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Gender matters in farm investment: Implications for land tenure security and household welfare

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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, and household welfare, as well as 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 nationally representative panel survey in Zambia and take advantage of the two distinct kinship systems 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, soil and land management 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 in patrilineal but not matrilineal societies. This heterogeneity suggests that the gender gap in rural areas stems from the male dominance in land stewardship. These findings therefore provide insights into the underpinnings of policies that empower women and increase their bargaining power within households through land reform.

Keywords: Women empowerment, Land rights, Bargaining power, Matrilineal and patrilineal societies, Food security, Sub-Saharan Africa

JEL classification: J16, Q12, Q15

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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, and household welfare, as well as 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 nationally representative panel survey in Zambia and take advantage of the two distinct kinship systems 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, soil and land management 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 in patrilineal but not matrilineal societies. This heterogeneity suggests that the gender gap in rural areas stems from the male dominance in land stewardship. These findings therefore provide insights into the underpinnings of policies that empower women and increase their bargaining power within households through land reform.

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Highlights

- We investigate land tenure security, farm investment, and household welfare in Zambia.
- Increased land tenure security promotes soil and land management.
- Women decision-makers with land tenure are more likely to invest in tree planting.
- Tree planting increases farm income and reduces food insecurity.
- Women in male-dominant societies benefit more from land tenure and farm investment.

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1. Introduction

Agriculture has long been a critical component of economies in Sub-Saharan Africa (SSA) 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 (Figure 1) and the share of the agriculture, forestry, and fishing sector's value-added to 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 compel women to say that they work in the 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 in order to achieve gender equality and empowerment of all women and girls, as declared in Sustainable Development Goal 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 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 could be one way to narrow the gender gap in agricultural productivity and, consequently, improve household welfare in SSA.

There are several definitions of women's land rights (WLR): 1) land ownership; 2) the right

to make planting decisions; and 3) the right to make output decisions (Kang, Schwab, & Yu, 2020). For example, ownership is linked to farmers' investments in soil quality improvement, terracing, bun walls, irrigation channels, 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 household decision-making processes (sole vs. joint decision-making). For representing WLR, this information is more reliable than other information such as the gender of household head or plot holders (de la O Campos, Covarrubias, & Prieto Patron, 2016).

In this paper, we address 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 examine 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 for the 2022 Census (Indaba Agricultural Policy Research Institute, 2016). Furthermore, we exploit the facts that Zambia has both patrilineal and matrilineal kinship systems 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 a substantial body of literature on 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 is associated 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, in contrast 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 according to 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 and patrilineal kinship systems coexist. To our knowledge, previous 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 reveal 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. Soil and land management increases farm income and reduces food insecurity. Moreover, we find 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, namely, the customary and 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 displacement 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, the Zambian government implemented the Lands Act to allow for individual ownership rights and other formal land rights transfers. If households want formal access to customary lands through the statutory system, the lands must be devolved from customary to statutory status (Chamberlin & Ricker-Gilbert, 2016). Moreover, once 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 the rights to sell, rent, mortgage, and transfer their land (Chapoto, Jayne, & Mason, 2011). According to the statutory law, women in Zambia can apply for any land in the country, the same as their male counterparts. 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 any children, the house (Kapihya, 2017). However, this Act is generally not applied to customary land. If the deceased husband held customary land, the widow may be permitted to continue utilizing the land. However, the widow may also be ejected from the land by relatives of the deceased (Kapihya, 2017). Because of 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

Zambia is one of the most ethnically diverse countries in SSA (Posner, 2004), and thus social norms can vary across the country. In a matrilineal society, an individual's descent is traced 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 transferred 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 about land, men still rule most of the decisions as clan leaders. For instance, for land sales, even though women own the land, they must turn to their maternal uncles, who have the final say in decisions. Hence, consideration of gender roles in patrilineal and matrilineal systems can provide a deeper understanding of women's empowerment and rural development in SSA.

3. Data

We use 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 the maize marketing years 2011/2012 and 2014/2015, respectively. A total of 8571 households in the first wave, and 7579 households in the second wave, were surveyed in 442 Standard Enumeration Areas¹ (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 enables 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 conduct household- and plot-level analyses. In our household-level analysis, the title variable takes a value of 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- and household-level relationships, the plot and household characteristics are shown in Table 1. For plot-level characteristics, the differences in all variables between 2012 and 2015 are statistically significant. Regarding farm investment variables, in terms of household-level characteristics, there is no significant difference in farm income but there is one in food insecurity. Moreover, the share of matrilineal households is approximately 32%–36%. As 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 variable takes a value of 1 if the plot is customary or statutory tenured and 0 otherwise. The household-level tenure security variable takes a value of 1 if the household owns at least one plot secured by the government and 0 otherwise. The variable for the gender of decision-makers is assigned a value of 1 if the decision-makers are women and 0 otherwise at the plot level. At the household 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 types of farm investments are included in the analysis: soil and land management, tree planting, and irrigation. These are also measured according to application areas at the plot and household levels. Finally, two outcome variables are analyzed. The first outcome variable is farm income, which captures income from farm products, such as maize, cassava, vegetables, fruits, and other crops. Values are given in Zambia Kwacha (ZMW). The values are deflated to real 2017 terms². The second outcome variable is food insecurity, which measures the number of months in 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 tend to use more land than women. Table 4 shows that the ratio of land titles possessed by smallholder farmers was slightly less than that

possessed by 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 shows 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 area (ha). From the graphical analysis, we cannot 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 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 variations in plot-level ownership (Doss, 2018), and women's plot ownership does not always imply their managerial rights (Doss, Kovarik, Peterman, Quisumbing, & van

den Bold, 2015). Therefore, it is worth noting that we conduct plot-level analysis for farm investment decisions, without 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 expected 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 the perspective of gender 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 of land (Palacios-Lopez, Christiaensen, & Kilic, 2017). Therefore, it would induce less farm output because adult male labor is found to contribute more than adult female labor to agricultural production at the margin (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 with 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 the perspective of gender. 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 than men to invest when a plot has tenure security.

