1. Introduction

Agriculture has long been a critical component of the economic and labor structure in Sub-Saharan Africa (SSA), and Zambia is no exception. In 2019, the share of employment in agriculture was over 50% (Figure 1) and the GDP share of the agriculture, forestry, and fishing sectors in terms of value-addition remained at 2.7% in 2020 (Mulenga, 2021). In the agrarian sector, women play a crucial role in increasing food security; however, social norms force 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 market and/or technological changes, 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, there is need to build women's access to the resources needed for productive agriculture 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) identified drivers of the gender gap in agricultural productivity. These include the fact that women have less access to male family labor and land. The researchers also found that women 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 of narrowing the gender gap in agricultural productivity and, consequently, to improve household welfare in SSA[1].

There are several definitions of women's land rights (WLR): 1) land tenure; 2) the right to make planting decisions; 3) the right to transfer/sell farm produce or property, and 4) the right to make output decisions (Kang, Schwab, & Yu, 2020). For example, land tenure is linked to farmers' investments in soil quality improvement, such as bunding, terracing, irrigation, and fallowing (Agarwal & Mahesh, 2023). WLR and women's participation in decision making are highly linked together (Twyman, Useche, & Deere, 2015; Gacia-Moran & Yates, 2022). 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). To represent WLR, this information is more reliable than the commonly used 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 the relation between land tenure security and farm investment are gendered Finally, we examine whether there are any heterogeneous associations among land tenure security, farm investment, farm income, and food insecurity across kinship systems (matrilineal vs patrilineal). To this end, we use a new nationally representative panel dataset 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. Furthermore, we exploit the fact that Zambia has both patrilineal and matrilineal kinship systems to examine whether the gender gaps in agricultural productivity stem from inequality in land tenure security and power differentials in agricultural decision-making due to differences in the kinship systems.

There is a substantial body of literature on the relationship between land tenure security 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 debate continues as to 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 like kinship systems.

The main contribution of this paper is threefold. First, we provide novel evidence of a link among land tenure security, farm investment decisions, and household welfare in Zambia where matrilineal and patrilineal kinship systems coexist. Previous empirical studies have not 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 gender status 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 kinship systems in Zambia

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. Customary land is advantageous to many farmers at the village level. Under this system, land is easy to acquire because the process is short and affordable for many users. However, customary land tenure system is governed using ethnically diverse and unwritten local cultural rules, whereas western style statutory tenure system is based on national laws enacted by the Zambian parliament. Hence, enforcement of statutory laws supersedes customary laws. This situation renders usufruct land users vulnerable to displacement by more powerful individuals and corporations (Chu, Young, & Phiri, 2015).

In 1995, the Zambian government implemented the Lands Act to allow for individual ownership rights and other formal land rights transfers. The Lands Act aimed at protecting land rights of holders from displacement by external people, and it gives chance for conversion of customary land to leasehold tenure for those seeking larger production (Sitko, Chamberlin, & Hichaambwa , 2014). 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). However, once converted, land 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 both customary and statutory tenure systems in this study. However, in Zambia, as in almost all SSA, women rarely own or oversee 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.

Zambia is one of the most ethnically diverse countries in SSA (Posner, 2004), and thus social norms can vary across the country. There are matrilineal and patrilineal societies in Zambia. 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, Murombedzi, Nkonkomalimba, Sambo, & Sommerville 2017). However, in most cases, women acquire rights to land through their husbands when they marry. Under the statutory system, women have the right to land ownership regardless of the kinship systems, but titles tend to be transferred through male relatives in both matrilineal and patrilineal societies (Chapoto et al.

2011). 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, together with the Central Statistical Office 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 Areas[2] (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. 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 and Table 2. Because we explore both plot- and household-level relationships, the plot and household characteristics are shown in Table 1 and Table 2. 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 here]

[Table 2 here]

3.1. **Measurement of key variables**

The variables of interest are land tenure security, soil and land management, tree planting, irrigation, 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 at plot level is assigned a value of 1 if the decision-makers are women and 0 otherwise. 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 measured according to application areas at the plot and household levels both in plot-level and household-level. Due to the data availability, we consider farm investment as both stock and flow because the dataset we use does not include the timing of investment. In terms of tree planting, *Faidherbia albida* and *Gliricidia sepium*, a sort of legume, are mainly planted to protect the harvest of crops, especially maize. These trees have a relatively higher germination rate, and they improve the soil quality since they are in the family of legumes. Their leaves are even used for feeding livestock. Thus, tree planting can be considered as investment rather than speculation. 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. It is important to note that farm income accounts for partially observed costs of production. Thus, the net farm income accounts for fertilizer costs and the costs of transportation, but not for labor, transaction, seed, or other input expenditures due to data availability. Values are given in Zambia Kwacha (ZMW) and deflated to real 2017 terms[3]. The second outcome variable is food insecurity, which measures the number of months in which a household lacks enough food to meet its needs. Although household food security is generally captured by food availability which is usually measured by food expenditure and food accessibility which is usually measured by dietary diversity (Matsuura, Luh, & Islam, 2023), the dataset we use fails to contain the information. In terms of the food security variable, we have to be cautious about the interpretation of it because it may mainly reflect the seasonality of access to food, whether from production or markets.

