured by the customary or statutory system. However, in Zambia, as in almost all SSA, women rarely own or are in charge of the land (Southern & Africa Office, 2003). Therefore, understanding how the interaction between the gender of the plot decision-maker and land tenure security relates to both investment and household welfare would encourage policymakers to plan interventions that empower women in rural economies.

2.2. Matrilineal systems

Because Zambia is one of the most ethnically diverse countries in SSA (Posner, 2004), social norms can vary across Zambia. In a matrilineal society, an individual traces descent through a female line (Mizinga, 2000) and inheritance of property, including land, passes through the female line (Hall et al., 2017). Women acquire rights to land through their husbands when they marry. Under the statutory system, women have the right to land ownership but titles tend to be transited through male relatives in both matrilineal and patrilineal societies (Republic of Zambia, (2005), as cited in Chapoto et al., (2011)). Although women in matrilineal societies have the legal right to make decisions on land, men still rule most of the decisions as clan leaders. For instance, regarding land sales, even though women own the land, they must turn to their maternal uncles, who have the final say in decisions. Hence, considering gender roles in patrilineal (matrilineal) systems provides a deeper understanding of women's empowerment and rural development in SSA.

3. Data

We used the Rural Agricultural Livelihood Survey (RALS), a two-round household panel survey conducted in 2012 and 2015 by the Indaba Agricultural Policy Research Institute (IAPRI), together with the Central Statistical Office (CSO) and the Ministry of Agriculture in Zambia (Fung, Liverpool-Tasie, Mason, & Oyelere, 2020). The RALS covers the 2010/2011 and 2013/2014 agricultural years and is in accordance with maize marketing years (2011/2012 and 2014/2015). A total of 8571 household in the first wave, and 7579 households in the second wave were surveyed in 442 Standard Enumeration Areas[1] (SEAs) in all districts of the country after removing observations with missing values. The sample was designed to represent rural farm households that cultivate less than 20 ha of land for farming and/or livestock production (Sitko, Chamberlin, & Hichaambwa, 2014). This survey enabled us to examine a variety of questions about smallholder farmers who have land titles and their effects on farm investments. This is an advantage because the land tenure information in this survey was observed at the plot level. To take advantage of the availability of plot-level characteristics, we conducted household- and plot-level analyses. In our household-level analysis, the title was considered equal to one if one or more of a farm household's plots were titled. Descriptions of the variables used in this study are provided in Table 1. Because we explore both plot-level relationships and household (HH)-level relationships, plot and household characteristics are shown in Table 1. Because we explore both plot-and household (HH)-level relationships, the plot and household characteristics are shown in Table 1. Regarding plot-level characteristics, the differences in all variables between 2012 and 2015 were statistically significant. Regarding, farm investment variables, in terms of household-level characteristics, there is no statistical difference in farm income but food insecurity. Moreover, the share of matrilineal households is approximately 32%–36%. While the number of plots decreases, the number of households planting cash crops and obtaining credit increases over time.

[Table 1]

3.1. Measurement of key variables

The variables of interest are land tenure, soil and land management, tree planting, irrigation, total household income, farm income, and months of food insecurity. The plot-level land tenure security measures 1 if the plot is tenured by the government and 0 otherwise. The HH-level tenure security measures 1 if the household owns at least one plot secured by the government and 0 otherwise. Regarding the gender of decision-makers, it captures 1 if the decision-makers are women and 0 otherwise at the plot level. At the HH level, joint decision-making means that households have both male and female decision makers, while women's decision-making means that only women participate in decision-making in land management. Three farm investments were included in the analysis: soil and land management, tree planting, and irrigation. They were also measured by the application areas at the plot and HH-level. Finally, two outcome variables were analyzed. The first outcome variable is farm income, which captures income from farm products, such as maize, cassava, other crops, vegetables, and fruits. The unit is Zambia Kwacha (ZMW). The values were deflated to real 2017 terms[2]. Another outcome variable is food insecurity, which measures the number of months for which a household lacks enough food to meet its needs.

3.2. Descriptive statistics

Table 2 shows that female decision-makers are more likely to own secured land, regardless of the gender of the household head. This result is contrary to our intuition that women have less access to land. One plausible explanation is that women can decide how to use a plot that is relatively central to the networks of social and political power that permeate a community (Goldstein & Udry, 2008). Table 3 reports the relationships among kinship, mean plot size, and the gender of decision-makers. Women are more likely to make decisions in a matrilineal system than in a patrilineal system. However, men tended to use more land than women. Table

4 shows that the ratio of land titles possessed by smallholder farmers was slightly less than that of medium-sized farmers. Figure 2 presents the geographical distribution of farmers with land titles, farm income, and farm investment management based on RALS 2012 and 2015. Panel A presents the geographical distribution of farmers with land tenure (%). Panel B shows the geographical distribution of the average annual farm income (ZMW). Copperbelt Province, Central Province, and Southern Province have the highest farm incomes and are the pivots of the Zambian rural economy (Zambia Statistics Agency, 2015). Panels C, D, and E show the geographical distribution of the farm investment areas (ha). From the graphical analysis, we could not distinguish among the linkages between land tenure security, farm investment, and household welfare. Therefore, we examine this nexus empirically in the following sections.

[Table 2 here]

[Table 3 here]

[Table 4 here]

[Figure 2 here]

4. Methodology

To address our research questions, we construct a conceptual framework and employ empirical approaches. This conceptual framework presents a concise and potential mechanism for the link between land tenure security, farm investment, income, and food insecurity through graphical and descriptive representations. Empirical approaches outline a method for estimating the model specified in a conceptual framework using a dataset.

4.1. Conceptual framework

The aim of this analysis is to provide insights in the nexus among land tenure security, farm investment, and household welfare. In many African settings, agricultural production is conducted simultaneously on many plots controlled by different household members. Typically, many studies on gender and agricultural labor use household-level information, which ignores

within-household plot-level ownership variations (Doss, 2018), and women's plot ownership does not always imply managerial rights to women (Doss, Kovarik, Peterman, Quisumbing, & van den Bold, 2015). Therefore, it is worth noting that we conduct plot-level analysis for farm investment decisions, not assuming a unitary household. Figure 3 illustrates the conceptual framework of the links between land tenure security, farm investment, and household welfare. Land tenure security is believed to improve household welfare by increasing farm investment (Bellemare et al., 2020; Goldstein & Udry, 2008; Issahaku & Abdulai, 2020). Babatunde and Qaim (2010) show that an increase in farm income, which is supposed to be associated with farm investment, is positively correlated with household food security. Although Deininger, Xia, Kilic, and Moylan (2021) found that women's rights affect investment, little is known about the relationship between land ownership and productivity from a gender perspective in most regions (Agarwal & Mahesh, 2023). In Africa, customary systems, such as patrilineal succession, restrict or even exclude women's access to ownership and control over land (Najjar, Baruah, & El Garhi, 2020). This is related to the lower female labor supply in farming without ownership for land (Palacios-Lopez, Christiaensen, & Kilic, 2017). Therefore, it would induce less farm output because adult male labor is found to contribute more to agricultural production at the margin than adult female labor (Jacoby, 1991). Furthermore, as theory predicts that women prefer to devote resources to improving their nutritional status (Thomas, 1990); households with land tenure that are solely held by a woman, compared to those without land tenure, allocate more of their family budget to food (Menon, van der Meulen Rodgers, & Nguyen, 2014). Our study contributes to the literature on land tenure security and farm investment from a gender perspective. Based on the above discussion, we propose two hypotheses to be tested by our empirical approach.

Hypothesis I. Land tenure security enhances farm investment. In particular, women are more likely to invest than men when a plot has tenure security.

Hypothesis II. Farm investment improves household welfare, farm income and food security. The effect of farm investment is more sizable for farmers with women decision making because women get empowered within a household in this case.