Hypothesis II. Farm investment improves household welfare, farm income, and food security. The effect of farm investment is larger for farmers with women decision-makers

because women are empowered within a household in this case.

[Figure 3 here]

4.2. Empirical model

First, we use plot-level variables to explore the association 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 propensity score matching (PSM) as an estimation method when other plausible instruments were not available (Bellemare & Novak, 2017; Issahaku & Abdulai, 2020; Lawin & Tamini, 2019). To estimate the propensity to own land tenure, we first estimate the binary model as follows:

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

where T_{pit}^* is the latent variable for the land tenure security of plot p of household i in year t , x_{pit} is the vector of the characteristics of plot p of household i in year t , X_{it} is the vector of characteristics of household i in year t , ρ_t is a year dummy to control for the time trend, v_g is a 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 a Probit model. The probability of titled plots, conditioned on the plot and household characteristics, can be expressed as

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

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 match a plot that is titled and a plot that is not titled that have a close propensity score based on the nearest-neighbor matching method. An important assumption of PSM is the common support assumption, which requires substantial overlap in covariates

between titled plots and non-titled plots, so that plots being compared have a common probability of being both titled and non-titled, such that $0 < \hat{p}(x_{pit}X_{it}) < 1$.

After matching plots and creating a matched sample, we estimate fixed-effects models to investigate the association between land tenure security and farm investment over gender with incorporation of the interaction term between the gender of decision-makers and land tenure security. A limitation of PSM is that if unobservable characteristics affect land tenure security, the estimated results may be biased by selection on the unobservables. To minimize selection-on-unobservables bias, we use fixed-effect models so that bias based on time-invariant unobserved characteristics can be addressed. Therefore, we can write the specified econometric model as follows:

$$I_{pit} = \beta_1 T_{pit} + \beta_2 T_{pit} * women_{pit} + \beta_3 x_{pit} + \beta_4 X_{it} + a_i + \sigma_t + v_g + u_{pit}, \quad (2)$$

where I_{pi} is farm investment, soil and land management, tree planting, and irrigation of plot p of household i , T_{pit} is a dummy variable for the land tenure status of plot p of household i in year t , $women_{pit}$ is a dummy variable for whether 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. These estimation strategies can address observable characteristics and unobservable time-invariant factors, but they cannot account for the unobservable time-invariant factors or reverse causality. Farm investment would increase the possibility of being aware of or gaining land tenure.

Beyond the relationship between land tenure security and farm investment, we examine the factors affecting household welfare using household-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 variable³. The specification model is written as

follows:

$$Y_{it} = \gamma_1 + \gamma_2 T_{it} + \gamma_3 I_{it} + \gamma_4 X_{it} + a_i + \sigma_t + v_g + \epsilon_{it}. \quad (3)$$

Here, Y_{it} is the outcome variable including farm income and months of food insecurity, T_{it} is a land tenure dummy variable for whether household i has at least one cultivated plot with tenure, I_{it} is the cultivated area 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 (3)) changes depending on sole or joint decision-making, we include the interaction term between land tenure or farm investment and sole or joint decision-making in Equation (3). We estimate Equation (3) with fixed effects to account for time-constant unobservable factors that 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 must be 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 A 1 shows the results of Equation (1) estimated by the Probit model and linear probability model⁴. 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-maker 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 greater 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 years of education. 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).

5.2. Association between land tenure and farm investment

Table 5 summarizes the results of the PSM fixed-effects model 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, such as 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 coefficient of the interaction term between land tenure security and female decision-maker is positive and significant. The results indicate that land tenure security increases tree planting by female decision-makers. Considering that insecure rights for women can undercut growth and productivity (Dillon & Voena, 2018), the present results highlight the importance of women's decision-making in agriculture for sustainable agricultural development. This result is consistent with those of Otsuka, Quismbing, and Payongayong (2003) and Dillon and Voena (2018). The results confirm our Hypothesis I and emphasize that land tenure security encourages women decision-makers to invest in agricultural practices to enhance output, especially tree planting. However, we do not find a significant association between land tenure and irrigation. This may be because there are further barriers other than land tenure security to adopt irrigation systems.

[Table 5 here]

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

As discussed in Section 4, our main research objective is to examine the empirical link between land tenure, farm investment, and household welfare. Table 6 presents factors related to household welfare, including farm income and food insecurity, by estimating Equation (4)⁵. The coefficient estimates for the factors related to farm income are shown in Columns (1), (3), and (5). The results derived using fixed-effects ordinary least squares with control variables indicate that soil and land management have a significant positive association with farm income. This indicates that investment in an additional hectare of soil and land management leads to an average increase of 17.1% in farm income. Moreover, irrigation is significantly associated with farm income, indicating that investment in an additional hectare of irrigation provides households with an average increase in farm income of 11.6% in Column (5). Land tenure and tree planting are significantly associated with farm income in Column (1), but their coefficients are not significant in Column (5).

