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Development outcomes of land tenure formalization under customary and statutory land tenure systems in Tanzania: a multinomial endogenous switching regression approach

Haji Athumani Msangi[1,2,3*], Betty Waized[2], Katharina Löhr[1,4], Stefan Sieber[1,5] and Daniel Wilson Ndyetabula[2]

Abstract

Background: Land Tenure Formalization (LTF) is long advocated as a policy prescription that fosters growth and reduces poverty in developing countries. However, the empirical evidence on LTF effects is mixed and inconclusive, proving unclear implications for policy. A set of possible conceptual and methodological flaws arising from treating LTF as a dichotomy between formalized and non-formalized alongside potential selectivity biases are amongst the main explanations for the mixed and inconclusive results. Using Tanzania's National Panel Survey data from the 2014/2015 wave and employing a Selectivity Corrected Multinomial Endogenous Switching Regression, this study models the development outcomes of LTF with clear distinction of LTF between customary and statutory land tenure systems in Tanzania.

Findings: The study finds that possession of formal land tenure certificates [Certificate of Customary Right of Occupancy (CCRO) or Certificate of Granted Right of Occupancy (CGRO)] improves perceived land tenure security, but the effect is relatively larger and more significant for CGRO holders than CCRO holders especially in economically high potential areas, where land is becoming more individualized and commoditized. With regard to credit access, our results show variations in the effects between general, formal, and informal credit access. While there is no significant effect of LTF on general access to credit, possessing a CGRO significantly reduces the uptake of informal credit and appears to improve access to formal credit. With regard to land investments, our results show positive and significant effects of LTF on organic and inorganic fertilizer use as well as trees and permanent crops investments, but only for CGRO plots.

Conclusions: The study concludes that the effects of LTF differ significantly between the land tenure systems, thus, treating LTF as a dichotomy between formalized and non-formalized is an oversimplification that could potentially mislead policy decisions. Therefore, the study recommends that the design, implementation and evaluation of LTF

*Correspondence: Haji.Msangi@zalf.de; hmsangi@cbe.ac.tz

[1] Leibniz-Centre for Agricultural Landscape Research (ZALF), 15374 Müncheberg, Germany
Full list of author information is available at the end of the article

programs should recognize this distinction for greater clarity about LFT effects and more meaningful policy messages. The study, further, recommends strategic land policy interventions that aim to enhance land tenure security, especially in high potential areas for more socio-economically optimal outcomes of the interventions.

Keywords: Land tenure formalization, Land tenure policies, Land tenure systems , Multinomial endogenous switching regression, Tanzania

Introduction

Property rights to land, as a key productive resource, are long advocated as an important policy measure to foster growth and reduce poverty in developing countries. Proponents of property rights argue that the absence of well-developed property right system is often an impediment for agricultural productivity and general prosperity in most developing regions [3, 8, 25, 35]. These arguments are based on the assumptions that well-defined and protected property rights to land can increase tenure security over the land, thus acting as an incentive for land owners to pursue medium-to-long-term land investments, including irrigation schemes, tree planting, terracing, and other soil conservation activities [3]. Unlike informal land rights, formal and well-documented property rights allow for collateralization of land, thus facilitating access to credit and improvement of agricultural productivity [3, 17, 20]. Clearly defined and effectively protected land rights simplify land exchanges and lower land transaction costs, thus promoting land market development [3, 34, 39]. According to Besley [3] and De Soto [8], well-functioning land markets facilitate land transfers from less productive to more productive land users thereby increasing the allocative efficiency of scarce agricultural resources.

The role of property rights is especially critical in the African contexts, where problems of localized land scarcities are rapidly increasing, while large chunks of land are still held under informal tenure [3, 37, 39]. Notable factors, like rapid population growth, recent global food and energy crises, climate change, and unsustainable utilization of natural resource are intensifying pressures and creating more land scarcity [2, 25]. The expanding land pressures increase competition for land between multiple users, ranging from large scale domestic and international investors to smallholder farmers and herders [6, 25]. In many parts of Africa, increasing land pressures have triggered tenure insecurity and land conflicts, ultimately constraining the productive potential of agricultural land and economic growth [25]. However, it is widely accepted that Land Tenure Formalization (LTF) programs could strengthen land rights and address tenure insecurity by conferring full legal recognition of customary land rights and converting informal land tenure into more standardized formal systems of tenure [3, 11]. For that reason, LTF programs in Africa have become a popular policy measure to foster agricultural productivity and overall economic growth in a more socially optimal manner.

In the 1990s, like other Sub-Saharan Africa (SSA) countries, Tanzania implemented comprehensive reforms of land laws and policies to transform the dominating customary system of land tenure into more formal systems of tenure designed to enhance effective management and allocation of rural and urban lands for inclusive socio-economic development [2, 36, 44]. These include establishment of the National Land Policy of 1995 [43], from which two major land Acts were derived, the Land Act No.4 (1999) and the Village Land Act No.5 (1999) [44]. The Land Act No.4 (1999) provides for the administration of land and formalization of land tenure under general land by offering the Granted Rights of Occupancy (GRO), where land owners under general land can apply for certificate of Granted Right of Occupancy (CGRO) for their plots. One the other hand, the Village Land Act, No. 5 (1999) provides for a customary right of occupancy over rural land, where land owners under customary systems are able to formalize their land tenure by applying for a Certificate of Customary Right of Occupancy (CCRO) [44]. As an attempt to strengthen the customary land tenure rights, the CCRO is accorded as equal legal status as CGRO [44]. Several other LTF interventions, including the Mkurabita program in 2004, Oxfam's land titling initiative in 2008, and a number of World Bank's land titling programs were implemented in Tanzania [23, 32, 38].

While governments and the donor community implemented a number of LTF programs starting in the late 1990s, rigorous empirical evidence on the impacts of such interventions is scarce. Furthermore, existing empirical evidence is mixed and inconclusive. For example, a plethora of empirical studies on LTF impacts in Africa [1, 3, 7, 9, 10, 15, 27] find very weak or no significant impact of LTF on key agricultural development outcomes, such as credit access, investment, and productivity. Empirical studies in Tanzania by [1, 2, 9, 27, 28] find mixed and inconclusive evidence, thus failing to establish consensus on the hypothesized effect of LTF

on various development outcomes. Amidst these mixed findings, the empirical question on whether, how, and to what extent LTF interventions contribute to the expected development outcomes remains inconclusive and a subject for further investigation.

Although it is not uncommon for empirical evidence to contradict theoretical assertions, the prevalent conflicting findings of the impacts of LTF in Tanzania and other African countries raise concerns regarding the analytical approaches in LTF impact evaluations [2, 19]. One of the main concerns stems from potential heterogeneity biases in LTF interventions that is often overlooked in the empirical literature resulting in potentially biased empirical findings of the LTF impact assessments [19, 30]. We argue that LTF interventions may vary significantly, especially after carefully distinguishing on how property rights are defined and affected by the interventions in question [14, 45]. The current paper seeks address this concern. In Tanzania, for example, Land Act No. 4 of 1999 and the Village Land Act No. 5 of 1999 provide for two systems of land tenure, Granted Right of Occupancy (GRO) and Customary Right of Occupancy (CRO). In that respect, LTF existing under these two main tenure systems, has two major types of tenure certificates, namely, CCROs and CGROs. Although the CCROs is accorded equal legal status as CGROs, the customary legal power of the local authorities is either non-existent or being constantly weakened and distorted as a result of growing competition over land resources [41]. Vulnerabilities to conflicts and dispossessions are, therefore, predominant under this form of land tenure. Furthermore, ownership transfer procedures are not as straightforward as it is for land owned through the GRO [40]. Consequently, lending institutions are increasingly reluctant to accept CCROs as loan collateral as they are overly worried about the legal complications associated with appropriation of the land owned under CRO in case of non-payment [2, 36]. As a result, most land owners under CRO systems are unable to use their land certificates as collateral to access credit from financial institutions (FIs). For example, Grebmer et al. [21] indicate that out of approximately 8000 CCRO holders in Iringa region, Tanzania, only 21 have used their CCROs as collateral to secure credit from FIs, while majority of the CCRO holders are unable to use their CCROs as collateral [21]. In this regard, it is plausible to assume that LTF under the two land tenure systems may likely yield different magnitudes of outcomes. Nonetheless, most LTF impact assessment studies in SSA tend to treat LTF as a dichotomy of formalized or non-formalized assuming homogeneity of the interventions and, hence, the outcomes.

Against this backdrop, we argue in this study that the assumption that LTF under customary and statutory tenure systems can deliver homogenous outcomes is a sweeping generalization that could explain inconsistent results regarding the impact of LTF using the same data sets by Kassa [28] and Hombrados et al. [27]. The mixed and inconsistent results may potentially mislead policy decisions leading to sub-optimal policy outcomes. This suggests the need for more rigorous empirical studies with innovative approaches to examine the differential outcomes of LTF under customary and statutory land tenure systems in Tanzania. This study hypothesizes that the two different types of LTF deliver different magnitudes of outcomes. Therefore, the study examines the development outcomes of LTF with respect to perceived land tenure security, credit access, and land-based investment with clear distinction of the outcomes between customary and statutory tenure systems. This study limits its scope to intermediate outcomes (perceived land tenure security, credit access, and land-based investment) as the LTF interventions are mainly motivated by a set of theoretical assumptions regarding how changes in land rights impact the outcomes to the land owners and the community in which they live. Nevertheless, the empirical literature typically focuses on the impacts of intermediate outcomes [18, 19].

The rest of this paper is structured as follows: "Methodology" section describes the study methodology including the theoretical, conceptual, and analytical frameworks, as well as the data source and analysis. "Results and discussion" section presents the results and discussion. A brief note on study limitations is presented in "Study limitations" section, while "Conclusion and recommendations" section concludes, providing policy recommendations and suggestions for further studies.

Methodology

Theoretical framework

This study is underpinned by the Random Utility Theory (RUT) and the Evolutionary Theory of Land Rights (ELTR). The RUT establishes that economic agents are rational beings who tend to pursue the options that maximize their utility [33]. Hence, the utility (U) derivable from the choice alternative can be viewed as consisting of a deterministic component, V, and stochastic component, ε, that follows a pre-determined distribution [33]. This can be illustrated as follows:

$$U_{ij} = V_{ij} + \varepsilon_{ij} \tag{1}$$

That is to say the ith individual will choose jth alternative from a set of choice alternatives (J) given that the choice maximizes his utility.