[Figure 3 here]

4.2. Empirical model

We use plot-level variables to explore the nexus between land tenure security and farm investments. However, land tenure security may be related to plots and household characteristics, which affect farm investment behavior. Therefore, we explicitly account for the selection on observable factors and match farmers with similar characteristics. Previous studies on decision-making in agriculture have used estimation methods such as propensity score matching (PSM), inverse probability weighting (IPW), and the doubly robust (DR) method when other plausible instruments are not available (Bellemare & Novak, 2017; Issahaku & Abdulai, 2020; Lawin & Tamini, 2019). We apply the DR method, or more accurately, an inverse-probability weighted regression adjustment that combines regression and propensity score weighting[3]. It is more robust than the PSM and IPW estimators because it can provide a consistent estimator when either the propensity score for land tenure security or the outcome regression in terms of tenure characteristics is correctly specified (Mano, Njagi, & Otsuka, 2022). To estimate the propensity to own land tenure, we first estimate the binary model as follows:

$$T_{pit}^{*} = \alpha_1 x_{pit} + \alpha_2 X_{it} + \rho_t + v_g + e_{pit}, \qquad with\ T_{pi} = \begin{cases} 1\ if\ T_{pi}^{*} > 0 \\ 0\ if\ T_{pi}^{*} \leq 0 \end{cases} \tag{1}$$

where T_{pit}^{*} is the latent variable of land tenure security of plot p of household i of year t, x_{pit} is the vector of plot p's characteristics of household i in year t, X_{it} is the vector of household i's characteristics of year t, ρ_t is the year dummy to control time trend, v_g is province dummy to account for geographical characteristics, and e_{pit} is the error term. Using Equation (1), we

calculate the propensity of plots with tenure using the Probit model. The probability of titled plots, conditional on the plot and household characteristics, can be expressed as

$$P\left(T_{pit}=1\middle|x_{pit},X_{it}\right)\equiv p\left(x_{pit},X_{it}\right)$$

where, $p(x_{pit},X_{it})$ is the propensity score of the tenured plot. Using the estimated propensity $\hat{p}(x_{pit}X_{it})$, we estimate the average treatment effect on the treated (ATT) of the land tenure security on farm investment I_{pit} representing area of farm investment:

$$\begin{gathered}\widehat{E(I_1)}=\frac{1}{n}\sum_{\{i=1\}}^{n}\left[\frac{T_{it}}{\hat{p}(x_{pit}X_{it})}I_{1pit}+\left(1-\frac{T_{it}}{\hat{p}(x_{pit}X_{it})}\right)\hat{I}_{1pit}\right]\\ \widehat{E(I_0)}=\frac{1}{n}\sum_{\{i=1\}}^{n}\left[\frac{1-T_i}{1-\hat{p}(x_{pit}X_{it})}I_{0pi}+\left(1-\frac{1-T_i}{1-\hat{p}(x_{pit}X_{it})}\right)\hat{I}_{0pi}\right]\\ \hat{\tau}_{ATT.DR}=\widehat{E(I_1)}-\widehat{E(I_0)}\end{gathered}\tag{2}$$

where $\hat{I}_{1pi}$ and $\hat{I}_{0pi}$ are the predicted farm investment from of what will happen under $T_{pi}=1, T_{pi}=0$ conditioned on x_{pi}, X_i, and n is the number of sample plots. $\hat{\tau}_{ATT.DR}$ is the doubly robust estimator of ATT which is an unbiased estimate of the statistical association between land tenure and farm investment. The outcome variables are farm investment I_{pi}, soil and land management, tree planting, and irrigation.

In addition to the DR methods, we utilize PSM with fixed effects to investigate the heterogeneous association between land tenure security and farm investment over gender by incorporating the interaction term. The reason for employing PSM with fixed effects is to address the endogeneity bias due to the observed characteristics and time-invariant unobserved characteristics. Moreover, this can serve as a robustness check for the DR methods. Thus, we can write the specified econometric model as follows:

$$I_{pit}=\beta_1 T_{pit}+\beta_2 T_{pit}*women_{pit}+\beta_3 x_{pit}+\beta_4 X_{it}+a_i+\sigma_t+v_g+u_{pit}\tag{3}$$

where I_{pi} is farm investment of plot-level *p* of household *i*, T_{pit} is the dummy variable of land tenure status of plot *p* of household *i* in year *t*, $women_{pit}$ is a dummy variable if the decision

maker of plot p is a women, $a_i$is the household fixed effect, σ_t is the time fixed effect, and u_{pit} is the error term.

Beyond the relationship between land tenure security and farm investment, we examine the factors affecting household welfare using HH-level data. Land tenure can be positively associated with household welfare through various mechanisms, of which more farm investment is only one. Other possible mechanisms include positive effects on land market participation, consolidation of land, and other confounders (Ali, Deininger, & Goldstein, 2014; Ma, 2022). To test whether farm investment is a relevant mechanism, we incorporate both the land tenure variable and the farm investment variable[4]. The specification model is written as follows:

$$Y_{it} = \gamma_1 + \gamma_2 T_{it} + \gamma_3 I_{it} + \gamma_4 X_{it} + a_i + \sigma_t + v_g + \epsilon_{it} \quad (4)$$

where, Y_{it} is the outcome variable including farm income and months of food insecurity, T_{it} is the land tenure which indicates a dummy variable that if household *i* has at least one cultivated plot with tenure, $I_{it}$is the cultivated areas with farm investments, a_i is the household fixed effect, and ϵ_{it} is the error term. Furthermore, to investigate whether the association between land tenure security or farm investment and household welfare (Y_{it} in Equation (4)) changes depending on sole or joint decision-making, we included the interaction term between land tenure or farm investment and sole or joint decision-making in Equation (4). We estimate Equation (4) with the fixed effects to account for the time-constant unobservable factors which affect farm investment decision and household welfare. Nonetheless, no study that relies on observational data can claim to have fully controlled for all unobservable factors, and it is possible that land tenure and farm investment are endogenous because of their potential correlation with unobservable time-varying factors. Therefore, statements regarding causality were made with caution.

5. Results and discussions

5.1. Determinants of land tenure security

Although our primary interest is the causal effect of tenure security on farm investment behavior, we first examine the determinants of land tenure security. by estimating Equation (1). Table 5 shows the results of Equation (3) estimated by the Probit model and Linear Probability Model (LPM)[5]. Regarding the plot characteristics, purchased land is more likely to be secured, as shown in Columns (1) and (2). In addition, the coefficient of women on the decision marker is positively significant. This indicates that if the decision-maker of a plot is a woman, the plot is more likely to be secured. One potential explanation is that women who possess land rights are likely to have bargaining power within households, which is correlated with decision-making (Meinzen-Dick et al., 2019). Moreover, the plot is more likely to be secured if the household head has more educational experience. This is consistent with a study conducted in Zambia by Sitko et al. (2014). The age of the household head and asset index were significantly correlated with land tenure security. It is reasonable that older or wealthier households are more likely to have tenured plots because they may hold influential positions in the local political hierarchy, and such people are likely to have more secure tenure rights (Goldstein & Udry, 2008).

[Table 5 here]

5.2. Effect of land tenure on farm investment

Table 6 summarizes the results of the DR estimation for the entire sample and the subsamples by estimating Equation (2). The result in Column (1) shows that land tenure security is positively associated with soil and land management to prevent soil erosion and flash flooding. This indicates that land tenure security induces farm investments, especially in soil and land management. We divide the entire sample into two subsample groups: female and male decision makers. The coefficient of land tenure is positively significant for soil and land management. If a plot is registered with de jure tenure security, the area invested in soil and

land management increase by approximately 0.07 ha. This finding indicates that land tenure encourages both men and women to invest in improving land fertility. This result is consistent with the findings of Goldstein and Udry (2008), Abdulai, Owusu, and Goetz (2011), Ali, Deininger, and Goldstein (2014), Lovo (2016), and Lawin and Tamini (2019). Column (2) shows that the only coefficient of land tenure of plots operated by women is significant. Column (2) shows that only the coefficient of land tenure for plots operated by women is significant. The results indicate that land tenure security increases tree planting by female decision makers. As insecure rights for women can undercut growth and productivity (Dillon & Voena, 2018), the results highlight the importance of women's decision-making in agriculture for sustainable agricultural development.

[Table 6 here]

Moreover, Table 7 shows the heterogeneous effect of land tenure on farm investment based on the gender of the decision-makers. In Column (2), the coefficient of the interaction term is positively significant, indicating that female decision makers of plots with land tenure are more likely to invest in planting trees to protect yield than male decision makers with land tenure. This result corroborates our findings in Table 5 and is consistent with those of Otsuka, Quismbing, and Payongayong (2003) and Dillon and Voena (2018). The results show that our Hypothesis I is confirmed and emphasize that land tenure security encourages women decision makers to invest in agricultural practices to enhance output, especially for tree planting.

[Table 7 here]

5.3. Potential mechanism among land tenure, farm investment, and household welfare

As discussed in Section 4, our main research objective was to examine the empirical link between land tenure, farm investment, and household welfare. Table 8 presents factors related to household welfare, including farm income and food insecurity by estimating Equation (4)[6]. The coefficient estimates for the factors related to farm income are presented in Columns (1),

(3), and (5). The results derived using OLS-FE with control variables indicate that soil and land management have a positive and significant association with farm income. This indicated that an additional hectare invested in soil and land management led to an average increase of 10.5% in farm income. Moreover, tree planting was significantly associated with farm income, indicating that an additional hectare invested in tree planting provides households with an average increase in farm income of 17.6%. Land tenure and irrigation are significantly associated with farm income in Column (1), but their coefficients are insignificant in Column (5).

For food insecurity (Columns (2), (4), and (6)), the benefits of tree planting are negative and significant. This indicates that planting an additional hectare of trees reduces 0.03 months of food insecurity. Although the estimates for land tenure security, soil and land management, and irrigation are significant, the coefficients become insignificant after controlling for covariates and fixed effects.

In Column (7), farm income is treated as an independent variable to investigate the mechanism through which it improves food, as shown in Figure 3. The coefficient of farm income was statistically significant. The results indicate that a 1% increase in farm income reduces 0.09 months of household food insecurity. These results are reasonable, because farm investment in agricultural practices increases farm income and efficiency, indicating an indirect effect of farm investment on food security through farm income. In all columns, the OLS estimation results work as a robustness check. Overall, the welfare benefits of tree planting in Zambia are generally consistent with those of previous studies by Abdulai and Huffman (2014), Nkomoki, Bavorová, and Banout (2018), and Issahaku and Abdulai (2020). Our findings contribute to the vast literature on farm investment and household welfare from the viewpoint of not only income, but also food security.