3.2. **Descriptive statistics**

Table 2 shows that the ratio of smallholder farmers among land title holders is lower than the one of non-title holders. It indicates that stallholder farmers are less likely to have land tenure security. Table 3 shows that the ratio of women decision makers on tenured plots is higher than the one of non-tenured plot. This result is contrary to our intuition that women have less access to land. One plausible explanation is that women who can decide how to use a plot are relatively central to the networks of social and political power in a community (Goldstein & Udry, 2008). Table 3 also reports the relationships between the kinship system and the decision making process. Women are more likely to make decisions in a matrilineal system than in a patrilineal system.

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. Panels C, D, and E show the geographical distribution of the farm investment area (ha). Panel F presents agro-ecological zone in Zambia. In Panel F, Zone I lie in southern, eastern, and western Zambia. Zone II includes much of central Zambia, and Zone III lies in band across northern Zambia. From the graphical analysis, linkages between land tenure security, farm investment, and household welfare superficially exists. Moreover, agro-ecological zones may be related to farm investment decisions. To claim the empirical linkage among them, we need to examine the nexuses empirically such as by controlling for geographical factors. The detailed empirical methods are explained in a following section.

[Table 3 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 extreme purpose of this analysis is to provide insights in the nexus among land tenure security, farm investment, and household welfare from perspectives on gender and social norms. Land tenure security is believed to increase farm investment because profits from farm investment will not be seized by others in the future. The cost of farm investment becomes lower than the sum of the additional profit from the investment. Second, land tenure security and farm investment may be linked through some factors such as credit access, gains from trade, and capital investment (Feder & Onchan, 1987; Galiani & Shargrodsky, 2010; Besley, 1995). Passing through the potential channels, we expect that land tenure security would increase farm investment: soil and land management, tree planting, and irrigation in this study.

Some possible determinants of farm investment should be considered in an empirical analysis. Risk preference may be a driver of farm investment (Liu, 2013). Unfortunately, we do not have any information about risk preferences of decision makers, but we manage to consider this dimension by including wealth level of household, educational level of household head and gender of decision makers. Moreover, farmers' knowledge through agricultural extension service may also affect farm investment decisions (Nakano, Tsusaka, Aida, & Pede, 2018). In this study, we consider the distance to the nearest paved road as a proxy of agricultural services.

In many African settings, agricultural production is conducted simultaneously on many plots controlled by different household members. 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. Since women are less likely to have access to land rights, we expect that they are more likely to invest in agricultural technologies when they have tenured plots. Furthermore, women in patrilineal societies may relatively have weaker bargaining power than women in matrilineal societies. The effect of land tenure security for women in patrilineal societies may be larger than the one for women in matrilineal societies.

Moreover, land tenure security is believed to improve household welfare by increasing farm investment (Bellemare et al., 2020; Issahaku & Abdulai, 2020). Fenske (2011) doubted short-lived investment such as labor, fertilizer, and pesticide, as a consequence of land tenure security. Thus, we focus on only long-lived investment such as soil and land management, tree planting, and irrigation. Soil and land management contributes to increasing soil quality and prevent land degradation (Abdulai & Huffman, 2014). Increased soil quality can increase farm income and yield which is related to self-consumption. Tree planting improves soil fertility and planted trees may feed livestock (Sitko, Chamberlin, & Hichaambwa , 2014). Thus, tree planting can increase farm income and improve household food security. Furthermore, irrigation improves efficiency of water use and increases yields and net returns (Abdulai & Huffman, 2014).

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 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 production because adult male labor is found to contribute more than adult female labor to the production (Jacoby, 1991). Furthermore, as theory predicts that women prefer to devote resources to improving their nutritional status (Thomas, 1990); households with land tenure security that are solely held by a woman, compared with those without land tenure security, allocate more of their family budget to food (Menon, van der Meulen Rodgers, & Nguyen, 2014). Therefore, we expect that households that are solely held by a woman in patrilineal households benefit more from farm investment and land tenure security than the matrilineal ones. Our study contributes to the literature on land tenure security and farm investment from the perspective of gender and social norms. Figure 3 illustrates the conceptual framework of the links between land tenure security, farm investment, and household welfare. The normal arrows show the possibility of causal relationship while the dashed arrows present potential reverse causality. 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 in patrilineal households are more likely to invest when a plot has tenure security than those in matrilineal societies.