For food insecurity (Columns (2), (4), and (6)), the benefits of soil and land management are negative and significant, with an additional hectare of soil and land management reducing food insecurity by 0.03 months. Although the estimates for land tenure security, tree planting, and irrigation are significant in Column (2), the coefficients become non-significant after controlling for covariates and fixed effects in Column (6).

In Column (7), farm income is treated as an independent variable to investigate the mechanism through which it improves food insecurity, as shown in Figure 3. The coefficient of farm income was statistically significant. The results indicate that a 1% increase in farm income reduces household food insecurity by 0.09 months. 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 serve 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 6 here]

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

Many views in the development community 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 trade-offs associated with targeting interventions at 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 straightforward, it neglects the contributions that women make to farms in households headed by men (and conversely, the contributions that men make to farms in households headed by women) (Doss, 2018). To address this gap, we utilize data on who makes decisions at the plot level 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 7 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 increases 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 lower relative to that 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, in terms of food insecurity, households where women are solely involved in decision-making benefit from land titles. We find that land tenure security for women increases their bargaining power 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 areas where irrigation is applied in our observations, as shown in

Table 1, we may not have been able to capture the variations in adoption of irrigation.

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 7 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 association between land tenure security and farm investments may vary with different farm investment measures. Therefore, we replace the application areas of farm investments with dummy variables. The estimation results are shown in Table A5. Similar to the results reported in Table 5, these results show that the associations between land tenure security and soil and land management are robust, indicating that land tenure security increases farm investment. Table A5 also shows the gendered heterogeneous association between land tenure security and tree planting. The results confirm that there is a significant difference in the association between land tenure security and tree planting according to the gender of decision-makers, as shown in Table 5. 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 association 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 find that women tend to invest more in tree planting when plots have land tenure. Our 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 investigate 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 stated in Hypothesis II. Moreover, we provide a deeper and new 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. Given that there are few studies examining the mechanism using nationally representative surveys in Zambia and addressing kinship systems, the results and implications should help policymakers consider sustainable agricultural development and land policies and avoid mistargeting.

Although our econometric estimations still have endogeneity concerns stemming from unobservable time-varying factors due to the characteristics of the dataset, the lessons learned in our study are valuable for considering future directions in rural development and women's empowerment in Zambia. This is the first study to examine how differences in the gender of decision-makers affects 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 it 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. Further research will help to generalize the results more broadly.

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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. In 2017, the exchange rate was 9.5 ZMW/US\$.
3. 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 by the coefficient of farm investment. Comparing the estimation 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, and farm investment then increases household welfare.
4. Our main interpretation comes from the estimation by the Probit model, but we use the linear probability model to account for the unobservable heterogeneity of households.
5. The land tenure estimates in Table 6 are somewhat smaller than those in Table A 2, confirming that some of the positive household welfare associations of land tenure are channeled through 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			2012-2015
Land tenure	1 if a decision maker of the plot is aware of land tenure, 0 otherwise	24,335	0.066	0.249	20,759	0.050	0.219	0.015***
Soil and land management	Areas of preventing soil erosion and/or flash flooding (ha)	24,335	0.160	0.576	20,759	0.166	0.616	-0.006***
Tree planting	Areas of planting trees to protect yield (ha)	24,335	0.025	0.242	20,759	0.030	0.295	-0.006***
Irrigation	Irrigated areas (ha)	24,335	0.004	0.074	20,759	0.007	0.126	-0.003***
Purchased	1 if the plot is acquired by purchasing, 0 otherwise	24,335	0.049	0.215	20,759	0.060	0.238	-0.011***
Inherited	1 if the plot is acquired by inheritance, 0 otherwise	24,335	0.117	0.322	20,759	0.195	0.396	-0.078***
Allocated	1 if the plot is acquired by allocation, 0 otherwise	24,335	0.745	0.436	20,759	0.659	0.474	0.086***
Possibility to change the tenure status	1 if the plot's status is possibly changed, 0 otherwise	24,335	0.329	0.470	20,759	0.278	0.448	0.050***
Decision making by women	1 if the decision maker of the plot is woman, 0 otherwise	24,335	0.246	0.430	20,759	0.267	0.442	-0.021***
Cash crop	1 if a cash crop is planted, 0 otherwise	24,335	0.112	0.315	20,759	0.092	0.289	0.019***
Hectare	Hectare of plot	24,335	0.799	1.101	20,759	0.835	1.262	-0.036**
Household characteristics								
Farm income	Total Farm income (ZMW)	7,055	5256.374	13483.630	7,055	4965.929	18918.860	290.444
Food insecurity	Number of months of food insecurity	7,055	1.174	1.799	7,055	1.522	2.121	-0.347***
Educational level of HH	Educational year of household head	7,055	6.275	3.968	7,055	5.936	3.911	0.338***
Matrilineal household	1 if the household is matrilineal, 0 otherwise	7,055	0.388	0.487	7,055	0.316	0.465	0.072***
Local household	1 if the household head is local,	7,055	0.881	0.323	7,055	0.894	0.308	-0.013*

head	0 otherwise								
Number of plots	Number of plots	7,055	3.084	1.612	7,055	2.895	1.392	0.190***	
Cash crop	1 if the household plant a cash crop, 0 otherwise	7,055	0.142	0.349	7,055	0.195	0.396	-0.053***	
Credit	1 if the household can obtain credit, 0 otherwise	7,055	0.184	0.388	7,055	0.193	0.395	-0.009	
Age of HH	Age of household head	7,055	45.515	14.888	7,055	49.177	14.980	-3.662***	
Adult equivalent	Number of adult equivalents	7,055	3.708	1.912	7,055	4.798	2.388	-1.090***	
Asset index	Asset index based on principal component analysis	7,055	0.093	2.274	7,055	0.000	2.319	0.093**	
Tropical Livestock Unit	Ownership and access to tropical livestock	7,055	2.363	7.652	7,055	2.666	8.625	-0.303**	
Time to the nearest paved road	Time from homestead to the nearest paved road (minutes)	7,055	105.433	242.318	7,055	105.407	175.558	0.027	