[Table 8 here]

5.4. Does gender matter in farm investment and household welfare?

Many views in development communities assume that the causality between agricultural intervention and women's productivity is rational, and donors are increasingly calling for gender issues to be addressed in development projects and proposals. Others continue to cast doubt on a women-focused blueprint in the agrarian sector, or at least suggest that there may be trades associated with targeting interventions in women (Doss, 2018). To assess women's agricultural productivity, one approach that has been widely acknowledged is to consider the 'household farm enterprise' as the production unit and to compare the productivity of different households, differentiating between male- and female-headed households. Although this approach is relatively easy, it neglects the contributions that women make to farms in men-headed households (and conversely, the contributions that men make to farms in women-headed households) (Doss, 2018). To address this gap, we utilize data on who makes a decision in a plot so that we can consider women's contribution to a farm in households headed by men. This section investigates whether farm households benefit more from farm investment when women are involved in household decision making.

Table 9 summarizes the estimation results for the heterogeneous association between farm investment and household welfare among households with female decision-making, joint decision-making, and male decision-making. Columns (1) and (2) present the estimation results for patrilineal households, whereas columns (3) and (4) present the results for matrilineal households. After controlling for confounding factors, soil and land management significantly increased farm income for households with only women as decision-makers, as shown in Column (1). However, this significant relationship disappears for matrilineal societies, as shown in Column (3). This result plausibly explains that investment in soil and land may make up for the lower labor input from household members and fertilizer for women's plots, especially in patrilineal societies where women's bargaining power is relatively lower than in

matrilineal societies (Fenske, 2011; Udry, 1996). Moreover, the acquisition of land tenure security alleviates food insecurity for households with female decision-making, as shown in Column (2). As in Column (2), no significant association is found in Column (4). This indicates that households where women are solely involved in decision-making benefit from land titles for food insecurity. We find that land tenure security for women increases the bargaining power of women within households, taking care of more food consumption and nutrition, as stated in Hypothesis II. In our analysis, irrigation was not significantly correlated with household welfare. Because there are few application areas for irrigation in our observations, as shown in Table 1, we may not have been able to capture the variations in irrigation adoption.

Overall, it is important to note that land tenure security and farm investments provide benefits for farm income and household food security, especially when women participate in decision-making in male-dominated societies. From the perspective of women's empowerment, these are encouraging results because they imply that policymakers should promote farm investments by strengthening land tenure security for female decision-makers in Zambia.

[Table 9 here]

5.5. Robustness checks

In this section, we conduct a robustness check to determine whether the results change when a different measurement method is used. The effects of land tenure security on farm investments may vary with different farm investment measures. Therefore, we replace the application areas of farm investments with dummy variables. The estimated results are in Table A4 and Table A5. Similar to the results reported in Table 6, these results show that the effects of land tenure security on soil and land management are robust, indicating that land tenure security increases farm investment. Regardless of the gender of the decision makers, significant relationships were uniformly observed in Table A4. Table A5 shows the heterogeneous association between land tenure security and farm investment. The results confirm that there is

a significant difference in the gender of decision-makers regarding the association between land tenure security and tree planting, as shown in Table 7. This indicates that plots with female decision-makers are more likely to invest in tree planting.

6. Summary and concluding remarks

This study makes two major contributions to the literature. First, it assesses the impact of land tenure security on farm investments and how the effect differs according to the gender of the decision-makers. To this end, we take advantage of informative RALS datasets, including information on the gender of decision makers on plots. Although there have been mixed empirical findings on the relationship between land tenure security and farm investments, we found that women tend to invest more in tree planting when plots have land tenure. An empirical analysis of Zambian farmers provides robust evidence in support of Hypothesis I, given the conceptual framework stating the positive association between greater tenurial security and further farm investments. Second, we investigated the mechanism by which household welfare improves through farm investment with land tenure security. Our findings corroborate previous evidence that farm investment increases farm income and improves food insecurity, ultimately improving household welfare as Hypothesis II. Moreover, we provide a deeper understanding of the associations between land tenure security, farm investment, and household welfare from a gender perspective. The heterogeneous analysis shows that land tenure security improves food security, and soil and land management increase farm income only in patrilineal societies when decision makers are women. Since there are few studies looking at the mechanism using nationally representative surveys in Zambia and addressing descent systems, the results and implications would help policymakers consider sustainable agricultural development and land policies and avoid mistargeting.

Although our econometric estimations retain endogeneity concerns stemming from unobservable time-varying factors due to the characteristics of the dataset, the lessons learned

in our study are valuable for future directions in rural development and women's empowerment in Zambia. This is the first study to examine how different in gender of decision makers the relationship among land tenure, farm investment and household welfare among patrilineal and matrilineal households. We suggest that households in which women have the final say in household decisions increase household welfare through farm investments and land tenure security. Furthermore, robustness checks that account for alternative measurements support our main findings.

This study highlights the significance of land tenure security and suggests that land tenure security can promote gender equality in agricultural production. Land policies that secure women's rights could improve household welfare by enhancing farm investments, especially for women in male-dominant societies. Although our study uses datasets from Zambia, we can draw policy recommendations for countries near Zambia, such as Malawi, Mozambique, and Angola, where environmental settings are similar and both patrilineal and matrilineal societies coexist. Indeed, further research will help to generalize the results more broadly.

Reference

Abdulai, A., & Huffman, W. (2014). The adoption and impact of soil and water conservation technology: An endogenous switching regression application. *Land Economics, 90*(1), 26–43. doi:10.3368/le.90.1.26.

Abdulai, A., Owusu, V., & Goetz, R. (2011). Land tenure differences and investment in land improvement measures: Theoretical and empirical analyses. *Journal of Development Economics, 96*(1), 66–78. doi:10.1016/j.jdeveco.2010.08.002.

Agarwal, B., & Mahesh, M. (2023). Does the landowner's gender affect self-cultivation and farm productivity? An analysis for India. *Journal of Development Studies, 59*(5), 758–777. doi:10.1080/00220388.2022.2162883.

Ali, D. A., Deininger, K., & Goldstein, M. (2014). Environmental and gender impacts of land tenure regularization in Africa: Pilot evidence from Rwanda. *Journal of Development Economics, 110*, 262–275. doi:10.1016/j.jdeveco.2013.12.009.

Ali, D., Bowen, D., Deininger, K., & Duponchel, M. (2016). Investigating the gender gap in agricultural productivity: Evidence from Uganda. *World Development, 87*, 152–170. doi:10.1016/j.worlddev.2016.06.006.

Babatunde, R. O., & Qaim, M. (2010). Impact of off-farm income on food security and nutrition in Nigeria. *Food Policy, 35*(4), 303–311. doi:10.1016/j.foodpol.2010.01.006.

Republic of Zambia. (2005). *Baseline Survey on Women's Access to Agricultural Land in Zambia*. Retrieved from https://catalog.ihsn.org/citations/35683. Lusaka, Zambia: Republic of Zambia.

Bellemare, M. F., Chua, K., Santamaria, J., & Vu, K. (2020). Tenurial security and agricultural investment: Evidence from Vietnam. *Food Policy, 94*, 101839. doi:10.1016/j.foodpol.2020.101839.

Bellemare, M. F., & Novak, L. (2017). Contract farming and food security. *American Journal*

of Agricultural Economics, 99(2), 357–378. doi:10.1093/ajae/aaw053.

Chamberlin, J., & Ricker-Gilbert, J. (2016). Participation in rural land rental markets in sub-Saharan Africa: Who benefits and by how much? Evidence from Malawi and Zambia. *American Journal of Agricultural Economics, 98*(5), 1507–1528. doi:10.1093/ajae/aaw021.

Chapoto, A., Jayne, T. S., & Mason, N. M. (2011). Widows' land security in the era of HIV/AIDS: Panel survey evidence from Zambia. *Economic Development and Cultural Change, 59*(3), 511–547. doi:10.1086/658346.

Chu, J., Young, K., & Phiri, D. (2015), *Large-scale land acquisitions, displacement and resettlement in Zambia.* Cape Town, South Africa. University of the Western Cape.

de la O Campos, A. P., Covarrubias, K. A., & Prieto Patron, A. (2016). How does the choice of the gender indicator affect the analysis of gender differences in agricultural productivity? Evidence from Uganda. *World Development, 77*, 17–33. doi:10.1016/j.worlddev.2015.08.008.

Deere, C. (2005). The feminization of agriculture? Economic restructuring in rural Latin America. *UNRISD Occasional, paper no. 1*.

Deininger, K., Xia, F., Kilic, T., & Moylan, H. (2021). Investment impacts of gendered land rights in customary tenure systems: Substantive and methodological insights from Malawi. *World Development, 147*, 105654. doi:10.1016/j.worlddev.2021.105654.