The probability (P) of the ith individual choosing jth alternative can be given as follows:

$$P_{ij} = Pr(U_{ij} > U_{iJ}) \forall_J \neq j \quad (2)$$

On the other hand, ETLR contends that, due to the joint forces of population growth and market integration, land rights evolve toward more individualized tenure, where land owners start pressing for a more duly formalized tenure. The ETLR establishes that land, like any other property, is considered more secure and, perhaps, productive when it is held under private ownership [39]. Therefore, according to this theory, the core role of property rights in any economy is to ensure tenure security, thus providing incentives for economic agents to efficiently allocate their scarce resources in a manner that is sustainable and maximizes their returns [12, 24].

Conceptual framework

Conceptually this study is based on the idea that, in countries such as Tanzania where the problems of rapidly growing pressure on agricultural land persist, markets are fast evolving, while land tenure systems are mainly customary with inefficient land administration systems, greatly hampering household land access and tenure security [1, 8, 20]. According to Holden, Otsuka and Deininger [26] there are two major sources of tenure insecurity: the state and private individuals. The state may trigger insecurity by limiting land rights by converting it from private or group land to public land for such purposes as construction of public infrastructure, natural resource reserves, or reallocation to other households [26]. State-induced tenure insecurity can also stem from overlapping laws, poor law enforcements, and corruption by government officials [11]. Private sources of tenure insecurity include land disputes, where there are unclear boundaries as well as encroachment from powerful individuals, including urban and/or political elites [26].

According to Plateau [39], as joint forces of rapid population growth and market integration expand, the insecurity of tenure further increases. Consequently, land rights gradually evolve toward more individualized tenure, where land owners start advocating for duly formalized private ownership. This is a need for which the state will have some incentives to respond, since it has a role in ensuring tenure security and making the information available to the public [26]. LTF is amongst the major types of land tenure reforms that the state undertakes with expectation that it will improve the perceived tenure security of the right holders, thus improving both supply and demand of land markets, which increases investment incentives [16, 20]. The main assumption here is that, with duly formalized land rights, land owners are able to exercise their user rights through land investments. Furthermore, LTF enables land owners exercise their mortgaging rights, thus making it possible to use land as collateral when accessing credit, which can be used to finance the land-based investments and other agricultural productivity enhancing investments [3], thus

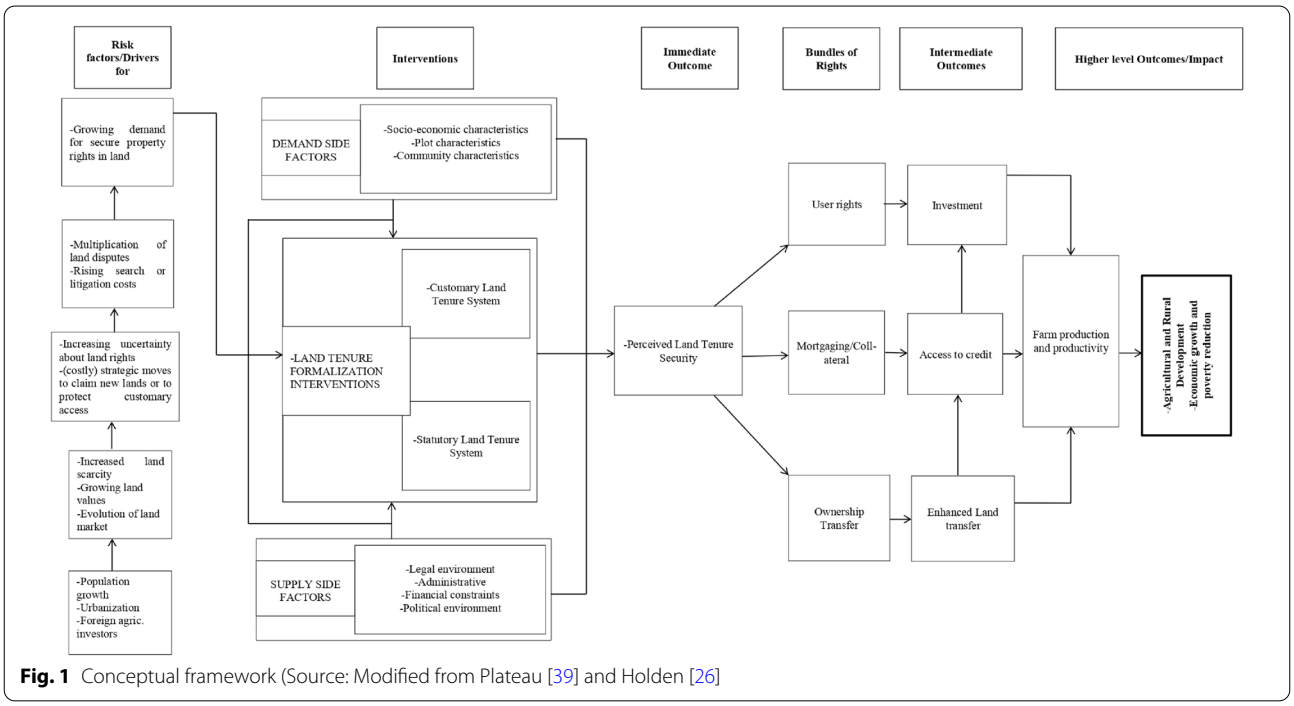

Fig. 1 Conceptual framework (Source: Modified from Plateau [39] and Holden [26]

promoting economic growth and prosperity [15, 17], see Fig. 1 for illustration.

Analytical framework

Given the sporadic nature of land tenure formalization in Tanzania, the identification of LTF effects is a complex task as it is prone to endogeneity due to potential selectivity bias arising from land owners self-selecting themselves into LTF given their distinctive characteristics. To that effect, plot owners with certain types of formal land certificate are, in essence, not a random sample of the entire population in Tanzania. To address the potential selection bias, this study employs the selectivity-corrected Multinomial Endogenous Switching Regression (MESR) approach proposed by Bourguignon et al. [4] to model the development outcomes of LTF under customary and statutory tenure systems. The estimation under this method is completed in two stages. The first stage involves the estimation of the selection equation by Multinomial Logit Model (described in "Multinomial logit selection model" section). In the second step (described in "Multinomial endogenous switching regression model" section), the endogenous switching regressions are estimated with the use of selection correction terms (inverse Mills ratio) obtained from step 1.

Multinomial logit selection model

This is the first stage of MESR, which involves estimation of selection equation to obtain the selection correction terms that will be used in the second stage. Consider a land plot owner i facing three mutually exclusive choices whether to formalize the plot with CCROs or CGROs, or not to formalize. This leads into three sub-samples from the main sample: (i) plots without any land ownership certificate, $T=0$; (ii) plots with Certificate of Granted Right of Occupancy (CGROs), say $T=1$; (iii) plots with CCROs, $T=2$. According to random utility theory, a rational farm household will opt for one of the above choices that will give the highest maximum benefits. The plot owner's choice of LTF options ($\boldsymbol{T_i}$=0, 1, or 2) depends on the perceived benefits that can be derived from the choice option. These benefits are denoted by a latent variable (T^*) that is, itself, a function of observed set of characteristics (Z_i), unobserved factors ($\overline{\mathbf{Z}}_{ij}$) captured by mean of household, plot and individual characteristics; and disturbance term (ν_i), as indicated in Eq. 3:

$$\boldsymbol{T_i} = \begin{Bmatrix} 0 \; if \; \boldsymbol{T^*_{i0}} > {}_{T\neq 0}{}^{\boldsymbol{Max}}\left(\boldsymbol{T^*_{i(j\neq 0)}}\right) \boldsymbol{or} {}_{T\neq 0}{}^{\boldsymbol{Max}}\left(\boldsymbol{T^*_{i(T\neq 0)}} - \boldsymbol{T^*_{i0}}\right) < 0 \\ \cdot \\ \cdot \\ 2 \; if \; \boldsymbol{T^*_{i2}} > {}_{T\neq 2}{}^{\boldsymbol{Max}}\left(\boldsymbol{T^*_{i(j\neq 2)}}\right) \boldsymbol{or} {}_{T\neq 2}{}^{\boldsymbol{Max}}\left(\boldsymbol{T^*_{i(T\neq 2)}} - \boldsymbol{T^*_{i2}}\right) < 0 \end{Bmatrix} \tag{3}$$

with

$$\boldsymbol{T^*_i} = \boldsymbol{\gamma Z_i} + \overline{\mathbf{Z}}_{\boldsymbol{ij}} + \boldsymbol{\nu_i} \tag{4}$$

where ν is assumed to be independent and identically Gumbel distributed with zero conditional mean, under the Independent Irrelevant Alternatives (IIA) hypothesis. The determinants of the existence of different types of land tenure certificates can be modelled by a Multinomial Logit Model (MNL) drawing from McFadden [33], where the probability that ith land owner has a land certificate (T), $\boldsymbol{p_{iT}}$, in the MNL framework, is expressed as follows:

$$\boldsymbol{p_{iT}} = \boldsymbol{p}(\boldsymbol{\nu_{iT}}|\mathbf{Z}_{iT}) = \frac{\boldsymbol{exp}(\boldsymbol{\beta}_T \mathbf{Z}_{ij})}{\sum_{T\neq 0}^{J} \boldsymbol{exp}(\boldsymbol{\beta}_T \mathbf{Z}_{iT})} \frac{\boldsymbol{exp}(\boldsymbol{\beta}_T \mathbf{Z}_{ij} + \overline{\mathbf{Z}}_{ij})}{\sum_{T\neq 0}^{J} \boldsymbol{exp}(\boldsymbol{\beta}_T \mathbf{Z}_{iT} \overline{\mathbf{Z}}_{iT})} \tag{5}$$

The above MNL model can be estimated using the standard maximum likelihood methods [5, 42].