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 (Livelihoods Centre, Unknown). 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)

Decision maker	Land title		
	No	Yes	
Men	31,649	1,920	33,569
	94.28%	5.72%	100%
Women	10,794	731	11,525
	93.66%	6.34%	100%
Total	42,443	2,651	45,094
	94.12%	5.88%	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		Total
	Men	Women	
Patrilineal	7,275	1,864	9,139
	79.60%	20.40%	100%
Matrilineal	3,691	1,280	4,971
	74.25%	25.75%	100%
Total	10,966	3,144	14,110
	77.72%	22.28%	100%
			Diff
Mean plot size (ha)	0.897	0.579	0.318***
SD	(1.254)	(0.882)	

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		Total
	No	Yes	
5 to 19.99 ha	3,010	347	3,357
	89.66%	10.34%	100%
0 to 4.99 ha	9,892	861	10,753
	91.99%	8.01%	100%
Total	12,902	1,208	14,110
	91.44%	8.56%	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 Heterogeneous association between land tenure and farm investment

	(1) Soil and land management	(2) Tree planting	(3) Irrigation
Land tenure security	0.070*** (0.026)	0.009 (0.010)	-0.000 (0.005)
Land tenure security × Women decision maker	-0.028 (0.044)	0.036** (0.018)	-0.006 (0.005)
Decision making by women	-0.002 (0.010)	-0.004 (0.004)	0.001 (0.001)
Purchased	-0.016 (0.028)	-0.000 (0.011)	0.007 (0.006)
Allocated	0.044*** (0.011)	0.008 (0.005)	0.002 (0.003)
Inherited	0.042*** (0.013)	0.015* (0.008)	0.001 (0.003)
Possibility to change the tenure status	0.015 (0.009)	0.004 (0.005)	-0.003* (0.002)
Plot size	0.181*** (0.015)	0.036*** (0.005)	0.004*** (0.001)
Educational level of HH	0.039*** (0.010)	0.018*** (0.006)	0.001 (0.002)
Cash crop planted	-0.015 (0.011)	0.006 (0.005)	0.002 (0.002)
Matrilineal household	0.021 (0.016)	0.005 (0.008)	0.003 (0.002)
Local household head	-0.000 (0.000)	0.000 (0.000)	-0.000 (0.000)
Plot size	-0.002 (0.001)	-0.001 (0.001)	0.000 (0.000)
Age of HH	0.000 (0.003)	0.000 (0.001)	0.000 (0.000)
Adult equivalent	0.016*** (0.003)	0.005*** (0.002)	0.001 (0.000)
Asset index	-0.000 (0.001)	-0.000 (0.000)	0.000 (0.000)
Tropical Livestock Unit	-0.000 (0.000)	-0.000 (0.000)	-0.000* (0.000)
Time to the nearest paved road	0.070*** (0.026)	0.009 (0.010)	-0.000 (0.005)
Household FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Province FE	Yes	Yes	Yes
Observations	45,096	45,096	45,096

Note: Bootstrap-robust standard errors are shown in parentheses. This is a plot-level analysis. Land tenure

security is a dummy variable. The unit of the outcome variable is hectare. Fixed effect model is used after PSM. ***, **, * denote level of significance at 1%, 5% and 10% respectively. Source: Authors' calculations using RALS RALS2012 and 2015 data

Table 6 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	0.600*** (0.101)	-0.360*** (0.051)	0.014 (0.101)	0.016 (0.055)	-0.104 (0.141)	-0.095 (0.085)	-0.107 (0.084)
Soil and land management	0.445*** (0.029)	-0.120*** (0.011)	0.194*** (0.019)	-0.021** (0.009)	0.171*** (0.028)	-0.025* (0.015)	-0.009 (0.015)
Tree planting	0.164** (0.067)	-0.055** (0.021)	-0.023 (0.026)	0.004 (0.010)	-0.017 (0.045)	-0.013 (0.017)	-0.015 (0.017)
Irrigation	0.264*** (0.045)	-0.064*** (0.017)	0.073* (0.044)	0.004 (0.018)	0.116* (0.070)	-0.008 (0.033)	0.002 (0.032)
Decision making by women			-0.594*** (0.067)	0.208*** (0.041)	-0.573*** (0.098)	0.223*** (0.059)	0.167*** (0.059)
Joint decision making			0.211*** (0.077)	0.100** (0.049)	0.373*** (0.120)	0.063 (0.073)	0.096 (0.072)
Farm income							-0.094*** (0.007)
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	15,729	15,757	14,110	14,156	14,110

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 7 Heterogeneous association on different decision making processes (Household-level

OLS FE)