Hypothesis II. Farm investment improves farm income and food security. The effect of farm investment is larger for farmers with women decision-makers in patrilineal societies.

[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 by mathing farmers with similar characteristics at first. 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 security, 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 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

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

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 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 to account for observable characteristics, 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[4]. 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:

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

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 security 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. As Deininger & Jin (2006); Fenske (2011) mention that households undertake farm investments to establish more secure property rights to land, the revese causality should be addressed by a causal inference method such as instrumental variable appoarch and Difference in Differences. In this study, our interepretation should be made with caution about causality because we are not able to address the issure due to the limitation of the dataset and lack of finding a suitable instrument variable.

Beyond the relationship between land tenure security and farm investment, we examine the factors affecting household welfare using household-level data. Land tenure security 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 security and the farm investment variable[5]. 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 security 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 we cannot address that land tenure security and farm investment are endogenous because of their potential correlation with unobservable time-varying factors. Therefore, although some studies using only fixed effect models give insightful implications in economics studies such as Kathage & Qaim (2012) and Kubitza, Krishna, Urban, Alamsyah, & Qaim (2018), our findings should be merely treated as an association rather than causality.

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 A1 shows the results of Equation (1) estimated by the Probit model and linear probability model[6].

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). Another logic is that women who can have managerial rights are relatively hub of a community's social and political power networks (Goldstein & Udry, 2008). However, interpretation of the coefficients is just association rather than causal relationships. 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 security and farm investment

Table 4 summarizes the results of the PSM fixed-effects model 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, regardless of gender of decision makers. This result is consistent with the findings of Goldstein & Udry (2008), Abdulai, Owusu, & Goetz (2011), Ali, Deininger, & Goldstein (2014), Lovo (2016), and Lawin & 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 only female decision-makers. There are several plausible reasons behind this result. One is that women with decision making power are more likely to invest is that there would be possibilities that women's land without tenure is exploited by someone especially man. Another is that female has a longer life expectancy than male in Zambia. Therefore, women are more likely to receive the higher returns from tree planting compared to men. Therefore, the interaction term between land tenure security and decision making by women is positive and significant.

Table 5 shows the result of sub-sample analysis dividing the whole sample into patrilineal households and matrilineal households. Column (2) shows the coefficient of an interaction term between land tenure securitys and decision making by women is positive and significant while Column (5) shows the coefficient of the interaction term is insignificant. It indicates that women decision makers in patrilineal households are likely to invest in tree planting when they have land tenure security whereas those in matrilineal are not. 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, & Payongayong (2003) and Dillon & 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. However, we do not find a significant association between land tenure security and irrigation. This may be because there are further barriers other than land tenure security to adopt irrigation systems.

[Table 4 here]

[Table 5 here]

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

As discussed in Section 4, our main research objective is to examine the empirical link between land tenure security, farm investment, and household welfare. Table 6 presents factors related to household welfare, including farm income and food insecurity, by estimating Equation (4)[7]. 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 has a positive and significant association with farm income in Column (5). 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 security and tree planting are significantly associated with farm income in Column (1), but their coefficients are not significant in Column (5).

For the food insecurity outcome (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 agronomic 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 soil and land management 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 food security as well as income.

[Table 6 here]

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

Many views by development practitioners 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 related to targeting interventions at women (Doss, 2018). To evaluate 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. First, Columns (1) and (2) shows the results of whole sample analysis with interaction terms of land tenure security and farm investment with decision making by women. Columns (1) presents a positive and significant coefficient of the interaction term between soil and land management and decision making by women, indicating that soil and land management has more sizable association with farm income when only women involve in intrahousehold decision making. Moreover, Column (2) shows that having secure land tenure security reduces food insecurity in households where women make decisions. Second, Columns (3) and (4) present the estimation results for patrilineal households, whereas Columns (5) and (6) present the results for matrilineal households. The sub-sample analysis gives insights whether social norms are related to this heterogeneous association among decision making processes. 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 (3). However, this significant relationship disappears for matrilineal societies, as shown in Column (5). 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 (4). In contrast with Column (4), no significant association is found in Column (6). 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 and Table 2, 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 vary 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 A6. 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 A6 also shows the gendered heterogeneous association between land tenure security and tree planting. Furthermore, we use a restricted sample which contains households who have both tenured and non-tenured plots to exploit the variation within households. Table A7 even corroborates our main findings. 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.

Moreover, we estimate the household welfare equation with the area weighted land tenure security. The results are shown in Table A8. We find that when the land tenure security is considered as continuous as well as binary, significance of coefficients of land tenure security and farm investment does not vary.