Dillon, B., & Voena, A. (2018). Widows' land rights and agricultural investment. *Journal of Development Economics, 135*, 449–460. doi:10.1016/j.jdeveco.2018.08.006.

Doss, C. (2006). The effects of intrahousehold property ownership on expenditure patterns in Ghana. *Journal of African Economies, 15*(1), 149–180. doi:10.1093/jae/eji025.

Doss, C. R. (2018). Women and agricultural productivity: Reframing the Issues *(Development policy review)*. *Development Policy Review*, *36*(1), 35–50. doi:10.1111/dpr.12243.

Doss, C., Kovarik, C., Peterman, A., Quisumbing, A., & van den Bold, M. (2015). Gender

inequalities in ownership and control of land in Africa: Myth and reality. *Agricultural Economics, 46*(3), 403–434. doi:10.1111/agec.12171.

Doss, C., Meinzen-Dick, R., Quisumbing, A., & Theis, S. (2018). Women in agriculture: Four myths. *Global Food Security, 16*, 69–74. doi:10.1016/j.gfs.2017.10.001.

Fenske, J. (2011). Land tenure and investment incentives: Evidence from West Africa. *Journal of Development Economics, 95*(2), 137–156. doi:10.1016/j.jdeveco.2010.05.001.

Food and Agriculture Organization. (2018). The gender gap in land rights. Retrieved from https://www.fao.org/3/i8796en/I8796EN.pdf. Rome, Italy: Food and Agriculture Organization of the United Nations (FAO).

Fung, W., Liverpool-Tasie, L. S. O., Mason, N. M., & Oyelere, R. U. (2020). Do crop purchase programs improve smallholder welfare? The case of Zambia's food reserve agency. *Agricultural Economics*, *51*(4), 519–533. doi:10.1111/agec.12569.

Goldstein, M., & Udry, C. (2008). The profits of power: Land rights and agricultural investment in Ghana. *Journal of Political Economy, 116*(6), 981–1022. doi:10.1086/595561.

Hall, M., Murombedzi, J., Nkonkomalimba, M., Sambo, P., & Sommerville, M. (2017), *Zambia customary Lannd documentation tenure assessment.* Lusaka, Zambia: United States Agency for International Development Tenure and Global Climate Change Program.

Hayes, J., Roth, M., & Zepeda, L. (1997). Tenure security, investment and productivity in Gambian agriculture: A generalized probit analysis. *American Journal of Agricultural Economics*, *79*(2), 369–382. doi:10.2307/1244136.

Indaba Agricultural Policy Research Institute. (2016). *Rural agricultural livelihoods survey; 2015 survey report*. Retrieved from http://www.iapri.org.zm/. Lusaka, Zambia: Indaba Agricultural Policy Research Institute.

Issahaku, G., & Abdulai, A. (2020). Household welfare implications of sustainable land management practices among smallholder farmers in Ghana. *Land Use Policy, 94*, 104502.

doi:10.1016/j.landusepol.2020.104502.

Jacoby, H. G. (1991). Productivity of men and women and the sexual division of labor in peasant agriculture of the Peruvian Sierra. *Journal of Development Economics, 37*(1–2), 265–287. doi:10.1016/0304-3878(91)90090-I.

Kang, M., Schwab, B., & Yu, J. (2020). Gender differences in the relationship between land ownership and managerial rights: Implications for intrahousehold farm labor allocation. *World Development, 125*, 104669. doi:10.1016/j.worlddev.2019.104669.

Kapihya, L. (2017), *A comparative study on women's land rights in Zambia: Access, ownership, control, and decision-Making.* Washington DC: United States Agency for International Development Tenure and Global Climate Change Program.

Lawin, K. G., & Tamini, L. D. (2019). Land tenure differences and adoption of Agri-Environmental practices: Evidence from Benin. *Journal of Development Studies, 55*(2), 177–190. doi:10.1080/00220388.2018.1443210.

Lawry, S., Samii, C., Hall, R., Leopold, A., Hornby, D., & Mtero, F. (2017). The impact of land property rights interventions on investment and agricultural productivity in developing countries: A systematic review. *Journal of Development Effectiveness, 9*(1), 61–81. doi:10.1080/19439342.2016.1160947.

Lovo, S. (2016). Tenure insecurity and investment in soil conservation. Evidence from Malawi. *World Development, 78*, 219–229. doi:10.1016/j.worlddev.2015.10.023.

Mano, Y., Njagi, T., & Otsuka, K. (2022). An inquiry into the process of upgrading rice milling services: The case of the Mwea Irrigation Scheme in Kenya. *Food Policy, 106*, 102195. doi:10.1016/j.foodpol.2021.102195.

Meinzen-Dick, R., Quisumbing, A., Doss, C., & Theis, S. (2019). Women's land rights as a pathway to poverty reduction: Framework and review of available evidence. *Agricultural Systems, 172*, 72–82. doi:10.1016/j.agsy.2017.10.009.

Menon, N., van der Meulen Rodgers, Y., & Nguyen, H. (2014). Women's land rights and children's human capital in Vietnam. *World Development, 54*, 18–31. doi:10.1016/j.worlddev.2013.07.005.

Mizinga, F. M. (2000). Marriage and bridewealth in a matrilineal society: The case of the Tonga of Southern Zambia: 1900–1996. *African Economic History, 28*, 53–87. doi:10.2307/3601649.

Muchomba, F. M. (2017). Women's land tenure security and household human capital: Evidence from Ethiopia's land certification. *World Development, 98*, 310–324. doi:10.1016/j.worlddev.2017.04.034.

Mulenga, B, Kabisa, M, and Chapoto, A. (2021). *Zambia Agricultural Status Report*. Lusaka, Zambia: Indaba Agricultural Policy Research Institute.

Najjar, D., Baruah, B., & El Garhi, A. (2020). Gender and asset ownership in the old and new lands of Egypt. *Feminist Economics, 26*(3), 119–143. doi:10.1080/13545701.2020.1743877.

Nkomoki, W., Bavorová, M., & Banout, J. (2018). Adoption of sustainable agricultural practices and food security threats: Effects of land tenure in Zambia. *Land Use Policy, 78*, 532–538. doi:10.1016/j.landusepol.2018.07.021.

Otsuka, K., Quismbing, A., & Payongayong, E. (2003). Land tenure and the management of land and trees: The case of customary land tenure areas of Ghana. *Environmental and Development Economics, 8*(1), 77–104. doi:10.1017/S1355770X03000056

Palacios-Lopez, A., Christiaensen, L., & Kilic, T. (2017). How much of the labor in African agriculture is provided by women? *Food Policy, 67*, 52–63. doi:10.1016/j.foodpol.2016.09.017.

Place, F. (2009). Land tenure and agricultural productivity in Africa: A comparative analysis of the economics literature and recent policy strategies and reforms. *World Development, 37*(8), 1326–1336. doi:10.1016/j.worlddev.2008.08.020.

Posner, D. N. (2004). Measuring ethnic fractionalization in Africa. *American Journal of Political Science, 48*(4), 849–863. doi:10.1111/j.0092-5853.2004.00105.x.

Sitko, N. J., Chamberlin, J., & Hichaambwa, M. (2014). Does smallholder land titling facilitate agricultural growth?: An analysis of the determinants and effects of smallholder land titling in Zambia. *World Development, 64*, 791–802. doi:10.1016/j.worlddev.2014.07.014.

Southern, U., & Africa Office. (2003), *Land tenure systems and sustainable development in Southern Africa.* Lusaka, Zambia: United Nations Economic Commission for Africa.

Thomas, D. (1990). Intra-household resource allocation: An inferential approach. *Journal of Human Resources, 25*(4), 635–664. doi:10.2307/145670.

Udry, C. (1996). Gender, agricultural production and the theory of the household. *Journal of Political Economy, 104*(5), 1010–1046. doi:10.1086/262050.

United Nations. (2019). Women, *7*, 9. The Gender Gap in Agricultural Productivity in Sub-Saharan Africa. Women, U. N., *Policy briefs* p. 5.

Zambia Statistics Agency. (2015, December 31). Agriculture statistics of Zambia, 2014. Retrieved from Zambia Data Portal. Retrieved from https://zambia.opendataforafrica.org/ZMAGRISTAT2016/agriculture-statistics-of-zambia-2014.

1. SEAs are the lowest geographical sampling units used by CSO and are the primary sampling units in RALS. An SEA typically contains 100-200 households.
2. 2017 exchange rate: 9.5 ZMW/US$
3. We used *teffects ipwra* in STATA to run the DR method.
4. We also estimate a model without farm investment variables. If land tenure increases farm investment, part of the effect of land tenure would be captured the coefficient of farm investment. Comparing the estimates models with and without farm investment, the smaller coefficient of land tenure in Equation (4) would support our hypothesis that land tenure security increases farm investment, then farm investment increases household welfare.
5. Our main interpretation comes from the estimation by the Probit model, but we use LPM to account for the unobservable heterogeneity of households.
6. The land tenure estimates in Table 5 are somewhat smaller than those in Table A 1, confirming that some of the positive household welfare associations of land tenure are channeled though farm investment, as hypothesized.