	(1)	(2)	(3)	(4)
	Patrilineal		Matrilineal	
	Farm income	Months of food insecurity	Farm income	Months of food insecurity
Land tenure	-0.628* (0.338)	-0.022 (0.202)	0.116 (0.884)	-0.705 (0.537)
Soil and land management	0.133** (0.056)	-0.005 (0.033)	0.193 (0.194)	-0.007 (0.111)
Tree planting	0.040 (0.074)	0.033 (0.040)	0.209 (0.242)	-0.126 (0.225)
Irrigation	0.192 (0.164)	-0.040 (0.068)	-0.038 (0.341)	-0.124 (0.246)
Decision making by women	-0.770*** (0.224)	0.381*** (0.131)	-0.650 (0.493)	0.380 (0.299)
Joint decision making	0.375 (0.264)	-0.005 (0.161)	0.549 (0.679)	0.346 (0.435)
Land tenure×Decision making by women	0.659 (0.698)	-0.785* (0.408)	0.008 (2.018)	-0.221 (1.060)
Land tenure×Joint decision making	-0.317 (0.804)	0.354 (0.447)	-0.335 (1.899)	0.457 (1.241)
Soil and land management×Decision making by women	0.348** (0.176)	-0.013 (0.088)	0.374 (0.533)	0.069 (0.304)
Soil and land management×Joint decision making	-0.072 (0.138)	0.015 (0.086)	-0.120 (0.377)	-0.133 (0.331)
Tree planting×Decision making by women	-0.360 (0.387)	-0.149 (0.150)	-1.050 (1.132)	-0.028 (0.479)
Tree planting×Joint decision making	-0.143 (0.193)	-0.041 (0.098)	-0.351 (0.287)	0.076 (0.240)
Irrigation×Decision making by women	0.280 (0.599)	0.351 (0.274)	0.149 (0.755)	0.014 (0.479)
Irrigation×Joint decision making	-0.202 (0.229)	-0.031 (0.124)	0.273 (0.509)	0.266 (0.375)
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 RALS2012 and 2015 data.