6. Conclusions and policy implications

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 RALS datasets, which include 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 in patrilineal household tend to invest more in tree planting when plots have land tenure security. 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. Our findings corroborate previous evidence that farm investment increases farm income and improves food insecurity, ultimately improving household welfare as stated in Hypothesis II. Lastly, 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 security, 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. In addition, land policies that secure women's rights could improve household welfare by enhancing farm investments, especially for women in male-dominant societies. Given that inheritance laws which disfavors women in terms of their access and rights to land, we also suggest their reforms. Although our study uses datasets only from Zambia, we can draw policy recommendations for countries near Zambia, such as Malawi, Mozambique, Tanzania, 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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Table 1 Description of plot and household variables (Plot-level, baseline)

Variable	Description	N	Mean	SD	N	Mean	SD	Dif
			Tenured			Non tenured		Tenured-Non tenured
Soil and land management	Areas of preventing soil erosion and/or flash flooding (ha)	1,618	0.232	0.833	22,730	0.156	0.562	0.076***
Tree planting	Areas of planting trees (ha)	1,618	0.037	0.294	22,730	0.024	0.237	0.013**
Irrigation	Irrigated areas (ha)	1,618	0.007	0.097	22,730	0.004	0.070	0.003*
Purchased	1 if the plot is acquired by purchasing, 0 otherwise	1,618	0.277	0.448	22,730	0.033	0.178	0.244***
Inherited	1 if the plot is acquired by inheritance, 0 otherwise	1,618	0.064	0.245	22,730	0.121	0.326	-0.057***
Allocated	1 if the plot is acquired by allocation, 0 otherwise	1,618	0.534	0.499	22,730	0.760	0.427	-0.226***
Rented	1 if the plot is acquired by rental 0 otherwise	1,618	0.070	0.318	22,730	0.022	0.217	0.048***
Possibility to change the tenure status	1 if the plot's status is possibly changed, 0 otherwise	1,618	0.477	0.500	22,730	0.318	0.466	0.158***
Decision making by women	1 if the decision maker of the plot is woman, 0 otherwise	1,618	0.287	0.452	22,730	0.243	0.429	0.044***
Cash crop	1 if a cash crop is planted, 0 otherwise	1,618	0.108	0.311	22,730	0.112	0.315	-0.004

Note: Authors' calculation using RALS2012. Zambian Kwacha (ZMW) values are in real 2017 terms. 2017 exchange rate: 9.5 ZMW/US$. We excluded households who earn less than 0 ZMW as outliers. ***, **, * denote level of significance at 1%, 5% and 10% respectively.

Table 2 Descriptive statistics (Household-level, baseline)

Variable	Description	N	Mean	SD	N	Mean	SD	Dif
			Tenured			Non tenured		Tenured-Non tenured
Farm income	Total Farm income (ZMW)	763	6478.620	17290.790	6,292	5108.158	12939.970	1370.462***
Food insecurity	Number of months of food insecurity	763	0.974	1.663	6,292	1.199	1.814	-0.225***
Soil and land management	Areas of preventing soil erosion and/or flash flooding (ha)	763	0.584	1.683	6,292	0.504	1.353	0.080
Tree planting	Areas of planting trees (ha)	763	0.134	0.789	6,292	0.122	0.876	0.012
Irrigation	Irrigated areas (ha)	763	0.123	0.888	6,292	0.079	0.647	0.044*
Educational level of HH	Educational year of household head	763	8.465	4.925	6,292	6.009	3.750	2.456***
Matrilineal household	1 if the household is matrilineal, 0 otherwise	763	0.367	0.482	6,292	0.391	0.488	-0.238***
Local household head	1 if the household head is local, 0 otherwise	763	0.813	0.391	6,292	0.890	0.313	-0.077*
Number of plots	Number of plots	763	2.780	1.638	6,292	3.121	1.605	-0.341***
Cash crop	1 if the household plant a cash crop, 0 otherwise	763	0.087	0.281	6,292	0.149	0.356	-0.062***
Credit access	1 if the household can obtain credit, 0 otherwise	763	0.138	0.345	6,292	0.190	0.392	0.052***
Age of HH	Age of household head	763	47.225	14.741	6,292	45.307	14.894	1.918***
Adult equivalent	Number of adult equivalents	763	4.126	2.146	6,292	3.658	1.876	0.468***
Asset index	Asset index based on principal component analysis	763	1.180	3.405	6,292	-0.038	2.058	1.219***
Tropical Livestock Unit	Ownership and access to tropical livestock	763	2.765	9.477	6,292	2.314	7.400	0.451
Time to the nearest paved road	Time from homestead to the nearest paved road (minutes)	763	69.558	332.616	6,292	109.784	228.613	-40.225***
Smallholder	1 if households are small-scale farmers cultivating 4.99 hectares of crop or less, otherwise 0	763	0.735	0.441	6,292	0.766	0.423	-0.031**