Multinomial endogenous switching regression model

The second stage involves the implementation of the endogenous switching regression model suggested by Dubin and McFadden [13] and Bourguignon et al. [4] to estimate the effect of different land certificates on land tenure security, credit access, land value, and long-term land investments as follows:

$$y_{iT}^{*}Y_{iT}^{*} = x_i bX_i\beta + \tau T_i + \mu_i \tag{6}$$

with

$$Y_{ij} = \left\{ \begin{array}{l} 1 \ if y_i^{*} > {}_{T\neq 0}{}^{Max}\left(Y_{i(T\neq 0)}^{*}\right) \\ 0 \ Otherwise \end{array} \right\} for\ T = j \tag{7a}$$

where Y_{ij} represents the *j*th regime's binary outcome variables as defined in Table 7 and Y_i^{*} is a latent variable, β is a vector of coefficients to be estimated, τ is the coefficient of the endogenous treatment dummy, and μ_i is a disturbance term. The binary outcome equations, for each outcome variable, conditional on three mutually exclusive LTF options (no land certificate, CCROs only, and CGROs only) are specified as an endogenous switching regime models as indicated in Eqs. (8a–9):

Regime 0:

$$\begin{aligned} Y_{i0} =& X_{i0}\beta_{0k} + \overline{X}_{i0}\vartheta_{0k} + \widehat{\lambda}_{i0}\psi_{0k} \\ &+ \mu_{i0} \text{if} Y_{i0} = f\left(Y_{i0}^{*} > {}_{T\neq 0}{}^{Max}\left(Y_{i(T\neq 0)}^{*}\right)\right) \end{aligned} \tag{8a}$$

Regime 2:

$$\begin{aligned} Y_{iJ} =& X_{iJ}\beta_{Jk} + \overline{X}_{iJ}\vartheta_{Jk} + \widehat{\lambda}_{iJ}\psi_{Jk} \\ &+ \mu_{iJ} \text{if} Y_{iJ} = f\left(Y_{iJ}^{*} > {}_{T\neq J}{}^{Max}\left(Y_{i(T\neq J)}^{*}\right)\right) \end{aligned} \tag{8b}$$

$$y_i = \left\{ \begin{array}{l} y_{i0} \ if\ T = 0 \\ \quad . \\ \quad . \\ y_{i2} \ if\ T = 2 \end{array} \right\} \quad Y^{*} = \left\{ \begin{array}{l} Y_{i0} \ if\ T = 0 \\ \quad . \\ \quad . \\ Y_{iJ} \ if\ T = J \end{array} \right\} \tag{9}$$

where Y_i is an observed outcome that describes a dichotomous realization of the latent outcome variable as defined in Eq. (9); Y^{*} is the latent variable that describe the observed binary outcomes Y for households with no land certificate, for those with CCROs only, CGROs only, and those with both CCROs and CGROs, respectively. X is a vector of weakly exogenous characteristics, while $\overline{X}$ is Mundlak's regime specific vector of mean values of plot-varying characteristics such as average farm size, average plot-market distance and average plot-dwelling distance which are used to capture the unobserved heterogeneity that determine the switch between three regimes [29]. Variable λ is the inverse Mills ratio predicted from the estimated selection equation in (5) as $\widehat{\lambda}_{iJ} = \sum_{j\neq J}^{J}\rho_J\left[\frac{jln\left(\overline{Pr}_j\right)}{1-\overline{Pr}_j} + ln\left(\overline{Pr}_J\right)\right]$ with ρ being correlation coefficient of disturbance terms; β, ϑ and ψ are vectors of coefficients to be estimated in each regime; and $\mu's$ are vectors of disturbance terms of the outcome equations in each regime. The parameters of interest are estimated by a full information maximum likelihood (FIML) technique, as in Lokshin and Sajaia [31] and Bourguignon et al. [4].

Exclusion restriction As pointed out in Bourguignon et al. [4], the estimation of MESR requires the use of a valid selection instrument (exclusion restriction) in the first stage. Although, in principle, the maximum likelihood parameter estimates could be identified using non-linearities generated by the model, for a more robust identification, we employ an exclusion restriction/instrumentation strategy by carefully selecting an instrument for tenure formalization that is both exogenous and relevant.

Based on the nature of the outcome variables, two different instruments are employed. First, we employ the travel cost from dwelling to district administrative offices as an instrument for perceived tenure security and land investment (only for investment in soil erosion control, trees, and permanent crops). The identifying assumption is that the travel cost to district offices is external to the plot owner's perceived land tenure security, investment in soil erosion control, trees, and permanent crops but very likely to affect the probability of seeking a formal land tenure certificate, because most land administration offices are located at the district administrative office. Second, we use a variable for land disputes (measured as to whether the plot holder has ever litigated about his/her rights to the plot) as an instrument for credit access and the use of organic or inorganic fertilizer. Our premise is that whether the plot holder has ever litigated may not directly predict the plot holder's current status with respect to credit access except through its effect on the probability of seeking for formal land tenure certificate.

For the purpose of comparison with previous studies, we adopted the empirical strategy of Besley [3] and employ the mode of plot acquisition as another instrument for LTF, where a dummy variable of whether the plot was acquired through inheritance is adopted in this case. The underlying assumption is that the way in which a land plot was acquired is unlikely to affect the perceived tenure security, credit access, and land investment (except through LTF) but likely impact the likelihood of seeking for a formal land certificate.

To establish the admissibility of the instruments, falsification tests [22] were done by running a simple regression of LTF status and the outcome variables indicate strong association between the instruments and LTF with no significant effect on the outcome variables thus satisfying the relevance assumption.

Expected actual and counterfactual outcomes (conditional expectations) Based on Carter and Milon (2005), Di Falco and Veronesi (2011), Eqs. (8a and 8b) are used to compute the expected actual and counterfactual outcomes for farmers who participated in LTF and those who did not. The actual expected outcomes are computed as follows:

LTF adopters who adopted (actual):

$$\boldsymbol{E}\left(\boldsymbol{Y_{ij}}|\boldsymbol{T}=\boldsymbol{j},\boldsymbol{X_{iJ}},\overline{\boldsymbol{X}}_{\boldsymbol{iJ}},\widehat{\boldsymbol{\lambda}}_{\boldsymbol{iJ}}\right)=\boldsymbol{X_{iJ}}\boldsymbol{\beta_{Jk}}+\overline{\boldsymbol{X}}_{\boldsymbol{iJ}}\boldsymbol{\vartheta_{Jk}}+\widehat{\boldsymbol{\lambda}}_{\boldsymbol{iJ}}\boldsymbol{\psi_{Jk}} \tag{10}$$

Non-LTF adopters who did not adopt (actual):

$$\boldsymbol{E}\left(\boldsymbol{Y}_{i0}|\boldsymbol{T}=0,\boldsymbol{X}_{i0},\overline{\boldsymbol{X}}_{i0},\widehat{\boldsymbol{\lambda}}_{i0}\right)=\boldsymbol{X}_{i0}\boldsymbol{\beta}_{J0}+\overline{\boldsymbol{X}}_{i0}\boldsymbol{\vartheta}_{0k}+\widehat{\boldsymbol{\lambda}}_{i0}\boldsymbol{\psi}_{0k} \tag{11}$$

LTF adopters had they chosen not to adopt (counterfactual):

$$\boldsymbol{E}\left(\boldsymbol{Y}_{i0}|\boldsymbol{T}=\boldsymbol{j},\boldsymbol{X}_{iJ},\overline{\boldsymbol{X}}_{iJ},\widehat{\boldsymbol{\lambda}}_{iJ}\right)=\boldsymbol{X}_{iJ}\boldsymbol{\beta}_{0k}+\overline{\boldsymbol{X}}_{iJ}\boldsymbol{\vartheta}_{0k}+\widehat{\boldsymbol{\lambda}}_{iJ}\boldsymbol{\psi}_{0k} \tag{12}$$

Non-LTF adopters had they chosen to adopt (counterfactual):

$$\boldsymbol{E}\left(\boldsymbol{Y}_{ij}|\boldsymbol{T}=0,\boldsymbol{X}_{i0},\overline{\boldsymbol{X}}_{i0},\widehat{\boldsymbol{\lambda}}_{i0}\right)=\boldsymbol{X}_{i0}\boldsymbol{\beta}_{Jk}+\overline{\boldsymbol{X}}_{i0}\boldsymbol{\vartheta}_{Jk}+\widehat{\boldsymbol{\lambda}}_{i0}\boldsymbol{\psi}_{Jk} \tag{13}$$

The derived conditional expectations are used to calculate the Average Treatment Effect on Treated (ATT) for LTF adopters and Average Treatment on Untreated (ATU) for non-LTF adopters. ATT is given by the difference between actual expected outcomes of LTF adopters (Eq. 10) and their counterfactual expected outcomes (Eq. 12) as indicated in Eqs. 14 and 15, respectively:

$$\begin{aligned}\boldsymbol{ATT}=&\ \boldsymbol{E}\left(\boldsymbol{Y}_{ij}|\boldsymbol{T}=\boldsymbol{j},\boldsymbol{X}_{iJ},\overline{\boldsymbol{X}}_{iJ},\widehat{\boldsymbol{\lambda}}_{iJ}\right)\\&-\boldsymbol{E}\left(\boldsymbol{Y}_{i0}|\boldsymbol{T}=\boldsymbol{j},\boldsymbol{X}_{iJ},\overline{\boldsymbol{X}}_{iJ},\widehat{\boldsymbol{\lambda}}_{iJ}\right)\\=&\ \boldsymbol{X}_{iJ}\left[\boldsymbol{\beta}_{Jk}-\boldsymbol{\beta}_{0k}\right]+\overline{\boldsymbol{X}}_{iJ}\left[\boldsymbol{\vartheta}_{Jk}-\boldsymbol{\vartheta}_{0k}\right]\\&+\overline{\boldsymbol{\lambda}}_{iJ}\left[\boldsymbol{\psi}_{Jk}-\boldsymbol{\psi}_{0k}\right]\end{aligned} \tag{14}$$

$$\begin{aligned}\boldsymbol{ATU}=&\ \boldsymbol{E}\left(\boldsymbol{Y}_{ij}|\boldsymbol{T}=0,\boldsymbol{X}_{i0},\overline{\boldsymbol{X}}_{i0},\widehat{\boldsymbol{\lambda}}_{i0}\right)\\&-\boldsymbol{E}\left(\boldsymbol{Y}_{i0}|\boldsymbol{T}=0,\boldsymbol{X}_{i0},\overline{\boldsymbol{X}}_{i0},\widehat{\boldsymbol{\lambda}}_{i0}\right)\\=&\ \boldsymbol{X}_{i0}\left[\boldsymbol{\beta}_{Jk}-\boldsymbol{\beta}_{0k}\right]+\overline{\boldsymbol{X}}_{i0}\left[\boldsymbol{\vartheta}_{Jk}-\boldsymbol{\vartheta}_{0k}\right]\\&+\overline{\boldsymbol{\lambda}}_{i0}\left[\boldsymbol{\psi}_{Jk}-\boldsymbol{\psi}_{0k}\right]\end{aligned} \tag{15}$$

The first component of Eqs. 14 and 15 represent the expected change in outcome variables ($\boldsymbol{Y_{ij}}$) due to adoption of LTF option $\boldsymbol{T}=\boldsymbol{j}$ conditional on observed choices and set of characteristics. The second components correct for the effect attributable to unobserved factors.