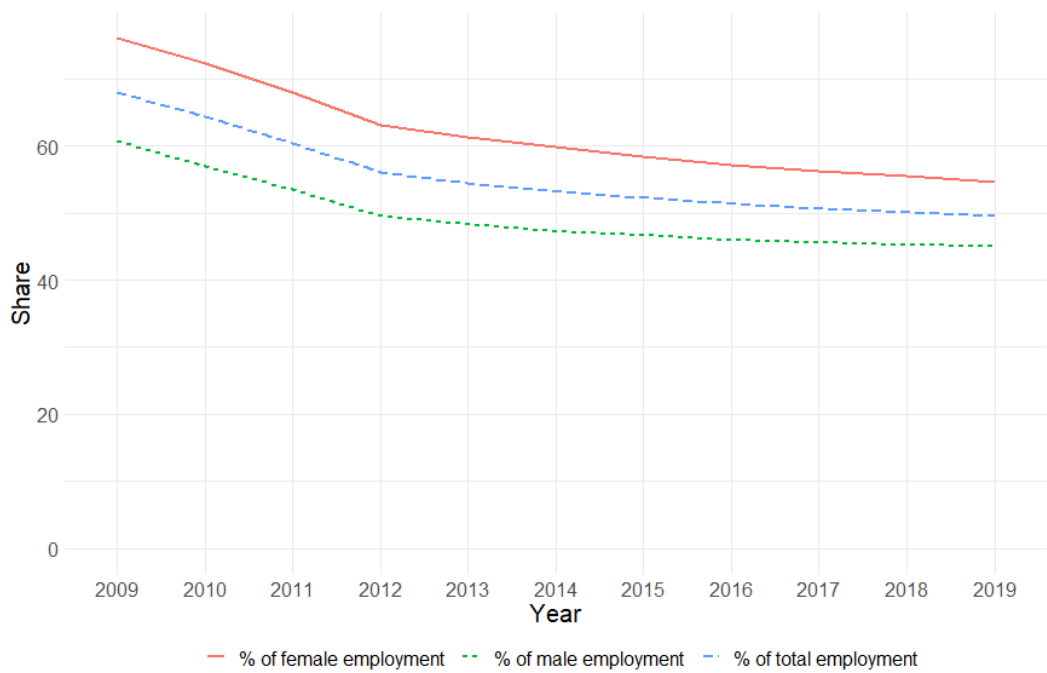


Figure 1 Employment in agriculture in Zambia

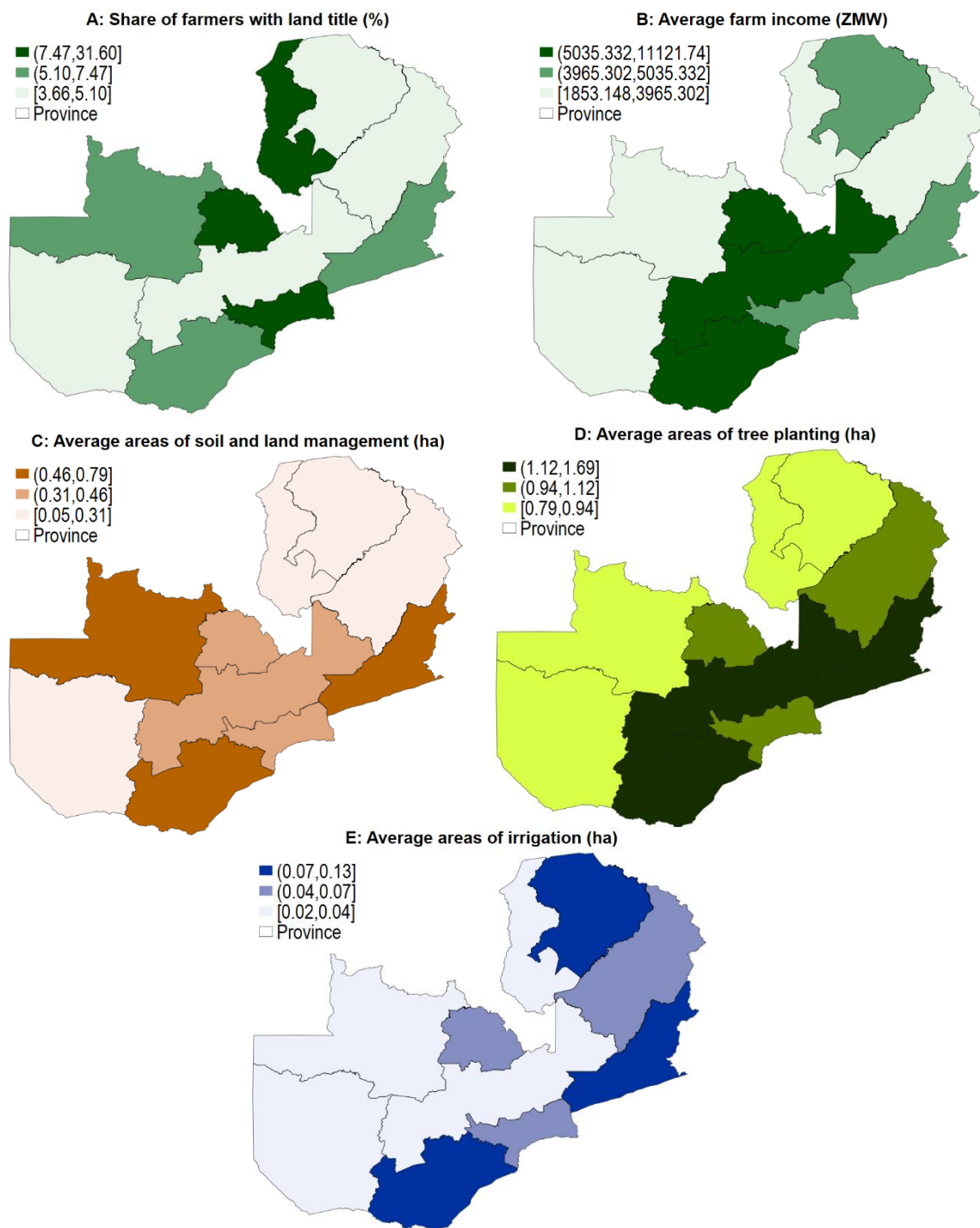


Figure 2 Land tenure, farm income, and farm investment in Zambia

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

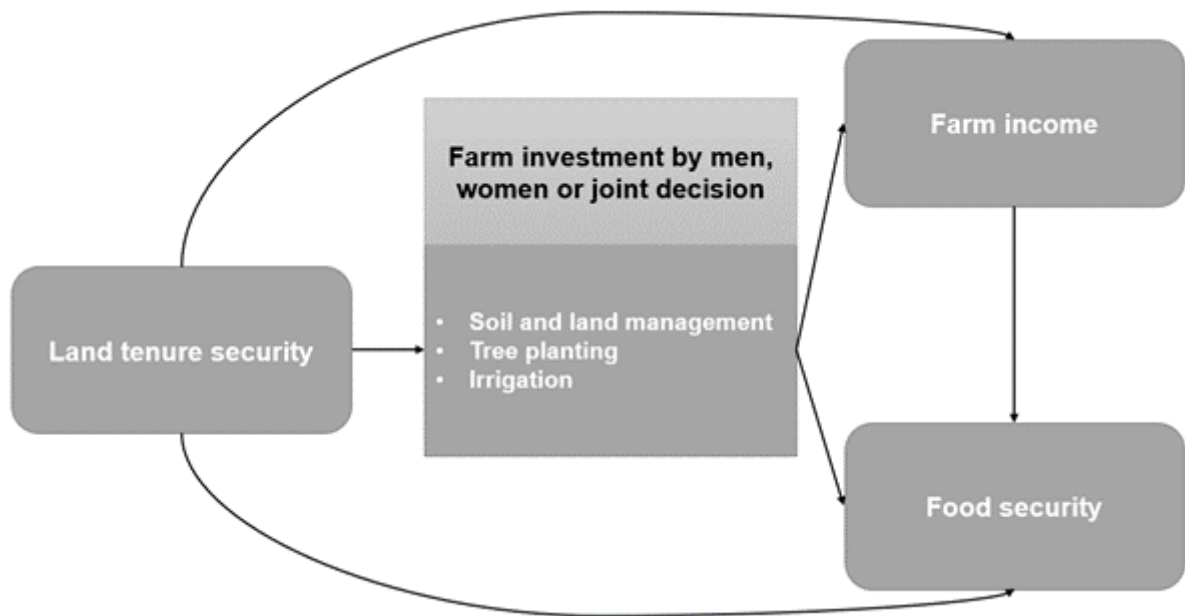


Figure 3 Conceptual framework about nexus among land tenure, farm investment, and household welfare

Source: Built by authors

Appendix

Table A 1 Determinants of land tenure security (plot-level)