Note: Authors' calculation using RALS2012. 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 (Otte & Chilonda, 2002). 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. 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 3 Decision making, plot-tenure, and kinship system

	Land title			Kinship		
	Yes	No	Dif	Patrilineal	Matrilineal	Dif
Decision making by women	0.273	0.254	0.192**	0.337	0.407	-0.071***
	(0.445)	(0.435)		(0.473)	(0.491)	
Observation	2,654	42,442	45,094	10,966	3,144	14,108

Source: Authors' calculation using the RALS2012 and 2015 data. Standard deviations are in parethesis. For land title, the data is plot-level. For kinship, the data is household-level. Dif means the mean difference between titled and non-titled plots and between patrilineal and matrilineal households. ***, **, * denote level of significance at 1%, 5% and 10% respectively.

Table 4 Heterogeneous association between land tenure security and farm investment

	(1) Soil and land management	(2) Tree planting	(3) Irrigation
Land tenure security	0.068***	0.011	0.000
	(0.025)	(0.009)	(0.004)
Land tenure security×Decision making by women	-0.046	0.020*	-0.006
	(0.038)	(0.012)	(0.004)
Decision making by women	-0.060***	-0.015***	-0.001
	(0.008)	(0.003)	(0.001)
Purchased	0.068**	0.008	0.012*
	(0.029)	(0.010)	(0.006)
Allocated	0.106***	0.013***	0.007**
	(0.015)	(0.004)	(0.003)
Inherited	0.106***	0.021***	0.006*
	(0.018)	(0.007)	(0.003)
Rented	0.122***	0.004	0.011
	(0.037)	(0.008)	(0.008)
Cash crop planted	0.052***	0.021***	0.002
	(0.012)	(0.006)	(0.002)
Possibility to change the tenure status	0.019*	0.004	-0.003*
	(0.010)	(0.004)	(0.002)
Educational level of HH	-0.003**	-0.001	0.000
	(0.001)	(0.001)	(0.000)
Matrilineal household	-0.023**	0.005	0.002
	(0.009)	(0.004)	(0.002)
Local household head	0.033**	0.005	0.003
	(0.015)	(0.007)	(0.002)
Age of HH	-0.000	0.000	-0.000
	(0.000)	(0.000)	(0.000)
Adult equivalent	0.004	0.001	0.000
	(0.003)	(0.001)	(0.000)
Asset index	0.039***	0.009***	0.001***
	(0.004)	(0.002)	(0.000)
Tropical Livestock Unit	0.001	0.000	0.000
	(0.001)	(0.000)	(0.000)
Time to the nearest paved road	-0.000	0.000	-0.000
	(0.000)	(0.000)	(0.000)
Household FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Province FE	Yes	Yes	Yes
Observations	45,108	45,108	45,108

Note: Robust standard errors are shown in parentheses. This is a plot-level analysis. Land tenure security is a dummy variable. The outcome variable is area of farm investment measured by hectare. Fixed effect model is used after PSM to account for both observed and unobserved time-invariant factors. ***, **, * denote level of significance at 1%, 5% and 10% respectively.
Source: Authors' calculations using RALS2012 and 2015 data

Table 5 Land tenure security and investment decision among kinship systems

	(1)	(2)	(3)	(4)	(5)	(6)
	Patrilineal			Matrilineal		
	Soil and land management	Tree planting	Irrigation	Soil and land management	Tree planting	Irrigation
Land tenure security	0.035	0.011	-0.004	0.094*	-0.002	0.018
	(0.043)	(0.011)	(0.006)	(0.056)	(0.008)	(0.020)
Land tenure security × Decision making by women	-0.116*	0.052**	-0.005	-0.031	0.009	0.002
	(0.063)	(0.023)	(0.004)	(0.074)	(0.014)	(0.007)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Household FE	Yes	Yes	Yes	Yes	Yes	Yes
Province dummy	Yes	Yes	Yes	Yes	Yes	Yes
Year dummy	Yes	Yes	Yes	Yes	Yes	Yes
Observations	28,725	28,725	28,725	15,434	15,434	15,434