Data source and variables

This study uses the Living Standard Measurement Study–Integrated Surveys in Agriculture (LSMS–ISA) data for the Tanzania National Panel Survey (NPS). These are nationally representative household survey data that provide various measures of poverty and agricultural production as well as several other key socio-economic development indicators from 2008/09 through 2014/15. The LSMS–ISA NPS covers a wide range of socio-economic aspects including, but not limited to, education, gender, health, income, and other household poverty monitoring indicators for developing countries. This study uses the fourth wave (2014/15) as it contains rich information on land ownership documentation, tenure systems, and tenure security that are meaningful for econometric analysis, especially with MNL, which involve the disaggregation of the main sample into subsamples. A sample size of 3352 households from 419 enumeration areas is used in this study.

As pointed out in previous sections, there are three dependent variables: perceived land tenure security, credit access, and land-based investment. Perceived tenure security is measured as a dichotomy of whether the land owner is confident leaving the plot uncultivated for several months without fear of losing it. Credit access is a binary variable that is categorized into three sub-variables: formal credit access that takes a value of 1 if a plot owner has access to credit from formal sources and is 0 otherwise; informal credit access that assumes a value of 1 if the plot owner has access to credit from informal sources and is 0 otherwise; and general credit that takes a value of 1 if the plot owner has access to credit from either formal or informal sources and is 0 otherwise. The land-based investments variable is categorized into two binary and one continuous sub-variables: the use inorganic or organic fertilizers, soil erosion control, and

number of permanent crops or trees per acre. The treatment variable is already discussed in detail in "Multinomial logit selection model" section and the description of covariates are given in Table 7.

Results and discussion

Descriptive results

This section presents descriptive statistics of the covariate variables for plots and households with different types of land tenure certificates and without land tenure certificates. The results indicate that only 8.5% of the surveyed plots have formal tenure certificates, with 4.7% having CCROs and 3.8% having CGROs. About 91.5% of the surveyed plots are not formalized.

The results in Table 7 show that households with formal land certificates and without formal land tenure certificates are similar in terms of their average farm size, average age of the household head, percent of female household heads, household size, percentage of married plot owners, and percentage of households who have ever experienced land conflicts. Nonetheless, the results indicate significant differences between plot owners with formal land tenure certificates (either CCROs or CGROs) in some of the variables. For example, we find that, plot owners with CCROs and CGROs are, on average, relatively more educated (7.3 years and 7.5 years of schooling, respectively) than those without any land tenure certificate (6.5 years).

When looking at access to formal waged employment, the results show that although access to formal waged employment is generally very low, CGRO and CCRO holders have more access to formal waged employment than those without a formal land tenure certificate. The proportion is even higher for CGRO holders compared to CCRO holders (0.069 and 0.044, respectively). The difference in access to formal employment is even bigger for employment in the public sector, where 3.3% of CGRO holders and 2.9% of CCRO holders are government employees; only 0.06% of those without land tenure certificate work for the government (Table 7). The superiority of CGRO and CCRO holders in terms of access to formal waged employment implies that access to formal employment may facilitate LTF as the plot owners might have reliable income to finance the process of LTF. The results further show a relatively higher proportion of CGRO and CCRO holders (0.812 and 0.729, respectively) with other land tenure documents, such as utility bills, other bills, a letter of allocation from village government, and an inheritance letter, compared to those without formal land certificate. Possession of other land documents might increase the likelihood of having formal land tenure due to previous experience with acquiring the land document that might decrease the relative costs for acquiring formal land tenure certificate.

Furthermore, we find a significantly higher proportion (0.306) of CGRO holders with Savings and Credit Cooperative Society (SACCOS) membership than CCRO holders and those with no formal land certificates, at 0.153 and 0.160, respectively. These results imply that individuals with SACCOS membership may likely have some social connection advantages that could help the land owners navigate the systems issuing formal land tenure certificates. We also find that plots with CGRO have twice as high average self-reported land values than plots with CCRO; about TZS 11,900,000 versus TZS 4,112,655 per acre, respectively. Plots with no land tenure certificates are valued at TZS 4,139,976 per acre (Table 7). The high value of plots with CGRO is attributable to location. The majority of CGRO plots are located in relatively high potential areas, such as near main roads, urban areas, and peri-urban areas, where land is relatively scarce.

Econometric results

Results from the multinomial selection equation

Table 7 in the Appendix presents the results of the multinomial selection equation. The results show a likelihood ratio (LR) test statistic of 2537.09, which is highly statistically significant suggesting that our full model predicts significantly better than the null model. This is further supported by the McFadden's pseudo-R-Squared of 0.481, which shows a better fit. The value of Wald Chi-Squared statistics for combining alternatives are 124.98 for CGRO versus CCRO, 164.05 for CGRO versus non-certificate, and 150.21 for CCRO versus non-certificate (Appendix Table 7). Since all the Wald Chi-Squared values are statistically significant, it makes sense to distinguish LTFs under different land tenure systems from non-formalization rather than simply treating it as dichotomy of formalized and non-formalized as is the case with most existing empirical studies.

We employ a number of covariates, including age, sex, education level of the household head, an individual's possession of other land tenure documents, access to formal employment, distance from dwelling to market, distance from dwelling to the road, and group membership dummies, to account for both observed and unobserved geographical characteristics.

Results in Appendix Table 8 confirm that the household head's socio-economic characteristics and plot characteristics are the key determinants for owning different types of land tenure certificates. For example, the household head's education level is significant and positively related to the likelihood of having CGROs relative to either CCROs or non-formalization. This implies that

individuals with higher education are more likely to possess the necessary skills, social connections, and income necessary to navigate the systems of LTF. The household's possession of dwelling certificate is another important determinant of LTF under different tenure systems, whereby having a dwelling certificate increases the likelihood of owning CGROs relative to non-formalization option (Appendix Table 8). This suggests that the process of acquiring a dwelling certificate might expose the plot owners to processes of acquiring a formal land certificate, thus reducing the transaction cost of acquiring the land tenure certificate. We also find a significant effect of the location dummies on the probability of owning CCROs or CGROs as indicated in Appendix Table 8. This supports the findings of Ali et al. [1] that LTF interventions are not homogeneously implemented across the country. Stated differently, there are many intra-Tanzanian variations in LTF programs in terms of the timing and demand for interventions as well as the nature and effectiveness of other land protection mechanisms.

The results further indicate that the plot owners from migrant headed household (migrated from other regions) are, on average, 5.2% more likely to formalize their land by CGRO than the non-formalization option. The likely reason for this is that in many African countries, migrants tend to have limited understanding of the local context as well as poor social connections to protect their land rights [1, 20]. This makes them among the most vulnerable groups to land tenure insecurity, thus, more likely to seek a formal land tenure certificate as a way to protect their land rights.

Multinomial endogenous switching regression results

Results from multinomial endogenous switching regression show that there are differences in parameter estimates of the outcome equations across LTF types (Tables 10, 11 and 12). This demonstrates the presence of heterogeneity in the samples with respect to our outcome variables of interest. We show that the coefficient estimates for Mundlak's mean of plot-varying characteristics is statistically significant in most of our regressions, suggesting that unobserved heterogeneity is captured by this variable. It is also important to note that most of the selection correction terms (inverse Mills ratio coefficients) are statistically significant, implying that LTF under customary or statutory land tenure systems will not have the same effects on those without formal land tenure certificate as it would on CCRO or CGRO holders. Furthermore, the Wald test shows that our selection instruments (Travel cost to district office and land dispute plots) is statistically significant in the multinomial logit selection model, but it does not affect the outcome variables for which they are instrumented, thus indicating the validity of our instruments and the robustness of our model.

Effect of land tenure formalization on perceived land tenure security Before analyzing the relationship between LTF and perceived land tenure security, we estimate the plot owners' land tenure security and disaggregate it by their LTF status. Table 7 shows that 88.30% of surveyed plot owners are tenure secure (that is, they feel comfortable leaving the plot uncultivated for several months without being worried about losing it), while the remain-

Table 1 ATT effects of customary and statutory LTF on perceived land tenure security

Outcome	Actual			Counterfactual			ATT	
		Mean	Std.Err		Mean	Std.Err	Mean	Std.Err
Perceived LTS	CGROs remain CGROs	1.004	0.013	If CGROs become none	0.798	0.028	0.206****	0.014
	CGROs remain CGROs	1.125	0.015	If CGROs become CCROs	0.999	0.048	0.126***	0.035
	CCROs remain CCROs	0.962	0.011	If CCROs become none	0.912	0.028	0.051**	0.025

*, **, and *** represent statistical significance at 10%, 5%, and 1% levels, respectively

Table 2 ATU effects of customary and statutory LTF on perceived land tenure security

	Counterfactual			Actual			ATU	
		Mean	Std.Err		Mean	Std.Err	Mean	Std.Err
Perceived LTS	If none certificates become CGROs	0.908	0.012	None certificates remain none	0.707	0.025	0.201***	0.075
	If none certificates remain CCROs	0.889	0.013	None certificates remain none	0.791	0.043	0.098***	0.023
	If CCROs become CGROs	0.916	0.010	CCROs remain CCROs	0.866	0.025	0.051**	0.026

*, **, and *** represent statistical significance at 10%, 5%, and 1% levels, respectively

ing 11.70% fears losing their land plot if left uncultivated for several months (Table 7). When the analysis of tenure security is disaggregated by LTF status, the results indicate that 84.40% of individuals with CGROs are tenure secure compared to 82.20% and 93.70% of individuals with CCROs and without land tenure certificate, respectively. The lower percentage of perceived tenure security for CGRO and CCRO plots could be linked to the fact that most formalized plots are located in economically high potential areas, such as high fertile non-remote areas, urban areas, and peri-urban areas, where competition for land is intense [26].

The ATT results presented in Table 1 show that tenure security significantly increase by 20.6% and 5.1%, respectively, if CCRO and CGRO plots had not been formalized. Furthermore, the ATT estimates show that, on average, perceived land tenure security will significantly increase by 12.6% if plot owners with CCRO certificates would have been certified as CGROs. The observed relatively larger effect of CGROs over CCROs on perceived land tenure security is not consistent with our descriptive results, which indicate higher tenure security for CCRO versus CGRO holders. However, the explanation for this seems obvious, that is, since most of CGRO plots are located in relatively high potential areas, where tenure insecurity is relatively higher as suggested by our descriptive results, the impact of LTF in these areas might easily translate into significant improvement in perceived tenure security. This argument is supported by Deininger, Ali and Alemu [9] who find that land certification program brings about rapid and notable improvement in land tenure security in areas, where tenure insecurity was higher at the beginning of program.