	(1) Probit	(2) LPM
Purchased	1.240*** (0.043)	0.300*** (0.011)
Allocated	-0.108*** (0.038)	-0.004 (0.005)
Inherited	-0.051 (0.045)	-0.013** (0.006)
Possibility to change the tenure status	0.227*** (0.022)	0.026*** (0.004)
Decision making by women	0.126*** (0.024)	0.013*** (0.003)
Educational level of HH	0.038*** (0.003)	0.006*** (0.001)
Cash crop planted	0.002 (0.036)	-0.001 (0.003)
Matrilineal household	-0.016 (0.023)	0.005 (0.003)
Local household head	-0.127*** (0.031)	-0.012** (0.006)
Hectare	-0.000 (0.008)	-0.001 (0.001)
Age of HH	0.005*** (0.001)	0.001*** (0.000)
Adult equivalent	-0.006 (0.005)	-0.001 (0.001)
Asset index	0.061*** (0.005)	0.010*** (0.001)
Tropical Livestock Unit	0.002 (0.001)	0.000 (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 A 2 Determinants of household welfare without farm investment

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Farm income (log)	Months of food insecurity	Farm income (log)	Months of food insecurity	Farm income (log)	Months of food insecurity	Months of food insecurity
Land tenure security	0.685*** (0.101)	-0.390*** (0.051)	0.025 (0.100)	0.008 (0.054)	-0.099 (0.140)	-0.104 (0.084)	-0.115 (0.083)
Decision making by women			-0.581*** (0.068)	0.201*** (0.041)	-0.556*** (0.098)	0.213*** (0.059)	0.160*** (0.059)
Joint decision making			0.235*** (0.077)	0.097** (0.049)	0.403*** (0.120)	0.058 (0.073)	0.093 (0.072)
Matrilineal household			-0.101* (0.057)	0.099*** (0.034)	-0.085 (0.084)	0.087* (0.049)	0.081* (0.049)
Age of household head			-0.013*** (0.002)	0.004*** (0.001)	-0.011*** (0.003)	0.005*** (0.002)	0.004** (0.002)
Local household head			0.188** (0.085)	0.070 (0.049)	0.057 (0.124)	0.061 (0.070)	0.063 (0.069)
Number of plots			0.514*** (0.019)	-0.127*** (0.011)	0.506*** (0.028)	-0.106*** (0.017)	-0.059*** (0.017)
Adult equivalent			0.011 (0.014)	0.011 (0.008)	0.017 (0.019)	0.007 (0.011)	0.008 (0.011)
Cash crop			0.217*** (0.081)	-0.016 (0.043)	0.127 (0.118)	-0.040 (0.064)	-0.023 (0.063)
Smallholder farmers			-0.721***	0.229***	-0.602***	0.254***	0.198***

Educational level of HH			(0.067)	(0.035)	(0.095)	(0.055)	(0.055)
			0.042***	-0.046***	0.031***	-0.046***	-0.043***
Credit			(0.008)	(0.004)	(0.011)	(0.006)	(0.006)
			0.590***	0.027	0.676***	0.055	0.116*
Tropical Livestock Unit			(0.075)	(0.040)	(0.110)	(0.062)	(0.061)
			0.012***	-0.005***	0.008	-0.004	-0.002
Asset index			(0.004)	(0.001)	(0.006)	(0.003)	(0.003)
			0.379***	-0.117***	0.384***	-0.101***	-0.067***
Time to the nearest paved road			(0.019)	(0.008)	(0.026)	(0.012)	(0.012)
			-0.001***	0.000***	-0.001***	0.000***	0.000***
Farm income			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
							-0.093***
							(0.007)
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	14,110	14,156	14,110

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 Determinants of household welfare (HH-FE)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Farm income (log)	Months of food insecurity	Farm income (log)	Months of food insecurity	Farm income (log)	Months of food insecurity	Months of food insecurity
Land tenure	0.600*** (0.101)	-0.360*** (0.051)	0.014 (0.101)	0.016 (0.055)	-0.104 (0.141)	-0.095 (0.085)	-0.107 (0.084)
Soil and land management	0.445*** (0.029)	-0.120*** (0.011)	0.194*** (0.019)	-0.021** (0.009)	0.171*** (0.028)	-0.025* (0.015)	-0.009 (0.015)
Tree planting	0.164** (0.067)	-0.055** (0.021)	-0.023 (0.026)	0.004 (0.010)	-0.017 (0.045)	-0.013 (0.017)	-0.015 (0.017)
Irrigation	0.264*** (0.045)	-0.064*** (0.017)	0.073* (0.044)	0.004 (0.018)	0.116* (0.070)	-0.008 (0.033)	0.002 (0.032)
Decision making by women			-0.594*** (0.067)	0.208*** (0.041)	-0.573*** (0.098)	0.223*** (0.059)	0.167*** (0.059)
Joint decision making			0.211*** (0.077)	0.100** (0.049)	0.373*** (0.120)	0.063 (0.073)	0.096 (0.072)
Matrilineal household			-0.106* (0.057)	0.103*** (0.034)	-0.094 (0.084)	0.093* (0.049)	0.086* (0.049)
Age of household head			-0.012*** (0.002)	0.004*** (0.001)	-0.010*** (0.003)	0.005*** (0.002)	0.004** (0.002)
Local household head			0.177** (0.085)	0.072 (0.049)	0.042 (0.123)	0.064 (0.071)	0.064 (0.069)
Number of plots			0.528*** (0.019)	-0.134*** (0.011)	0.515*** (0.028)	-0.111*** (0.017)	-0.063*** (0.017)
Adult equivalent			0.017 (0.014)	0.008 (0.008)	0.022 (0.019)	0.005 (0.011)	0.006 (0.011)
Cash crop			0.192** (0.081)	-0.013 (0.043)	0.125 (0.118)	-0.039 (0.064)	-0.022 (0.063)
Smallholder farmers			0.047*** (0.008)	-0.047*** (0.004)	0.036*** (0.011)	-0.047*** (0.006)	-0.043*** (0.006)
Educational level of HH			0.585*** (0.075)	0.024 (0.040)	0.671*** (0.110)	0.050 (0.062)	0.111* (0.061)
Credit			0.015***	-0.006***	0.010*	-0.005*	-0.003