Note: Robust standard errors are clustered by household in parentheses. Land tenure security is a dummy variable. The outcome variable is area of farm investment measured by hectare. ***, **, * denote level of significance at 1%, 5% and 10% respectively. Full regression table is available in Table A2.
Source: Authors' calculations using 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 security	0.600***	-0.360***	0.014	0.016	-0.104	-0.095	-0.107
	(0.101)	(0.051)	(0.101)	(0.055)	(0.141)	(0.085)	(0.084)
Soil and land management	0.445***	-0.120***	0.194***	-0.021**	0.171***	-0.025*	-0.009
	(0.029)	(0.011)	(0.019)	(0.009)	(0.028)	(0.015)	(0.015)
Tree planting	0.164**	-0.055**	-0.023	0.004	-0.017	-0.013	-0.015
	(0.067)	(0.021)	(0.026)	(0.010)	(0.045)	(0.017)	(0.017)
Irrigation	0.264***	-0.064***	0.073*	0.004	0.116*	-0.008	0.002
	(0.045)	(0.017)	(0.044)	(0.018)	(0.070)	(0.033)	(0.032)
Decision making by women			-0.594***	0.208***	-0.573***	0.223***	0.167***
			(0.067)	(0.041)	(0.098)	(0.059)	(0.059)
Joint decision making			0.211***	0.100**	0.373***	0.063	0.096
			(0.077)	(0.049)	(0.120)	(0.073)	(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 A4. Source: Authors' calculations using RALS2012 and 2015 data.

Table 7 Heterogeneous association on different decision making processes (Household-level OLS FE)

	(1)	(2)	(3)	(4)	(5)	(6)
	Whole sample		Patrilineal		Matrilineal	
	Farm income	Months of food insecurity	Farm income	Months of food insecurity	Farm income	Months of food insecurity
Land tenure	-0.276	0.017	-0.628**	-0.022	0.116	-0.705**
	(0.169)	(0.100)	(0.257)	(0.154)	(0.518)	(0.315)
Soil and land management	0.166***	-0.036**	0.133***	-0.005	0.193*	-0.007
	(0.032)	(0.017)	(0.042)	(0.025)	(0.114)	(0.065)
Tree planting	-0.017	0.002	0.040	0.033	0.209	-0.126
	(0.048)	(0.021)	(0.056)	(0.031)	(0.142)	(0.132)
Irrigation	0.178**	-0.026	0.192	-0.040	-0.038	-0.124
	(0.090)	(0.040)	(0.125)	(0.052)	(0.200)	(0.144)
Decision making by women	-0.674***	0.266***	-0.770***	0.381***	-0.650**	0.380**
	(0.107)	(0.064)	(0.170)	(0.100)	(0.289)	(0.175)
Joint decision making	0.405***	0.030	0.375*	-0.005	0.549	0.346
	(0.136)	(0.081)	(0.201)	(0.122)	(0.398)	(0.255)
Land tenure security ×Decision making by women	0.551	-0.601***	0.659	-0.785**	0.008	-0.221
	(0.345)	(0.201)	(0.532)	(0.311)	(1.183)	(0.621)
Land tenure security ×Joint decision making	0.437	0.169	-0.317	0.354	-0.335	0.457
	(0.415)	(0.234)	(0.612)	(0.341)	(1.113)	(0.727)
Soil and land management×Decision making by women	0.194**	0.047	0.348***	-0.013	0.374	0.069
	(0.096)	(0.049)	(0.134)	(0.067)	(0.313)	(0.178)
Soil and land management×Joint decision making	-0.068	0.026	-0.072	0.015	-0.120	-0.133
	(0.067)	(0.038)	(0.105)	(0.065)	(0.221)	(0.194)

Tree planting×Decision making by women	-0.124	-0.171**	-0.360	-0.149	-1.050	-0.028
	(0.188)	(0.087)	(0.294)	(0.114)	(0.664)	(0.281)
Tree planting×Joint decision making	0.040	-0.010	-0.143	-0.041	-0.351**	0.076
	(0.126)	(0.039)	(0.147)	(0.074)	(0.168)	(0.141)
Irrigation×Decision making by women	0.068	0.228	0.280	0.351*	0.149	0.014
	(0.329)	(0.144)	(0.456)	(0.209)	(0.443)	(0.281)
Irrigation×Joint decision making	-0.238*	0.017	-0.202	-0.031	0.273	0.266
	(0.127)	(0.068)	(0.174)	(0.094)	(0.298)	(0.220)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Household FE	Yes	Yes	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observation	14,110	14,156	6,012	6,030	1,844	1,846

Note: Robust standard errors are clustered by household in parentheses. The outcome variables were log farm income and number of months of food insecurity. Households who covert the kinship system between the waves are exclude for sub-sample analysis to include household fixed effects without singleton. ***, **, * denote level of significance at 1%, 5% and 10% respectively. Full regression table is available at Table A5.
Source: Authors' calculations using RALS2012 and 2015 data.