Table 1 Description of plot and household variables

Variable	Description	N	Mean	SD	N	Mean	SD	Dif
Plot characteristics			2012			2015		
Land tenure	1 if a plot has secured tenure, 0 otherwise	26,022	0.0867	0.281	21,517	0.0564	0.231	-0.003***
Soil and land management	Areas of preventing soil erosion and/or flash flooding (ha)	26,022	0.157	0.578	21,517	0.169	0.690	-0.007***
Tree planting	Areas of planting trees to protect yield (ha)	26,022	0.024	0.238	21,517	0.764	1.104	0.078***
Irrigation	Irrigated areas (ha)	26,022	0.004	0.074	21,517	0.007	0.126	-0.078***
Purchased	1 if the plot is acquired by purchasing, 0 otherwise	26,022	0.060	0.237	21,517	0.067	0.249	0.0460***
Inherited	1 if the plot is acquired by inheritance, 0 otherwise	26,022	0.115	0.319	21,517	0.193	0.395	-0.0170***
Allocated	1 if the plot is acquired by allocation, 0 otherwise	26,022	0.730	0.444	21,517	0.652	0.476	0.175***
Possibility to change the tenure status	1 if the plot's status is possibly changed, 0 otherwise	25,763	0.328	0.470	21,517	0.282	0.450	0.016***
Decision maker	1 if the decision maker of the plot is woman, 0 otherwise	25,973	0.248	0.432	21,517	0.265	0.441	-0.003***
Cash crop	1 if a cash crop is planted, 0 otherwise	25,821	0.108	0.310	21,460	0.092	0.288	-0.007***
Hectare	Hectare of plot	26,021	0.819	1.194	21,517	0.851	1.904	-0.032**
Household characteristics								
Farm income	Total Farm income (ZMW)	8,566	4,869	12,771	7,579	4,908	18,379	-38.948
Food insecurity	Number of months of food insecurity	8,571	1.335	1.915	7579	1.515	2.118	-0.180***
Educational level of HH	Educational year of household head	8,571	6.222	3.940	7,579	5.805	4.015	0.417***
Matrilineal household	1 if the household is matrilineal, 0 otherwise	8,553	0.364	0.481	7,579	0.313	0.464	0.051***
Local household	1 if the household head is local,	8,566	0.888	0.315	7,579	0.895	0.307	-0.007

head	0 otherwise							
Number of plots	Number of plots	8,571	3.019	1.592	7,579	2.896	1.391	0.124***
Cash crop	1 if the household plant a cash crop, 0 otherwise	8,571	0.126	0.332	7,579	0.195	0.397	-0.068***
Credit	1 if the household can obtain credit, 0 otherwise	8,571	0.166	0.372	7,579	0.192	0.394	-0.027***
Age of HH	Age of household head	8,568	45.64	14.97	7,416	49.16	14.97	-3.525***
Adult equivalent	Number of adult equivalents	8,571	3.688	1.903	7,579	4.692	2.458	-1.003***
Asset index	Asset index based on principal component analysis	8,571	-0.000	2.209	7,578	0.008	2.318	-0.008
Tropical Livestock Unit	Tropical livestock unit based on	8,571	2.515	7.955	7,579	2.692	8.779	-0.177
Time to the nearest paved road	Time from homestead to the nearest paved road (minutes)	8,366	117.9	256.7	7,578	106.2	178.3	11.755***

Note: Authors' calculation using RALS2012 and 2015. Zambian Kwacha (ZMW) values are in real 2017 terms. 2017 exchange rate: 9.5 ZMW/US$. The calculation of Tropical livestock Unit is based: cattle = 0.7, sheep = 0.1, goats = 0.1, pigs = 0.2, chicken = 0.01. We excluded households who earn less than 0 ZMW as outliers. It is important to note that costs of production are partially observed. Thus, net crop income accounts for fertilizer costs and the costs of transportation, but not for labor, transaction, seed, or other input expenditures. ***, **, * denote level of significance at 1%, 5% and 10% respectively.

Table 2 Gender of decision maker and tenure security (plot-level)

	Land title		
Decision maker	No	Yes	
Men	32,854	2,505	35,359
	92.92%	7.08%	100%
Women	11,167	964	12,131
	92.05%	7.95%	100%
Total	44,021	3,469	47,490
	92.7%	7.3%	100%

Note: The difference in sex is significant at 5% level.
Source: Authors' calculation using the RALS2012 and 2015 data.

Table 3 kinship system, plot size, and gender of decision maker

	Gender of decision makers		
	Men	Women	Total
Patrilineal	8,429	2,222	10,651
	79.14%	20.86%	100%
Matrilineal	4,065	1,416	5,481
	74.17%	25.83%	100%
Total	12,494	3,638	16,132
	77.45%	22.55%	100%
			Diff
Mean plot size (ha)	1.24	0.79	0.45***
SD	(0.02)	(0.03)	(0.04)

Note: The difference in gender is significant at 5% level. ***, **, * denote level of significance at 1%, 5% and 10% respectively.
Source: Authors' calculation using the RALS2012 and 2015 data.

Table 4 Cultivated land size and land titled (household-level)

	Land title		
	No	Yes	Total
5 to 19.99 ha	3,391	392	3,783
	89.64%	10.36%	100%
0 to 4.99 ha	11,369	992	12,361
	91.97%	8.03%	100%
Total	14,760	1,384	16,144
	91.43%	8.57%	100%

Note: Small-scale households are defined as household cultivating 4.99 hectares of crop area or less. Households cultivating between 5 and 19.99 hectares of area under crops are classified as Medium-scale households.
Source: Authors' calculation using the RALS2012 and 2015 data.

Table 5 Determinants of land tenure security (plot-level)

	(1) Probit	(2) LPM
Purchased	1.240***	0.300***
	(0.072)	(0.011)
Allocated	-0.108*	-0.004
	(0.060)	(0.005)
Inherited	-0.051	-0.013**
	(0.075)	(0.006)
Possibility to change the tenure status	0.227***	0.026***
	(0.042)	(0.004)
Women decision maker	0.126***	0.013***
	(0.041)	(0.003)
Educational level of HH	0.038***	0.006***
	(0.005)	(0.001)
Cash crop planted	0.002	-0.001
	(0.036)	(0.003)
Matrilineal household	-0.016	0.005
	(0.043)	(0.003)
Local household head	-0.127**	-0.012**
	(0.060)	(0.006)
Hectare	-0.000	-0.001
	(0.008)	(0.001)
Age of HH	0.005***	0.001***
	(0.001)	(0.000)
Adult equivalent	-0.006	-0.001
	(0.010)	(0.001)
Asset index	0.061***	0.010***
	(0.009)	(0.001)
Tropical Livestock Unit	0.002	0.000
	(0.002)	(0.000)
Time to the nearest paved road	-0.000	-0.000
	(0.000)	(0.000)
Household FE	No	Yes
Province FE	Yes	Yes
Year FE	Yes	Yes
Observations	45,868	45,868

Note: Robust standard errors clustered by households are presented in parentheses. ***, **, * denote level of significance at 1%, 5% and 10% respectively. Only plots where crops were planted were used for the estimation. Garden, natural fallow, rented/borrowed, orchard, and virgin plots were removed because the crops planted in these plots were not identified. The full regression table is available upon request. Source: Authors' calculations using RALS RALS2012 and 2015 data.

Table 6 Effect of land tenure security (Plot-level, Doubly Robust)

	(1) Soil and land management	(2) Tree planting	(3) Irrigation
ATT	0.068***	0.005	-0.008
N=45,878	(0.021)	(0.021)	(0.007)
Women decision makers' ATT	0.052**	0.040*	-0.002
N=11,771	(0.022)	(0.023)	(0.001)
Men decision makers' ATT	0.063**	-0.031	-0.012
N=34,107	(0.028)	(0.027)	(0.010)

Note: ATT represents average treatment effect in the treated group. Robust standard errors clustered by households are presented in parentheses. Land-tenure security is a dummy variable. The unit of the outcome variable was hectares. ***, **, * denote level of significance at 1%, 5% and 10% respectively. The full regression table is available upon request. Source: Authors' calculations using RALS RALS2012 and 2015 data.