The Average Treatment Effect for Untreated ATU estimates indicate that, in a hypothetical situation, where non-formalized plots were formalized with either CGROs or CCROs, the perceived tenure security would have significantly increased by 20.1% and 9.8%, respectively (Table 2). Taken together, these results suggest that although LTF under either customary or statutory tenure system significantly increases the households' perceived land tenure security, the effect of statutory LTF has relatively larger magnitude and is more significant than that of customary LTF.

With regard to the covariates, the signs and coefficients are mostly as expected. We find that the migrant status of the household head has a negative and significant effect on perceived land tenure security (Table 10). This is likely due to the fact that migrant households are likely to be less acquainted with the local community, thus having limited social connections resulting in limited protection of their land. Reinforcing these results, we find that the number of years, since the plot was first acquired is positive and significant on the perceived tenure security, implying that older land owners are more likely to feel tenure secure over their land compared to new landholders who, in any case, could be disfavored by the customary tenure system. Furthermore, the findings indicate that raising trees significantly increases the individual's likelihood of feeling tenure secure over land. There are two likely interpretations for this result: first, trees can act as fence to provide clear boundary demarcations to overcome potential future land disputes. Second, since it may constitute a significant share of household assets, tree crops can be a good proxy for a household's wealth status, whereby wealthy households are more likely to feel tenure secure. The coefficient of land value, as presented in Appendix Table 10, is significantly negative on perceived tenure security. This can be explained by the fact that most areas with high land values are subject to encroachments due to stiff competition over land; these escalate tenure insecurity among landholders.

Table 3 ATT effects of customary and statutory LTF on credit access

Outcomes	Actual			Counterfactual			ATT	
		Mean	Std.Err		Mean	Std.Err	Mean	Std.Err
General credit access	CGROs remain CGROs	0.111	0.030	If CGROs become none	0.092	0.025	0.019	0.013
	CGROs remain CGROs	0.124	0.033	If CGROs become CCROs	0.098	0.043	0.027	0.020
	CCROs remain CCROs	0.127	0.033	If CCROs become none	0.072	0.025	0.056	0.039
Informal credit access	CGROs remain CGROs	0.098	0.032	If CGROs become none	0.111	0.022	− 0.013**	0.006
	CGROs remain CGROs	0.082	0.027	If CGROs become CCROs	0.120	0.043	− 0.029*	0.017
	CCROs remain CCROs	0.110	0.036	If CCROs become none	0.088	0.025	0.012	0.008
Formal credit access	CGROs remain CGROs	0.038	0.013	If CGROs become none	0.014	0.006	0.024**	0.012
	CGROs remain CGROs	0.038	0.013	If CGROs become CCROs	0.022	0.008	0.016**	0.007
	CCROs remain CCROs	0.029	0.010	If CCROs become none	0.019	0.008	0.010	0.010

*, **, and *** represent statistical significance at 10%, 5%, and 1% levels, respectively

Table 4 ATU effects of customary and statutory LTF on credit access

Outcomes	Counterfactual			Actual			ATU	
		Mean	Std.Err		Mean	Std.Err	Mean	Std.Err
General Credit Access	If none certificates become CGROs	0.080	0.014	None certificates remain none	0.093	0.037	0.008	0.006
	If none certificates become CCROs	0.098	0.014	None certificates remain none	0.104	0.041	0.001	0.002
	If CCROs become CGROs	0.097	0.016	CCROs remain CCROs	0.104	0.025	0.021	0.019
Informal Credit Access	If none certificates become CGROs	0.076	0.022	None certificates remain none	0.088	0.022	0.021***	0.00 1
	If none certificates become CCROs	0.077	0.021	None certificates remain none	0.098	0.024	0.008**	0.004
	If CCROs become CGROs	0.081	0.011	CCROs remain CCROs	0.090	0.024	0.012*	0.007
Formal Credit Access	If none certificates become CGROs	0.035	0.007	None certificates remain none	0.018	0.002	0.018**	0.008
	If none certificates become CCROs	0.018	0.005	None certificates remain none	0.018	0.003	0.006*	0.003
	If CCROs become CGROs	0.037	0.010	CCROs remain CCROs	0.027	0.009	0.011 *	0.006

*, **, and *** represent statistical significance at 10%, 5%, and 1% levels, respectively

Reinforcing these results, the coefficient of residence status indicates that being an urban resident significantly decreases perceived tenure security. This could be due to the fact that most urban areas have vibrant economic activities with well-developed land markets that increase land value, thus intensifying competition for land and threatening land tenure security.

Effect of land tenure formalization on credit access We first present the descriptive results on formal credit access and disaggregate by LTF under different land tenure systems. The findings show that the use of credit is not widespread, whereby 13.9% of households have at least one member who has had access to credit from either formal (2.9%) or informal sources (10.9%) in the last 12 months. Interestingly, the findings in Table 7 show no significant difference in general credit access between CGRO holders, CCRO holders, and those without formal certificate. However, when considering credit access from formal sources, CGRO holders do slightly better than CCRO holders (4.1% and 2.3%, respectively) but the difference is not significant. Based on these findings, further econometric analysis estimates the effect of LTF on credit access; results are presented in "Effect of land tenure formalization on perceived land tenure security" section

The results of estimates of ATT and ATU effects of LTF on general credit access (i.e., credit access from any source) are presented in Tables 3 and 4, respectively. We find no evidence of the effect of LTF on general credit access. Nevertheless, when credit access is disaggregated into formal and informal, the results suggest otherwise. The ATT estimates show that access to informal credit significantly decreases by 1.3% for CGRO plots compared to a counterfactual scenario, where these plots were non-formalized. The explanation for negative effect of CGRO on informal credit access is that, since CGROs are relatively more trusted by formal lenders than CCROs, the possession of CGROs means farmers may be able to use their CCRO as collateral to obtain credit from formal sources, thus reducing the uptake of informal credit. An alternative, but complementary, explanation for these results is that CGRO plots are usually located in high potential areas, where land and credit markets are more vibrant and the fact that CGROs are more accepted as collateral by most formal lenders, reduces the share of informal lending, which tends to dominate, where credit markets are thin or absent. The results show no statistical evidence of the effect of possession of CCRO on informal credit access.

With regard to credit access from formal sources, the ATT estimates indicate a positive and significant, albeit smaller, effect of CGRO on formal credit access. This means credit access from formal sources will drop by 1.0% and 2.4% if CGRO and CCRO holders, respectively, would have not formalized their land tenure (Table 3). Only the ATT effect of CGROs on formal credit access is statistically significant. Further, the estimates of ATT indicate that formal credit access can significantly improve by 1.6% if CCRO plots would have been formalized with CGROs. Interestingly, the ATT estimates with respect to CCRO group indicate that the possession of CCROs has no significant effect on formal credit access. These results are in line with our descriptive results that indicate a higher proportion of CGRO holders with formal credit access relative to CCRO holders and those without formal land tenure certificate. The explanations

for these results are twofold: first, the fact that most CCRO plots are located in relatively lower potential and urban areas compared to CGRO plots means that most formal lenders may deem it unprofitable to extend credit to these areas as the credit monitoring costs might be higher. Therefore, the overall cost of formal lending in these areas may be exorbitant and, consequently, unbearable for most farmers. The second explanation is related to the fact that although CCROs are accorded an equal legal status to CGROs, the documented legal complications in ownership transfer of CCRO plots makes most formal financial institutions reluctant to accept CCROs as collateral for extending credit facilities [21]. The results of this nature are contrary to the results from most empirical studies [3, 11, 30], all of which find no noticeable effect of LTF on credit access. One reason for this important difference could be due to conceptual issues arising from these studies, in particular the common treatment of LTF as a dichotomy between treated and non-treated. This study addresses the issue by relaxing the assumption of dichotomous definition of LTF by disaggregating LTF into customary LTF and statutory LTF. To further support our argument, we run an Endogenous Switching Regression (ESR) assuming a dichotomous definition of LTF and present the ATT results in Appendix Table 7. Similar to most previous studies, our ESR results show that when dichotomously defined, LTF does not appear to have any significant effect on credit access. This suggests that although statutory LTF appear to have significant effect on credit access, while customary LTF does

Table 5 ATT effects of customary and statutory LTF on land-based investment

Outcomes	Actual			Counterfactual			ATT	
		Mean	Std.Err		Mean	Std.Err	Mean	Std.Err
Soil erosion control	CGROs remain CGROs	0.161	0.090	If CGROs become none	0.129	0.051	0.032	0.024
	CGROs remain CGROs	0.180	0.101	If CGROs become CCROs	0.160	0.070	0.020	0.018
	CCROs remain CCROs	0.152	0.074	If CCROs become none	0.145	0.068	0.016	0.013
Organic or Inorganic Fertilizer use	CGROs remain CGROs	0.128	0.036	If CGROs become none	0.079	0.023	0.046	0.031
	CGROs remain CGROs	0.107	0.030	If CGROs become CCROs	0.101	0.031	0.006	0.009
	CCROs remain CCROs	0.103	0.031	If CCROs become none	0.085	0.024	0.009	0.010
Trees or permanent crops	CGROs remain CGROs	68.196	3.751	If CGROs become none	57.114	2.950	11.029***	2.640
	CGROs remain CGROs	68.258	3.706	If CGROs become CCROs	62.162	3.003	6.046**	2.863
	CCROs remain CCROs	54.115	1.550	If CCROs become none	51.528	2.585	4.259*	2.4 56

*, **, and *** represent statistical significance at 10%, 5%, and 1% levels, respectively

Table 6 ATU effects of customary and statutory LTF on land-based investment

Outcomes	Counterfactual			Actual			ATU	
		Mean	Std.Err		Mean	Std.Err	Mean	Std.Err
Soil erosion control	If none certificates become CGROs	0.152	0.085	None certificates remain none	0.128	0.047	0.024	0.022
	If none certificates become CCROs	0.160	0.069	None certificates remain none	0.143	0.052	0.017	0.018
	If CCROs become CGROs	0.156	0.086	CCROs remain CCROs	0.144	0.056	0.012	0.012
Organic or Inorganic Fertilizer use	If none certificates become CGROs	0.124	0.036	None certificates remain none	0.000	0.000	0.123	0.100
	If none certificates become CCROs	0.089	0.030	None certificates remain none	0.083	0.019	0.020	0.017
	If CCROs become CGROs	0.115	0.046	CCROs remain CCROs	0.092	0.021	0.007	0.006
Trees or permanent crops	If none certificates become CGROs	67.461	3.873	None certificates remain none	61.890	3.023	5.570	3.613
	If none certificates become CCROs	60.407	3.656	None certificates remain none	54.505	3.116	12.135***	3.106
	If CCROs become CGROs	68.003	4.030	CCROs remain CCROs	54.565	3.120	5.109*	2.730

*, **, and *** represent statistical significance at 10%, 5%, and 1% levels, respectively

not, the dominance of customary LTF over statutory LTF in Tanzania implies that the observed effect of statutory LTF under MESR model is muted when LTF is taken as a dichotomy of formalized and non-formalized in ESR model.