Tropical Livestock Unit			(0.004)	(0.002)	(0.006)	(0.003)	(0.003)
			0.392***	-0.126***	0.392***	-0.110***	-0.074***
Asset index			(0.019)	(0.008)	(0.025)	(0.012)	(0.012)
			-0.001***	0.000***	-0.001***	0.000***	0.000***
Time to the nearest paved road			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
			-0.001***	0.000***	-0.001***	0.000***	0.000***
Farm income			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
							-0.094***
							(0.007)
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	14,110	14,156	14,110

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.

Table A 4 Heterogeneous association on different decision making processes

(Household-level OLS FE)

	(1)	(2)	(3)	(4)
	Patrilineal Farm income (log)	Months of food insecurity	Matrilineal Farm income (log)	Months of food insecurity
Land tenure	-0.628* (0.338)	-0.022 (0.202)	0.116 (0.884)	-0.705 (0.537)
Soil and land management	0.133** (0.056)	-0.005 (0.033)	0.193 (0.194)	-0.007 (0.111)
Tree planting	0.040 (0.074)	0.033 (0.040)	0.209 (0.242)	-0.126 (0.225)
Irrigation	0.192 (0.164)	-0.040 (0.068)	-0.038 (0.341)	-0.124 (0.246)
Decision making by women	-0.770*** (0.224)	0.381*** (0.131)	-0.650 (0.493)	0.380 (0.299)
Joint decision making	0.375 (0.264)	-0.005 (0.161)	0.549 (0.679)	0.346 (0.435)
Land tenure×Decision making by women	0.659 (0.698)	-0.785* (0.408)	0.008 (2.018)	-0.221 (1.060)
Land tenure×Joint decision making	-0.317 (0.804)	0.354 (0.447)	-0.335 (1.899)	0.457 (1.241)
Soil and land management×Deci sion making by women	0.348** (0.176)	-0.013 (0.088)	0.374 (0.533)	0.069 (0.304)
Soil and land management×Joint decision making	-0.072 (0.138)	0.015 (0.086)	-0.120 (0.377)	-0.133 (0.331)
Tree planting×Decision making by women	-0.360 (0.387)	-0.149 (0.150)	-1.050 (1.132)	-0.028 (0.479)
Tree planting×Joint decision making	-0.143 (0.193)	-0.041 (0.098)	-0.351 (0.287)	0.076 (0.240)

Irrigation×Decision making by women	0.280 (0.599)	0.351 (0.274)	0.149 (0.755)	0.014 (0.479)
Irrigation×Joint decision making	-0.202 (0.229)	-0.031 (0.124)	0.273 (0.509)	0.266 (0.375)
Age of HH	-0.007 (0.006)	0.002 (0.003)	-0.010 (0.013)	0.009 (0.009)
Local household head (=1 if yes)	0.073 (0.257)	-0.048 (0.136)	0.095 (0.624)	0.249 (0.354)
Number of plots	0.504*** (0.060)	-0.090** (0.035)	0.678*** (0.122)	-0.208*** (0.080)
Adult equivalent	0.021 (0.038)	0.014 (0.023)	0.026 (0.096)	-0.042 (0.058)
Cash crop planted (=1 if yes)	0.037 (0.236)	0.030 (0.124)	0.116 (0.704)	-0.138 (0.375)
Smallholder	0.046** (0.023)	-0.039*** (0.013)	0.053 (0.053)	-0.035 (0.034)
Educational level of HH (years)	0.531** (0.214)	0.079 (0.118)	0.852 (0.573)	-0.086 (0.319)
Obtaining credit (=1 if yes)	-0.002 (0.008)	0.000 (0.004)	0.111* (0.058)	-0.020 (0.029)
Tropical Livestock Unit	0.417*** (0.043)	-0.133*** (0.021)	0.430*** (0.143)	-0.106 (0.074)
Asset index	-0.001 (0.000)	0.000 (0.000)	-0.002* (0.001)	0.002* (0.001)
Time to the nearest paved road (min)	-0.628* (0.338)	-0.022 (0.202)	0.116 (0.884)	-0.705 (0.537)
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 5 Heterogeneous associations on decision maker (Probit-PSM)

	(1) Soil and land management	(2) Tree planting	(3) Irrigation
Land tenure security	0.177*** (0.030)	-0.000 (0.059)	0.107 (0.089)
Land titled×Decision making by women	-0.006 (0.062)	0.334*** (0.115)	-0.259 (0.219)
Control variables	Yes	Yes	Yes
Province dummy	Yes	Yes	Yes
Year dummy	Yes	Yes	Yes
Observations	45,457	45,457	45,457

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.