Table 7 Heterogeneous association between land tenure and farm investment (Plot-level, PSM-FE)

	(1) Soil and land management	(2) Tree planting	(3) Irrigation
Land tenure	-0.024	-0.144	0.017
	(0.090)	(0.153)	(0.026)
Land tenure×women decision maker	0.098	0.219**	-0.014
	(0.063)	(0.099)	(0.012)
Control variables	Yes	Yes	Yes
Household FE	Yes	Yes	Yes
Province dummy	Yes	Yes	Yes
Year dummy	Yes	Yes	Yes
Observations	33,947	33,947	33,947

Note: Bootstrap-robust standard errors are shown in parentheses. The full regression table is available upon request. Land-tenure security is a dummy variable. The unit of the outcome variable was hectares. ***, **, * denote level of significance at 1%, 5% and 10% respectively. The full regression table is available upon request. Source: Authors' calculations using RALS RALS2012 and 2015 data

Table 8 Determinants of household welfare (Household-level)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Farm income	Months of food insecurity	Farm income	Months of food insecurity	Farm income	Months of food insecurity	Months of food insecurity
	OLS	OLS	OLS	OLS	OLS-FE	OLS-FE	OLS-FE
Land tenure	0.641***	-0.373***	0.010	0.009	-0.094	-0.106	-0.116
	(0.100)	(0.051)	(0.100)	(0.054)	(0.146)	(0.088)	(0.087)
Soil and land management	0.344***	-0.107***	0.132***	-0.007	0.105***	-0.010	-0.000
	(0.041)	(0.013)	(0.023)	(0.009)	(0.036)	(0.015)	(0.015)
Tree planting	0.337***	-0.059***	0.146***	-0.027***	0.176***	-0.037***	-0.021*
	(0.024)	(0.008)	(0.021)	(0.009)	(0.025)	(0.013)	(0.013)
Irrigation	0.236***	-0.060***	0.056	0.009	0.101	-0.003	0.005
	(0.044)	(0.017)	(0.044)	(0.018)	(0.073)	(0.034)	(0.033)
Women decision making			-0.559***	0.198***	-0.512***	0.205***	0.156**
			(0.067)	(0.041)	(0.103)	(0.062)	(0.062)
Joint decision making			0.192**	0.102**	0.348***	0.067	0.097
			(0.076)	(0.049)	(0.127)	(0.077)	(0.076)
Farm income							-0.092***
							(0.008)
Control variables	No	No	Yes	Yes	Yes	Yes	Yes
Household FE	No	No	No	No	Yes	Yes	Yes
Province FE	No	No	No	No	Yes	Yes	Yes
Year FE	No	No	No	No	Yes	Yes	Yes
Observations	16,116	16,150	15,603	15,631	15,603	15,631	15,603

Note: Robust standard errors are clustered by household in parentheses. The outcome variables were log farm income and number of months of food insecurity. ***, **, * denote level of significance at 1%, 5% and 10% respectively. Full regression table is available in Table A1. Source: Authors' calculations using RALS RALS2012 and 2015 data.

Table 9 Heterogeneous association on different decision making processes (Household-level OLS FE)

	(1) Patrilineal	(2)	(3) Matrilineal	(4)
	Farm income	Months of food insecurity	Farm income	Months of food insecurity
Land tenure	-0.536	-0.012	-0.055	-0.647
	(0.333)	(0.200)	(0.876)	(0.525)
Soil and land management	0.090	0.009	0.142	-0.015
	(0.056)	(0.033)	(0.183)	(0.107)
Tree planting	0.173***	0.006	0.374***	-0.045
	(0.049)	(0.029)	(0.126)	(0.079)
Irrigation	0.179	-0.042	-0.070	-0.128
	(0.160)	(0.067)	(0.325)	(0.244)
Women decision making	-0.727***	0.367***	-0.639	0.399
	(0.249)	(0.142)	(0.552)	(0.331)
Joint decision making	0.481*	0.068	0.910	0.315
	(0.291)	(0.181)	(0.691)	(0.484)
Land tenure×Decision making by women	0.301	-0.741*	0.124	-0.281
	(0.685)	(0.397)	(1.944)	(1.052)
Land tenure×Joint decision making	-0.405	0.173	0.088	0.508
	(0.749)	(0.482)	(1.986)	(1.221)
Soil and land management×Decision making by women	0.346**	-0.018	0.371	0.052
	(0.171)	(0.089)	(0.515)	(0.296)
Soil and land management×Joint decision making	-0.059	0.013	-0.044	-0.110
	(0.141)	(0.083)	(0.406)	(0.332)
Tree planting×Decision making by women	0.003	-0.019	0.012	-0.027
	(0.135)	(0.057)	(0.379)	(0.166)
Tree planting×Joint decision making	-0.070	-0.040	-0.370*	0.012
	(0.078)	(0.045)	(0.200)	(0.122)
Irrigation×Decision making by women	0.236	0.335	0.135	0.009
	(0.614)	(0.276)	(0.836)	(0.479)
Irrigation×Joint decision making	-0.178	-0.030	0.151	0.249
	(0.226)	(0.123)	(0.516)	(0.378)
Control variables	Yes	Yes	Yes	Yes
Household FE	Yes	Yes	Yes	Yes

Province FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observation	10,288	10,305	5,366	5,377

Note: Robust standard errors are clustered by household in parentheses. The outcome variables were log farm income and number of months of food insecurity. ***, **, * denote level of significance at 1%, 5% and 10% respectively. Full regression table is available at Table A2. Source: Authors' calculations using RALS RALS2012 and 2015.