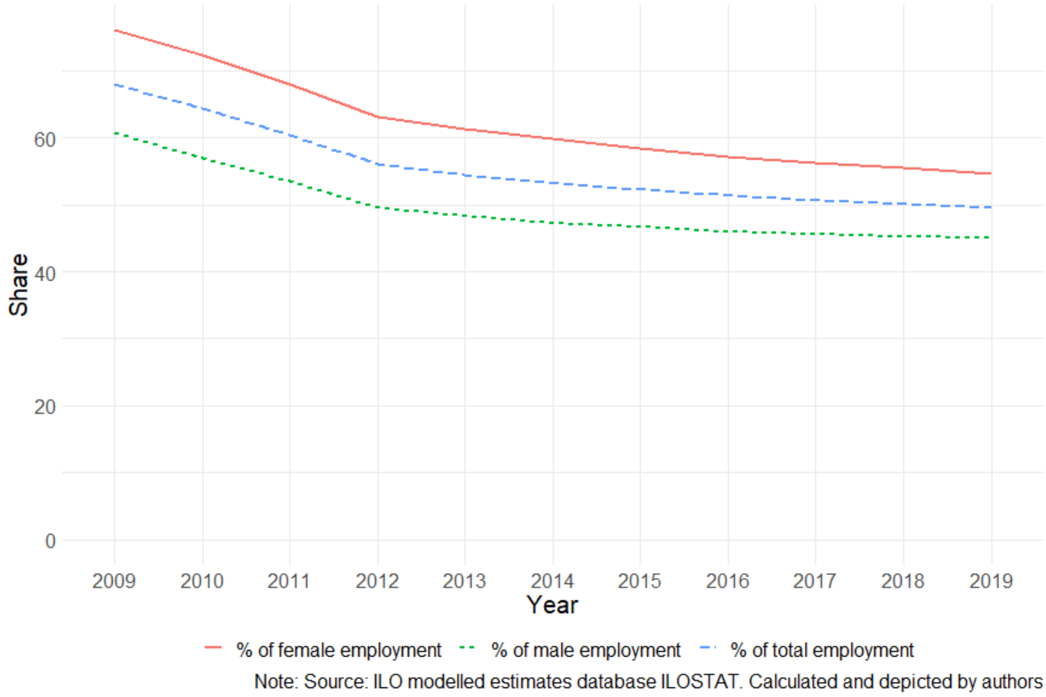

Figure 1 Employment in agriculture in Zambia

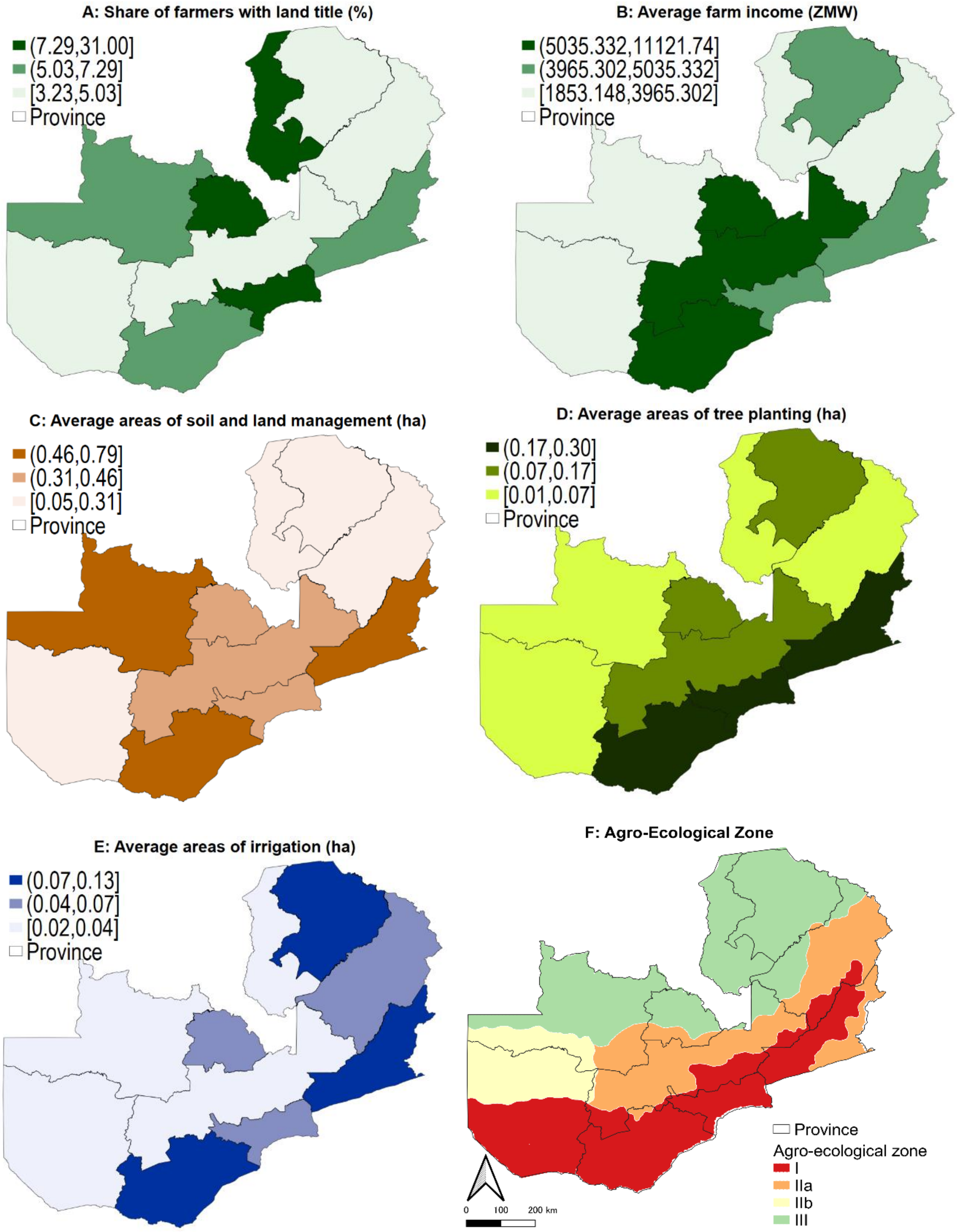

Figure 2 Land tenure security, farm income, and farm investment in Zambia

Note: 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. Panel F presents the agro-ecological zone. Source: Authors' compilations using the RALS2012 and 2015 data and SASSCAL Data and Information Portal.

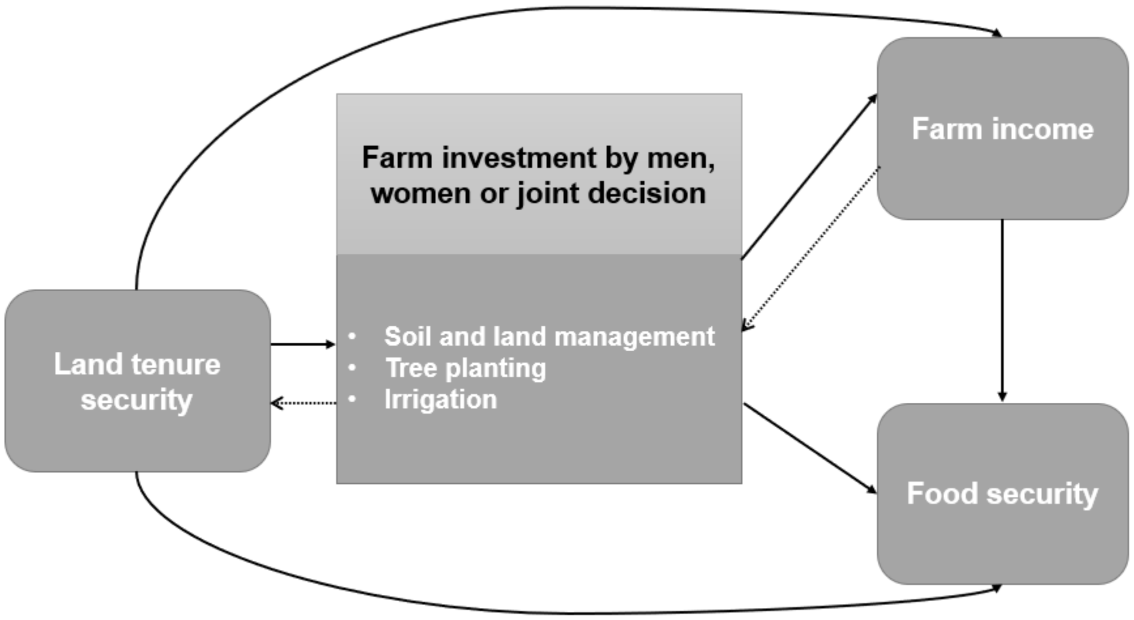

Figure 3 Conceptual framework for links among land tenure security, farm investment, and household welfare

Source: Build by authors. Note: Dashed lines show possible reverse causal relationships

[1] Granting rights are not enough to narrow the gender gap in agricultural productivity; operationalizing them is another important challenge in practice.

[2] 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.

[3] In 2017, the exchange rate was 9.5 ZMW/US$.

[4] The reverse causality between land tenure security and farm investment may be accounted for the usage of the time of acquisition to be used as instruments.

[5] We also estimate a model without farm investment variables. If land tenure security increases farm investment, part of the effect of land tenure security would be captured by the coefficient of farm investment. Comparing the estimation models with and without farm investment, the smaller coefficient of land tenure security in Equation (4) would support our hypothesis that land tenure security increases farm investment, and farm investment then increases household welfare.

[6] 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.

[7] The land tenure security estimates in Table 6 are somewhat smaller than those in Table A3, confirming that some of the positive household welfare associations of land tenure security are channeled through farm investment, as hypothesized.