In addition, categorizing credit access into groups of general, formal, and informal increases the value of this study as the results show contrasting outcomes.

Effect of LTF on land investments The average estimates of the three measures of land-based investment by LTF status are reported in Table 7. The results indicate that the proportion formal land certificate holders (CCROS or CGROs) who undertake investments in soil erosion control and fertilizer use is higher compared to those without formal land tenure certificate. On the same note, we find that investment in trees or permanent crops is significantly higher on non-formalized plots than CCRO or CGRO plots. These findings suggest that investment in trees and permanent crops could be among the alternative strategies adopted by non-formalized plot owners to protect their land ownership. Methodologically, these results imply that the analysis of the effect of LTF on investment may be subject to endogeneity problems arising from potential simultaneity bias from the trees and permanent crops investment. However, this study implements a valid exclusion restriction strategy to control for any possible endogeneity in modeling the effect of LTF on investment.

We show in Table 5 that the average number of trees and/or permanent crops would increase by 11% and 4% for CGRO plots and CCRO plots, respectively, compared to counterfactual situation, where the same would not have been formalized. However, the effect is only slightly significant for CGRO plots. The ATU estimates in Table 6 indicate that, on average, the number of trees and/or permanent crops will rise by 12% for non-formalized plots and 5% for CCRO would they been formalized with CCROs and CGROs, respectively. On the other hand, the ATT estimates show that the number of trees and/or permanent crops would increase by 6% for plots formalized with CGROs compared to a counterfactual scenario, where these plots were formalized with CCRO. These results suggest that although LTF under both tenure systems significantly increase investments in trees and/or permanent crops, the effect of statutory LTF is larger and more significant than that of customary LTF. The relatively larger effect of statutory LTF over that of customary LTF could be explained by the fact that, due to perceived low effective protection from customary tenure certificate, customary land owners tend invest in trees and/or permanent crops mostly as the alternative and/or additional land tenure protection mechanism and less often for land productivity enhancement motives. An alternative explanation is that plots formalized under statutory tenure systems are usually located in higher economically potential areas such as fertile areas nearby main roads, close proximity to urban area, and areas suitable for irrigation, where the returns on land-based investments are usually higher compared to customarily formalized plots that are typically located in low potential areas.

Similar to the MESR results, the ESR results in Appendix Table 13 also show a positive effect of LTF on tree and/or permanent crops planting, but non-significant effects on manure and/or fertilizer application or soil erosion control. Unlike MESR results, the ESR model in Table 13 results show only a slightly significant effect of LTF on investment in trees and/or permanent crops. Due to its inherent dichotomous definition of LTF, it is unclear whether the effect is the same for both CGRO and CCRO plots. Our MESR results clearly indicate that although the effect of LTF on investment in trees and permanent crops is positive as it is with ESR, it is relatively larger and highly significant for CGRO plots compared to a counterfactual scenario if CCRO plots were formalized with CGROs (Table 6).

Coefficients on control variables, presented in Appendix Table 12, indicate that the size of investment in trees and permanent crops increases with cultivated farm size while decreasing with land holding size. This might imply the presence of some positive economies of scale, especially for the initial investment cost for tree planting and related husbandry practices with larger cultivated farm sizes, while larger land holdings may imply competition between farm plots for land investments. The results further show that the coefficients for purchased plots, female household head, education of household head, and Savings and Credit Cooperative Society (SACCOS) membership are among the important determinants of land-based investments.

Study limitations

This study has its limitations. First, since the LSMS–ISA NPS data are observational data, we are compelled to employ non-experimental methods rather than purely experimental methods for LTF impact assessment. In that regard, our analyses are subject to potential endogeneity problems arising from selectivity biases that consequently deter the reliability of the study findings. Nonetheless, with the selectivity-corrected MESR approach supplemented with instrumental variable, we

managed to largely control for selectivity problem using the inverse Mills ratio, thus minimizing the endogeneity bias. Second, given that our data sets are mainly quantitative, we are unable to take advantage of qualitative information that can be used to supplement the quantitative data and enrich the discussion of the findings. Even so, we take advantage of our intensive review of literature and experience with land tenure and governance research to enrich the discussion of our findings.

Conclusion and recommendations

Conclusion

This study is motivated by the fact that, despite strong theoretical support for LTF interventions, the empirical findings are quite mixed and inconclusive, especially for Sub-Saharan Africa settings. This lack of clarity complicates policymaking with respect to the design and implementation of LTF interventions for more socially and economically optimal development outcomes. Using an innovative econometric approach, this study controls for potential selectivity biases while making a distinction between the LTF outcomes under customary and statutory LTF tenure systems. The study confirms that LTF interventions are subject to selectivity biases, suggesting that the identification challenge of the LTF outcomes of interest is attributed largely to endogeneity of the land tenure certificate. We show that the effect of LTF differs significantly between customary and statutory land tenure systems in all selected development outcomes. We also find that although formalized plots are less tenure secure than non-formalized plots, the possession of formal land tenure certificates (CCRO or CGROs) significantly improves the perceived land tenure security but the effect is even larger and more significant for plots with CGROs relative to those with CCROs. With regard to credit access, our results show variations in the effect of LTF between general, formal, and informal credit access. We find no evidence for the effect of LTF on general credit access under both land tenure systems. Nonetheless, when disaggregating credit access according to sources, the results show that possession of CGROs significantly improves the use of credit from formal sources while reducing the use of informal credit. On the same note, while possession of CCROs has no significant effect on formal credit access, the same increases uptake of credit from informal sources. Our results show a positive and significant effect of LTF on investment in permanent crops and/or tree planting for both CGRO and CCRO plots with the effect being even stronger for CCRO plots.

Recommendations

Based on this study's findings, the following recommendations are derived:

In wake of considerable proportion of land owners who are still tenure insecure, especially those from high potential areas, where land rights are becoming increasingly individualized and commoditized due to growing scarcity, the study recommends for strategic land tenure formalization programs that target, among others, high economically potential areas, where in addition to potentially higher uptake of interventions due to increasing tenure insecurity, the LTF interventions are proven to provide a significant improvement in perceived tenure security.

Although LTF shows some ability to enhance farmers' credit access, it is not a silver bullet for credit access. Efforts to formalize land tenure should be coupled with potential complementary interventions, such as credit access conditions, farm input subsidies, and social protection programs to translate into the expected improvement in credit access. However, since these complementary interventions may have substantial cost implications, future research should explore these interventions and evaluate their optimal combination for improving credit access and realization of other development outcomes.

The observed significant differences in the effect of LTF between customary and statutory land tenure systems, especially the superiority of statutory LTF over customary LTF, call for particular policy actions that seek to harmonize the customary and statutory land rights, especially enhancing the ease of transferability of ownership for plots with CCROs, thus improving the perceived value of CCROs and confidence on the demand side of the land markets (for example, lenders and land buyers). Since the study reaffirms the assertion that the effect of LTF varies by land tenure systems, it is further recommended that the future design and implementation of LTF interventions should clearly account for the existing institutional settings in land tenure and formalization processes. This would contribute to addressing the issues arising from treating LTF as a simple dichotomy between formalized and non-formalized while leaving important heterogeneities unaccounted for. This recommendation highlights the need for properly conceptualized empirical studies with innovative methodologies that recognize these distinctions for improving the clarity about the effects of LTF and more meaningful policy messages.

Appendix

See Tables 7, 8, 9, 10, 11, 12, 13.

Table 7 Descriptive statistics (mean values) of key variables

Variables		Mean Values by LTF Status			Overall Mean Values
Tenure formalization	**Description/Measure**	**No certificate**	**CCRO**	**CGRO**	
Outcome variables					
Perceived land tenure security	(1—If HH do not afraid of losing land if left uncultivated for some times, 0—Otherwise)	0.937	0.882*	0.844*	0.883
General credit access	(1—HH accessed formal or Informal credit, 0—Otherwise)	0.139	0.126	0.128	0.138
Informal credit access	(1—HH accessed Informal credit, 0—Otherwise)	0.112	0.076**	0.078**	0.109
Formal credit access	(1—HH accessed Formal credit, 0—Otherwise)	0.021	0.023	0.041***	0.029
Soil erosion control	(1—Yes, 0—Otherwise)	0.131	0.245***	0.142*	0.140
Tree or Permanent crops	(Number of trees or permanent crops per acre)	160.72	35.54***	38.61***	148.85
Fertilizer use	(1—If applied organic or inorganic fertilizer in the plot, 0—Otherwise)	0.089	0.102**	0.113***	0.111
Covariates					
HH Head Education Level	(Years of formal education)	6.508	7.315*	7.514*	6.590
HH Head Female	(1—Female, 0—Otherwise)	0.226	0.240	0.276	0.229
HH Head Age	Age of HH head in years	48.5	47.3	49.3	48.5
HH Size AE	Household size in Adult Equivalent (counts)	5.432	6.626	5.283	5.483
HH migrated from another region	(1—Yes, 0—Otherwise)	0.315	0.573	0.48	0.334
Plot Owners' Age	Age of plot owner in years	27.676	28.397	26.608	27.653
Married HH Head	(1—Yes, 0—Otherwise)	0.686	0.776	0.729	0.692
Dwelling Certificate	(1—Yes, 0—Otherwise)	0.115	0.228**	0.585***	0.138
Farm size	Farm size in Acres	5.259	4.892	2.006***	5.124
Purchased plot	((1—Yes, 0—Otherwise)	0.401	0.744***	0.738***	0.430
Inherited plot	(1—Yes, 0—Otherwise)	0.462	0.200***	0.213***	0.440
Modern roof (if the dwelling is built with modern roof)	(1—Yes, 0—Otherwise)	0.658	0.831***	0.787***	0.671
Concrete cement walls (if the dwelling is built with Concrete cement walls)	(1—Yes, 0—Otherwise)	0.342	0.524***	0.624***	0.361
Basic services (If the HH has access to all basic services)	(1—Yes, 0—Otherwise)	0.313	0.244***	0.372**	0.312
Dwelling-Plot-Distance	Km	5.221	6.964**	8.198***	5.417
Dwelling-Road-Distance	Km	2.285	1.391**	1.918	2.229
Dwelling-Market-Distance	Km	8.883	10.647***	7.035*	8.896
Distance to District Offices	Km	20.578	17.448	8.711***	20.100
Transport cost to district office	TZS	3285.72	2114.42***	1864.36***	3176.51
Other land documents	(1—Yes, 0—Otherwise)	0.156	0.729***	0.812***	0.208
Asset value	TZS	993 515	1 168 392***	1 803 892***	1 024 229
Monthly wage	TZS	51 111	109 468***	254 652***	59,463
Government employment	(1—Yes, 0—Otherwise)	0.006	0.029***	0.033***	0.008
Formal employment	(1—Yes, 0—Otherwise)	0.021	0.044***	0.069***	0.024
Land conflict experience (land dispute)	(1—Yes, 0—Otherwise)	0.006	0.009	0.003	0.007
HH own bank account	(1—Yes, 0—Otherwise)	0.113	0.209**	0.240**	0.122
HH received financial assistance	(1—Yes, 0—Otherwise)	0.312	0.271	0.373*	0.312
Land value	Self-assessed land value (TZS)	4 141 408	4 112 655	11 900 000***	4 420 764
Rented Plot	(1—Yes, 0—Otherwise)	0.009	0.002	0.008	0.008