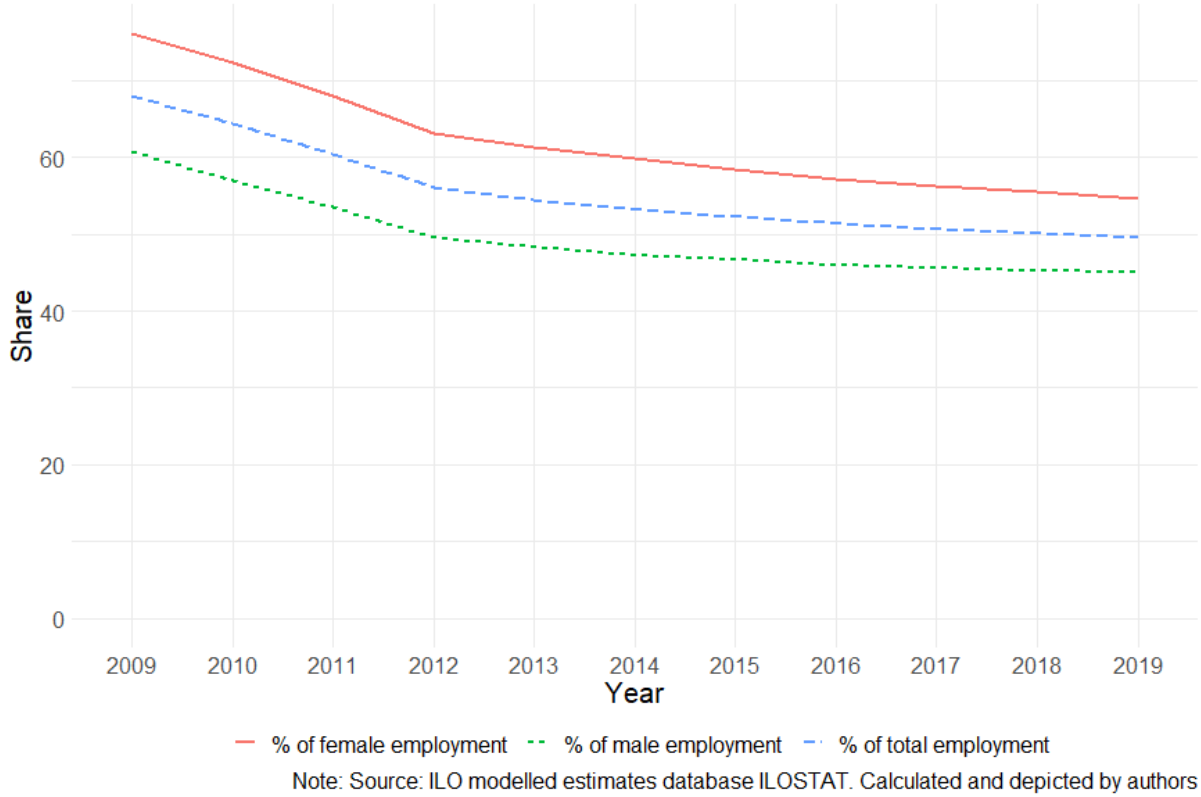

Figure 1 Employment in agriculture in Zambia

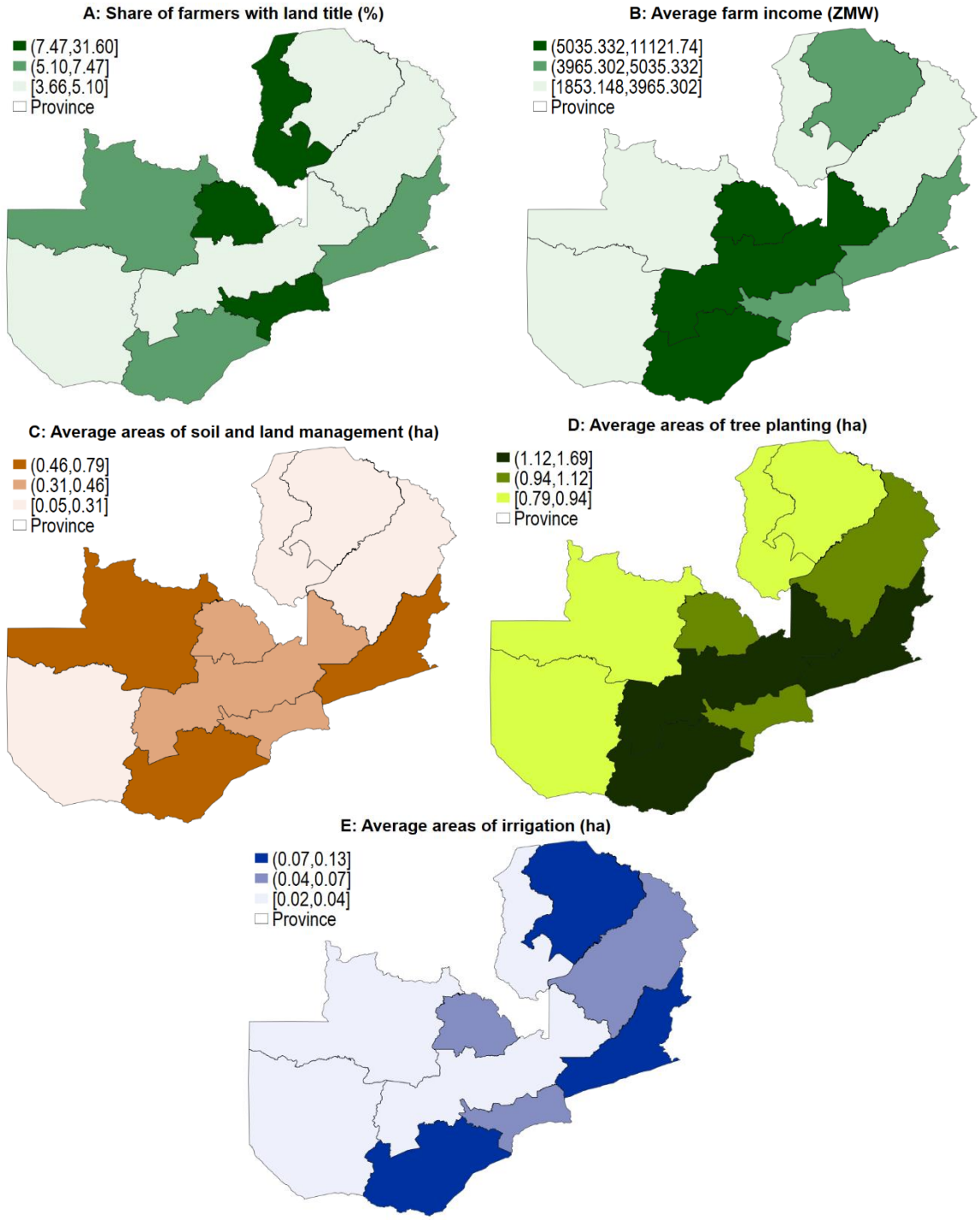

Figure 2 Land tenure, farm income, and farm investment in Zambia

Panel A shows the proportion of households with land title by province. Panel B shows the average farm income by province. Panel C shows the average areas of soil and land management per household by provinces. Panel D shows the average areas of tree planting per household by province. Panel E shows the average areas of irrigation per household by province. Source: Authors' compilations using the RALS2012 and 2015 data

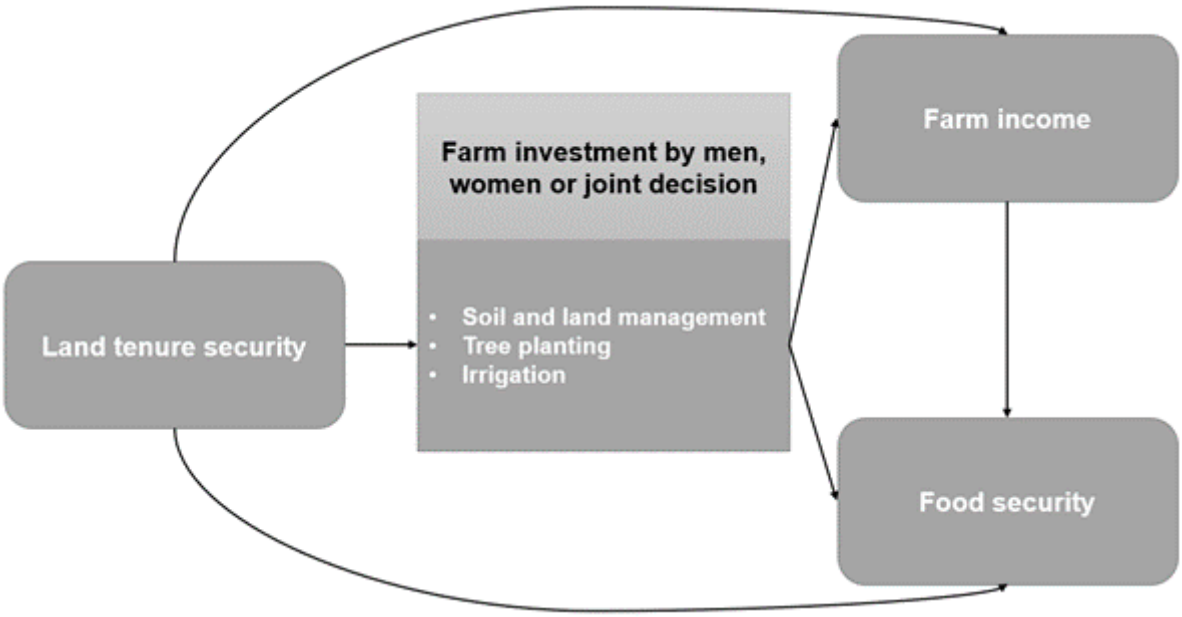

Figure 3 Conceptual framework about nexus among land tenure, farm investment, and household welfare

Source: Built by authors

Appendix

Table A 1 Determinants of household welfare without farm investment

	(1) Farm income (log)	(2) Months of food insecurity	(3) Farm income (log)	(4) Months of food insecurity	(5) Farm income (log)	(6) Months of food insecurity	(7) Months of food insecurity
Land tenure security	0.685***	-0.390***	0.025	0.008	-0.099	-0.104	-0.115
	(0.101)	(0.051)	(0.100)	(0.054)	(0.148)	(0.088)	(0.087)
Women decision making			-0.581***	0.201***	-0.556***	0.213***	0.160***
			(0.068)	(0.041)	(0.104)	(0.062)	(0.062)
Joint decision making			0.235***	0.097**	0.403***	0.058	0.093
			(0.077)	(0.049)	(0.127)	(0.077)	(0.076)
Matrilineal household			-0.101*	0.099***	-0.085	0.087*	0.081
			(0.057)	(0.034)	(0.089)	(0.052)	(0.051)
Age of household head			-0.013***	0.004***	-0.011***	0.005***	0.004**
			(0.002)	(0.001)	(0.003)	(0.002)	(0.002)
Local household head			0.188**	0.070	0.057	0.061	0.063
			(0.085)	(0.049)	(0.130)	(0.074)	(0.073)
Number of plots			0.514***	-0.127***	0.506***	-0.106***	-0.059***
			(0.019)	(0.011)	(0.030)	(0.018)	(0.018)
Adult equivalent			0.011	0.011	0.017	0.007	0.008
			(0.014)	(0.008)	(0.021)	(0.012)	(0.012)
Cash crop			0.217***	-0.016	0.127	-0.040	-0.023
			(0.081)	(0.043)	(0.124)	(0.067)	(0.066)
Smallholder farmers			-0.721***	0.229***	-0.602***	0.254***	0.198***

			(0.067)	(0.035)	(0.100)	(0.058)	(0.058)
Educational level of HH			0.042***	-0.046***	0.031***	-0.046***	-0.043***
			(0.008)	(0.004)	(0.012)	(0.007)	(0.007)
Credit			0.590***	0.027	0.676***	0.055	0.116*
			(0.075)	(0.040)	(0.116)	(0.065)	(0.065)
Tropical Livestock Unit			0.012***	-0.005***	0.008	-0.004	-0.002
			(0.004)	(0.001)	(0.006)	(0.003)	(0.003)
Asset index			0.379***	-0.117***	0.384***	-0.101***	-0.067***
			(0.019)	(0.008)	(0.027)	(0.013)	(0.012)
Time to the nearest paved road			-0.001***	0.000***	-0.001***	0.000***	0.000***
			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Farm income							-0.093***
							(0.008)
Household FE	No	No	No	No	Yes	Yes	Yes
Province FE	No	No	No	No	Yes	Yes	Yes
Year FE	No	No	No	No	Yes	Yes	Yes
Observations	16,116	16,150	15,729	15,757	15,729	15,757	15,729

Note: Robust standard errors clustered by households in parenthesis. Outcome variables are log farm income and number of months of food insecurity. ***, **, * denote level of significance at 1%, 5% and 10% respectively. Source: Authors' calculation using the RALS2012 and 2015 data.