*, **, and *** indicate a statistically significant difference at 10%, 5%, and 1%, levels, respectively using t test statistics for continuous variables and two proportion z test for binary variables. HH stands for household

Table 8 Determinants of land tenure formalization under different tenure systems: multinomial logit results

Land tenure formalization	CGRO			CCRO		
	Coef. (dy/dx)	Robust_Std.Err	P>|z|	Coef. (dy/dx)	Robust_Std.Err	P>|z|
Formal employment	0.559887	0.081817	0.000	− 0.491367	0.071783	0.000
Plot owner's age	0.000766	0.000336	0.000	− 0.000646	0.000412	0.129
Education above primary	0.124779	0.014521	0.000	0.087539	0.012188	0.000
Migrant from another region	0.062694	0.012394	0.000	− 0.034871	0.013031	0.008
Dwelling Certificate	0.061161	0.013683	0.000	− 0.018492	0.015139	0.221
Ln (Mean plot-varying factors)	0.030229	0.017357	0.091	− 0.039313	0.013678	0.004
Ln (Farm size)	0.014048	0.003215	0.000	− 0.007836	0.002553	0.002
Ln (Plot to market distance)	0.003161	0.011529	0.001	0.027121	0.011089	0.006
Female head	0.014725	0.003366	0.000	0.003780	0.002624	0.150
AE HH Size	− 0.002916	0.005095	0.567	0.021388	0.003612	0.000
Modern roof	0.054231	0.014836	0.000	− 0.022449	0.010243	0.028
Concrete cement walls	− 0.000949	0.001857	0.610	0.000840	0.001863	0.653
Basic services	0.003360	0.012593	0.793	− 0.014114	0.011089	0.204
HH own bank account	− 0.000001	0.000001	0.271	− 0.000001	0.000001	0.477
Received financial assistance	0.083895	0.013687	0.000	0.013675	0.011480	0.213
Married HH head	0.047699	0.012483	0.000	0.046862	0.009735	0.000
Inherited plot	0.066814	0.015432	0.000	− 0.014618	0.008396	0.083
Ln (Total HH expenditure)	0.459311	0.041152	0.000	− 0.120352	0.017895	0.000
Village land certificate	0.000000	0.000000	0.025	0.000000	0.000000	0.636
Agric. occupation	− 0.012844	0.012611	0.312	0.037635	0.007737	0.000
Cooperative	− 0.028570	0.012513	0.022	0.003200	0.013244	0.820
Livestock ownership TLU	− 0.022068	0.009701	0.023	0.027650	0.006539	0.000
Own registered company	− 0.003460	0.001252	0.006	0.002159	0.000800	0.007
Selection instruments						
Land dispute	0.170317	0.0125644	0.000	0.123009	0.059121	0.008
Transport cost district office	− 0.032069	0.009947	0.001	− 0.028488	0.010421	0.006
Constant	− 0.026257	0.017620	0.136	0.075840	0.010214	0.000
Number of observations	2015					
Wald chi2 (56)	2537.09					
Prob > chi2	0.000					
Pseudo R2	0.483					
Log pseudo-likelihood	− 391.104					
Base outcome (No land tenure certificate)						

Table 9 Wald tests for combining alternatives

Ho: All coefficients except intercepts associated with a given pair of alternatives are 0 (i.e., alternatives can be combined)			
Alternatives tested	**chi2**	**df**	**P > chi2**
CGRO-CCRO	123.870	28	0.000
CGRO-NO_CERTIFICATE	182.075	28	0.000
CCRO-NO_CERTIFICATE	149.204	28	0.000

Table 10 Multinomial endogenous switching regression of the effect of LTF on perceived land tenure security

Perceived land tenure security	CGRO		CCRO		No certificate	
	Coef.	Robust Std.Err.	Coef.	Robust Std.Err.	Coef.	Robust Std.Err.
Formal employment	0.113974	0.075235	0.000308	0.000111	0.001139	0.000139
Plot Owners' Age	0.000912	0.000493	0.002112	0.000102	0.009001	0.003301
Educ above primary	0.084000	0.078000	− 3.079200	0.000119	− 0.018000	0.024000
HH migrated from another region	0.078645	0.036834	1.710269	0.000072	0.018915	0.011946
Dwelling Certificate	0.296367	0.073259	− 0.592735	0.000160	− 0.194248	0.032190
Ln (Mean plot-varying factors)	− 0.082900	0.031962	0.000000	0.000025	0.014982	0.004994
Ln (Farm size)	− 0.070993	0.023998	0.000000	0.000025	− 0.003000	0.005000
Ln (distance market plot)	− 0.165165	0.068068	0.000000	0.000035	0.010010	0.007007
Female head	0.342718	0.100210	− 2.606462	0.000100	0.047099	0.020042
AE HH size	0.073234	0.019061	0.738355	0.000010	0.020064	0.002006
Modern roof	0.505605	0.220462	1.045828	0.000069	0.010021	0.013665
Concrete cement walls	− 0.082443	0.071383	− 1.888141	0.000064	− 0.001005	0.014076
Basic services	0.053762	0.044650	0.000000	0.000060	0.020047	0.011846
Transport cost to distr. office	0.010118	0.014120	0.060030	0.052109	0.0350106	0.028615
HH own bank account	0.165427	0.085740	2.840499	0.000091	0.035305	0.018157
HH received financial assistance	0.398656	0.086390	− 0.228575	0.000064	− 0.008999	0.012599
Married HH head	0.398295	0.086937	− 2.573751	0.000073	0.021229	0.016174
Inherited plot	0.038456	0.113344	− 2.596792	0.000067	− 0.042504	0.013156
Total HH expenditure	0.000570	0.000311	0.000465	0.000701	0.0003408	0.000553
Land dispute	0.003390	0.002602	0.002211	0.002107	0.001924	0.002191
Village has Village Land Certificate	− 0.497497	0.184785	− 1.553409	0.000067	0.060918	0.013199
Agric. occupation	0.058951	0.040656	0.000000	0.000077	− 0.049804	0.015246
HH cooperative member	0.000109	0.000068	0.000712	0.000450	0.000083	0.000097
Livestock ownership (TLU)	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
HH head own registered Company	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Selection correction terms						
_m0	0.125628	0.036366	− 0.955438	0.081194	0.017632	0.007714
_m1	0.171540	0.075280	0.354186	0.001027	0.003702	0.004936
_m2	0.016567	0.004418	0.162354	0.009884	0.004418	0.000521
_cons	1.635827	0.567069	0.376267	0.008311	0.720511	0.096068

Table 11 Multinomial endogenous switching regression of the effect of LTF on credit access

Regressors	General credit access						Informal credit access						Formal credit access					
	CGRO		CCRO		No certificate		CGRO		CCRO		No certificate		CGRO		CCRO		No certificate	
	Coef.	Robust Std.Err.	Coef.	Robust Std.Err.	Coef.	Robust Std.Err.	Coef.	Robust Std.Err.	Coef.	Robust Std.Err.	Coef.	Robust Std.Err.	Coef.	Robust Std.Err.	Coef.	Robust Std.Err.	Coef.	Robust Std.Err.
Formal Employment	0.036	0.002	0.023	0.009	0.034	0.014	− 0.057	0.032	− 0.149	0.110	− 0.149	0.110	0.126	0.053	0.018	0.096	0.149	0.110
Plot owner's age	0.000	0.000	0.000	0.000	− 0.001	0.000	0.003	0.002	− 0.001	0.000	− 0.001	0.000	− 0.001	0.000	0.000	0.000	− 0.001	0.000
Education above primary	0.016	0.012	1.099	0.040	− 0.004	0.002	0.186	0.235	− 0.032	0.024	− 0.032	0.024	− 0.021	0.019	− 0.012	0.017	− 0.032	0.024
Migrant from another region	0.003	0.006	0.018	0.001	0.003	0.002	0.091	0.107	0.016	0.019	0.016	0.019	0.000	0.015	0.016	0.013	0.016	0.019
Dwelling Certificate	0.010	0.009	− 0.180	0.008	− 0.010	0.003	− 0.109	0.097	− 0.001	0.029	− 0.001	0.029	− 0.035	0.017	0.036	0.024	− 0.001	0.029
Ln (Mean plot-varying factors)	0.018	0.005	− 0.007	0.001	0.005	0.001	0.002	0.045	0.009	0.005	0.009	0.005	0.014	0.005	− 0.006	0.003	0.009	0.005
Ln (Farm size)	0.004	0.003	− 0.067	0.004	− 0.007	0.001	0.006	0.034	0.010	0.006	0.010	0.006	0.015	0.005	− 0.004	0.004	0.010	0.006
Ln (Plot to market distance)	0.012	0.005	− 0.030	0.002	− 0.005	0.001	0.077	0.104	− 0.017	0.007	− 0.017	0.007	− 0.019	0.007	0.003	0.004	− 0.017	0.007
Female head	0.023	0.009	1.082	0.039	− 0.012	0.003	0.259	0.144	0.062	0.025	0.062	0.025	− 0.009	0.021	0.071	0.012	0.062	0.025
AE HH Size	− 0.006	0.002	− 0.140	0.005	0.005	0.000	− 0.087	0.032	0.001	0.003	0.001	0.003	− 0.011	0.002	0.012	0.002	0.001	0.003
Modern roof	− 0.043	0.015	− 0.089	0.006	− 0.025	0.002	− 0.276	0.407	0.014	0.015	0.014	0.015	− 0.002	0.014	0.015	0.006	0.014	0.015
Concrete cement walls	0.029	0.009	0.391	0.016	0.026	0.002	− 0.112	0.139	0.088	0.017	0.088	0.017	0.056	0.015	0.030	0.011	0.088	0.017
Basic services	− 0.029	0.008	0.012	0.001	− 0.001	0.002	− 0.060	0.106	− 0.035	0.014	− 0.035	0.014	− 0.015	0.012	− 0.020	0.008	− 0.035	0.014
Transport cost to district office	− 0.001	0.001	− 0.021	0.000	0.011	0.010	− 0.001	0.001	− 0.000	0.000	− 0.009	0.000	− 0.001	0.000	− 0.001	0.000	− 0.001	0.002
HH own bank account	0.028	0.010	− 1.019	0.037	0.008	0.002	− 0.255	0.175	− 0.129	0.024	− 0.129	0.024	0.018	0.017	− 0.146	0.018	− 0.129	0.024