Table A 2 Determinants of household welfare (HH-FE)

	(1) Farm income (log)	(2) Months of food insecurity	(3) Farm income (log)	(4) Months of food insecurity	(5) Farm income (log)	(6) Months of food insecurity	(7) Months of food insecurity
Land tenure	0.641***	-0.373***	0.010	0.009	-0.094	-0.106	-0.116
	(0.100)	(0.051)	(0.100)	(0.054)	(0.146)	(0.088)	(0.087)
Soil and land management	0.344***	-0.107***	0.132***	-0.007	0.105***	-0.010	-0.000
	(0.041)	(0.013)	(0.023)	(0.009)	(0.036)	(0.015)	(0.015)
Tree planting	0.337***	-0.059***	0.146***	-0.027***	0.176***	-0.037***	-0.021*
	(0.024)	(0.008)	(0.021)	(0.009)	(0.025)	(0.013)	(0.013)
Irrigation	0.236***	-0.060***	0.056	0.009	0.101	-0.003	0.005
	(0.044)	(0.017)	(0.044)	(0.018)	(0.073)	(0.034)	(0.033)
Women decision making			-0.559***	0.198***	-0.512***	0.205***	0.156**
			(0.067)	(0.041)	(0.103)	(0.062)	(0.062)
Joint decision making			0.192**	0.102**	0.348***	0.067	0.097
			(0.076)	(0.049)	(0.127)	(0.077)	(0.076)
Matrilineal household			-0.086	0.097***	-0.076	0.085*	0.080
			(0.057)	(0.034)	(0.088)	(0.052)	(0.051)
Age of household head			-0.012***	0.004***	-0.010***	0.005***	0.004**
			(0.002)	(0.001)	(0.003)	(0.002)	(0.002)
Local household head			0.170**	0.072	0.037	0.064	0.064
			(0.084)	(0.049)	(0.129)	(0.074)	(0.073)
Number of plots			0.479***	-0.122***	0.467***	-0.098***	-0.056***
			(0.019)	(0.011)	(0.030)	(0.018)	(0.018)
Adult equivalent			-0.001	0.013*	0.002	0.010	0.010
			(0.014)	(0.008)	(0.020)	(0.012)	(0.012)
Cash crop			0.165**	-0.008	0.098	-0.034	-0.020

			(0.080)	(0.043)	(0.124)	(0.067)	(0.066)
Smallholder farmers			-0.610***	0.215***	-0.493***	0.237***	0.191***
			(0.067)	(0.035)	(0.100)	(0.059)	(0.058)
Educational level of HH			0.045***	-0.046***	0.035***	-0.046***	-0.043***
			(0.008)	(0.004)	(0.012)	(0.007)	(0.007)
Credit			0.556***	0.032	0.630***	0.062	0.119*
			(0.074)	(0.040)	(0.116)	(0.065)	(0.065)
Tropical Livestock Unit			0.010**	-0.005***	0.006	-0.004	-0.002
			(0.004)	(0.001)	(0.006)	(0.003)	(0.003)
Asset index			0.338***	-0.111***	0.337***	-0.092***	-0.063***
			(0.019)	(0.008)	(0.026)	(0.013)	(0.013)
Time to the nearest paved road			-0.001***	0.000***	-0.001***	0.000***	0.000***
			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Farm income							-0.092***
							(0.008)
Household FE	No	No	No	No	Yes	Yes	Yes
Province FE	No	No	No	No	Yes	Yes	Yes
Year FE	No	No	No	No	Yes	Yes	Yes
Observations	16,116	16,150	15,603	15,631	15,603	15,631	15,603

Note: Robust standard errors clustered by households in parenthesis. Outcome variables are log farm income and number of months of food insecurity. ***, **, * denote level of significance at 1%, 5% and 10% respectively. Source: Authors' calculation using the RALS2012 and 2015 data.

Table A 3 Heterogeneous association on different decision making processes

(Household-level OLS FE)

	(1)	(2)	(3)	(4)
	Patrilineal		Matrilineal	
	Farm income (log)	Months of food insecurity	Farm income (log)	Months of food insecurity
Land tenure	-0.536	-0.012	-0.055	-0.647
	(0.333)	(0.200)	(0.876)	(0.525)
Soil and land management	0.090	0.009	0.142	-0.015
	(0.056)	(0.033)	(0.183)	(0.107)
Tree planting	0.173***	0.006	0.374***	-0.045
	(0.049)	(0.029)	(0.126)	(0.079)
Irrigation	0.179	-0.042	-0.070	-0.128
	(0.160)	(0.067)	(0.325)	(0.244)
Women decision making	-0.727***	0.367***	-0.639	0.399
	(0.249)	(0.142)	(0.552)	(0.331)
Joint decision making	0.481*	0.068	0.910	0.315
	(0.291)	(0.181)	(0.691)	(0.484)
Land tenure×Decision making by women	0.301	-0.741*	0.124	-0.281
	(0.685)	(0.397)	(1.944)	(1.052)
Land tenure×Joint decision making	-0.405	0.173	0.088	0.508
	(0.749)	(0.482)	(1.986)	(1.221)
Soil and land management×Decision making by women	0.346**	-0.018	0.371	0.052
	(0.171)	(0.089)	(0.515)	(0.296)
Soil and land management×Joint decision making	-0.059	0.013	-0.044	-0.110
	(0.141)	(0.083)	(0.406)	(0.332)
Tree planting×Decision making by women	0.003	-0.019	0.012	-0.027
	(0.135)	(0.057)	(0.379)	(0.166)
Tree planting×Joint decision making	-0.070	-0.040	-0.370*	0.012
	(0.078)	(0.045)	(0.200)	(0.122)

Irrigation×Decision making by women	0.236	0.335	0.135	0.009
	(0.614)	(0.276)	(0.836)	(0.479)
Irrigation×Joint decision making	-0.178	-0.030	0.151	0.249
	(0.226)	(0.123)	(0.516)	(0.378)
Matrilineal household (=1 if yes)	0.000	0.000	0.000	0.000
	(.)	(.)	(.)	(.)
Age of HH	-0.008	0.003	-0.008	0.009
	(0.006)	(0.003)	(0.013)	(0.009)
Local household head (=1 if yes)	0.074	-0.046	0.009	0.243
	(0.256)	(0.135)	(0.599)	(0.355)
Number of plots	0.452***	-0.075**	0.617***	-0.201**
	(0.061)	(0.036)	(0.123)	(0.080)
Adult equivalent	0.004	0.019	-0.005	-0.038
	(0.038)	(0.023)	(0.094)	(0.059)
Cash crop planted (=1 if yes)	-0.001	0.036	0.101	-0.150
	(0.234)	(0.123)	(0.690)	(0.374)
Smallholder	-0.333*	0.312***	-0.795*	-0.052
	(0.183)	(0.106)	(0.472)	(0.358)
Educational level of HH (years)	0.044**	-0.039***	0.054	-0.037
	(0.022)	(0.013)	(0.052)	(0.033)
Obtaining credit (=1 if yes)	0.491**	0.089	0.774	-0.076
	(0.212)	(0.118)	(0.571)	(0.319)
Tropical Livestock Unit	-0.005	0.001	0.098*	-0.021
	(0.007)	(0.004)	(0.058)	(0.030)
Asset index	0.371***	-0.118***	0.319**	-0.100
	(0.044)	(0.022)	(0.141)	(0.078)
Time to the nearest paved road (min)	-0.001*	0.000	-0.002	0.002*
	(0.000)	(0.000)	(0.001)	(0.001)
Household FE	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observation	10,288	10,305	5,366	5,377

Note: Robust standard errors clustered by households in parenthesis. Outcome variables are log farm income and number of months of food insecurity. ***, **, * denote level of significance at 1%, 5% and 10% respectively. Source: Authors' calculation using the RALS2012 and 2015 data.

Table A 4 Effect of land tenure security on farm investment (Doubly robust)

	(1) Soil and land management	(2) Tree planting	(3) Irrigation
ATT	0.055***	0.003	0.001
N=45,878	(0.009)	(0.006)	(0.003)
Women decision makers' ATT	0.045***	0.015	0.002
N=11,771	(0.017)	(0.011)	(0.003)
Men decision makers' ATT	0.053***	-0.007	0.001
N=34,107	(0.011)	(0.006)	(0.004)

Note: ATT is the average treatment effect on treated. Robust standard errors clustered by households in parenthesis. ***, **, * denote level of significance at 1%, 5% and 10% respectively. Full regression table is available upon requests. Source: Authors' calculation using the RALS2012 and 2015 data.

Table A 5 Heterogeneous associations on decision maker and cash crop (Probit-PSM)

	(1) Soil and land management	(2) Tree planting	(3) Irrigation	(4) Soil and land management	(5) Tree planting	(6) Irrigation
Land tenure security	0.167***	-0.099*	0.105	0.159***	-0.048	0.055
	(0.033)	(0.057)	(0.078)	(0.035)	(0.060)	(0.092)
Land titled×women decision maker	0.024	0.242**	-0.255			
	(0.066)	(0.110)	(0.178)			
Land titled×Cash crop				0.121	0.128	0.019
				(0.094)	(0.231)	(0.229)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Province dummy	Yes	Yes	Yes	Yes	Yes	Yes
Year dummy	Yes	Yes	Yes	Yes	Yes	Yes
Observations	45,458	45,458	45,458	45,458	45,458	45,458

Note: ATT is the average treatment effect on treated. Robust standard errors clustered by households in parenthesis. ***, **, * denote level of significance at 1%, 5% and 10% respectively. Full regression table is available upon requests. Source: Authors' calculation using the RALS2012 and 2015 data.