Table 11 (continued)

Regressors	General credit access						Informal credit access						Formal credit access					
	CGRO		CCRO		No certificate		CGRO		CCRO		No certificate		CGRO		CCRO		No certificate	
	Coef.	Robust Std.Err.	Coef.	Robust Std.Err.	Coef.	Robust Std.Err.	Coef.	Robust Std.Err.	Coef.	Robust Std.Err.	Coef.	Robust Std.Err.	Coef.	Robust Std.Err.	Coef.	Robust Std.Err.	Coef.	Robust Std.Err.
Received financial assistance	0.010	0.012	0.004	0.006	0.003	0.002	− 0.178	0.191	0.029	0.017	0.029	0.017	0.010	0.014	0.018	0.011	0.029	0.017
Married HH head	0.034	0.011	0.635	0.028	− 0.028	0.002	− 0.162	0.199	0.036	0.020	0.036	0.020	0.016	0.018	0.020	0.007	0.036	0.020
Inherited plot	− 0.003	0.009	0.741	0.026	− 0.005	0.002	0.025	0.168	0.014	0.015	0.014	0.015	− 0.038	0.013	0.054	0.009	0.014	0.015
Ln (Total HH expenditure)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Land dispute	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Village land certificate	− 0.035	0.010	1.193	0.041	0.004	0.002	− 0.232	0.162	− 0.097	0.017	− 0.097	0.017	− 0.043	0.015	− 0.053	0.008	− 0.097	0.017
Agric. occupation	0.005	0.005	− 0.006	0.001	0.021	0.003	− 0.006	0.080	0.000	0.019	0.000	0.019	− 0.002	0.016	0.001	0.011	0.000	0.019
Cooperative	0.037	0.017	− 0.429	0.015	0.005	0.002	0.129	0.302	0.041	0.016	0.041	0.016	− 0.003	0.013	0.044	0.010	0.041	0.016
Livestock ownership TLU	0.006	0.004	0.062	0.003	0.000	0.000	0.041	0.093	− 0.005	0.002	− 0.005	0.002	− 0.001	0.002	− 0.004	0.001	− 0.005	0.002
Own registered company	− 0.018	0.016	− 0.344	0.012	0.006	0.003	− 0.264	0.188	0.009	0.032	0.009	0.032	0.043	0.028	− 0.034	0.017	0.009	0.032
Selection correction terms																		
_m0	0.028	0.028	− 0.031	0.005	0.107	0.014	− 0.033	0.410	− 0.002	0.099	− 0.002	0.099	− 0.010	0.085	0.007	0.059	− 0.002	0.099
_m1	0.192	0.091	− 2.221	0.075	0.024	0.009	0.668	1.568	0.213	0.082	0.213	0.082	− 0.016	0.066	0.229	0.054	0.213	0.082
_m2	0.030	0.022	0.319	0.014	− 0.001	0.001	0.214	0.484	− 0.027	0.009	− 0.027	0.009	− 0.005	0.008	− 0.022	0.005	− 0.027	0.009
_cons	− 0.273	0.068	0.501	0.032	− 0.055	0.009	0.895	0.674	0.115	0.083	0.115	0.083	0.018	0.071	0.095	0.047	0.115	0.083

Table 12 Multinomial endogenous switching regression of the effect of LTF on land-based investment

Regressors	Soil erosion control						Organic or inorganic fertilizer use						Trees and permanent crops					
	CGROs		CCROs		No certificate		CGROs		CCROs		No certificate		CGROs		CCROs		No certificate	
	Coef.	Robust Std.Err.	Coef.	Robust Std.Err.	Coef	Robust Std.Err.	Coef.	Robust Std.Err.	Coef.	Robust Std.Err.	Coef.	Robust Std.Err.	Coef.	Robust Std.Err.	Coef.	Robust Std.Err.	Coef.	Robust Std. Err.
Formal Employment	− 0.014	0.097	− 0.071	0.088	− 0.027	0.106	− 0.386	0.135	0.000	–	0.182	0.142	− 31.89	26.53	− 1731.79	1458.65	− 2370.87	1839.32
Plot owner's age	0.000	–	0.002	0.002	− 0.071	0.067	0.000	–	− 1.168	0.110	0.093	0.107	0.000	–	1600.25	1689.21	1859.98	2025.78
Education above primary	0.002	0.001	0.817	1.555	0.001	0.000	0.004	0.002	0.002	0.002	0.000	0.001	0.086	0.152	2.132	2.754	2.811	2.983
Migrant from another region	0.308	0.138	− 0.104	0.089	− 0.022	0.029	− 0.218	0.166	− 3.558	2.111	0.062	0.035	− 979.32	187.71	83.58	206.49	217.64	304.90
Dwelling certificate	− 0.088	0.052	− 1.338	0.192	0.059	0.021	− 0.051	0.072	− 0.060	0.080	− 0.075	0.025	− 4.53	9.43	− 221.47	74.60	− 259.40	85.88
Ln (Mean plot-varying factors)	− 0.072	0.083	0.334	0.484	− 0.051	0.028	− 0.538	0.114	− 0.619	0.270	0.104	0.037	436.95	77.14	1293.44	452.42	1577.67	543.74
Ln (Farm size)	− 0.257	0.186	0.043	–	0.049	0.027	0.135	0.210	0.451	0.502	− 0.079	0.038	952.51	287.48	− 1167.57	355.58	− 1309.02	407.06
Ln (Plot to market distance)	0.042	0.025	0.093	0.161	0.012	0.004	0.086	0.047	0.024	0.038	0.038	0.007	139.93	29.97	15.55	29.49	25.95	30.04
Female head	− 0.046	0.019	0.158	0.104	0.008	0.006	0.015	0.025	0.126	0.178	− 0.003	0.008	50.18	15.03	− 55.15	21.09	− 53.20	24.03
AE HH size	− 0.094	0.049	1.929	1.822	0.035	0.006	− 0.043	0.096	0.104	0.108	− 0.002	0.009	− 61.47	33.69	− 81.85	37.36	− 94.16	43.18
Modern roof	0.290	0.059	− 0.296	0.268	− 0.103	0.025	0.330	0.104	− 3.822	2.053	0.040	0.031	− 380.14	93.50	− 155.24	89.89	− 72.04	96.74
Concrete cement walls	0.000	0.029	−1.719	0.464	0.003	0.003	− 0.169	0.034	0.579	0.302	− 0.002	0.004	250.77	58.60	− 57.37	26.28	− 69.53	31.34
Basic services	0.323	0.202	1.389	0.842	0.065	0.015	0.265	0.300	− 0.704	0.433	− 0.005	0.021	− 1116.67	287.41	419.05	113.07	356.98	91.78
Transport cost to district office	− 0.178	0.101	0.001	0.045	− 0.006	0.017	− 0.516	0.101	− 1.216	1.042	0.142	0.023	486.89	93.53	− 536.96	161.71	− 628.47	181.79

Table 12 (continued)

Regressors	Soil erosion control						Organic or inorganic fertilizer use						Trees and permanent crops					
	CGROs		CCROs		No certificate		CGROs		CCROs		No certificate		CGROs		CCROs		No certificate	
	Coef.	Robust Std.Err.	Coef.	Robust Std.Err.	Coef	Robust Std.Err.	Coef.	Robust Std.Err.	Coef.	Robust Std.Err.	Coef.	Robust Std.Err.	Coef.	Robust Std.Err.	Coef.	Robust Std.Err.	Coef.	Robust Std. Err.
HH own bank account	0.082	0.058	0.000	0.000	0.014	0.015	0.016	0.075	− 0.013	0.043	− 0.029	0.019	− 22.76	25.57	39.05	102.72	80.96	112.82
Received financial assistance	0.000	0.000	− 0.554	1.481	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	− 21.01	19.02	− 40.013	29.25	− 30.16	21.09
Married HH head	0.187	0.082	− 0.351	0.284	− 0.029	0.021	0.394	0.170	3.240	1.699	− 0.172	0.029	1045.48	255.47	− 34.67	135.43	21.58	171.27
Inherited plot	0.178	0.100	0.377	1.246	0.041	0.016	− 0.009	0.125	0.498	0.289	− 0.031	0.022	− 481.54	101.83	79.13	89.47	27.17	100.28
Ln (Total HH expenditure)	0.411	0.112	0.328	1.317	− 0.040	0.023	0.125	0.167	− 3.342	1.566	0.043	0.026	− 424.97	121.32	212.75	87.25	289.11	106.79
Land dispute	− 0.028	0.091	0.000	0.000	− 0.051	0.015	− 0.011	0.184	− 2.418	1.485	− 0.054	0.020	1328.35	357.68	22.97	96.61	9.93	104.68
Village land certificate	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	28.88	12.02
Agric. occupation	0.000	0.001	1.279	1.690	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.001	243.01	211.01	87.01	80.61	101.00	70.17
Cooperative	0.114	0.101	0.099	0.061	0.007	0.022	0.159	0.202	− 2.333	1.941	− 0.018	0.026	635.94	159.49	− 208.98	141.86	− 215.14	161.51
Livestock ownership TLU	− 0.087	0.035	− 0.545	0.570	− 0.035	0.019	− 0.023	0.067	0.116	0.064	0.083	0.025	− 4.061	5.683	− 122.29	155.29	− 139.60	171.73
Own registered company	− 0.015	0.165	0.386	0.146	0.055	0.017	− 0.238	0.182	0.425	0.667	− 0.048	0.020	− 21.45	491.84	− 95.139	76.90	− 100.19	77.13
Formal Employment	− 0.011	0.034	− 0.130	0.459	0.002	0.002	0.012	0.072	− 0.089	0.164	0.016	0.002	311.05	78.85	− 15.906	6.322	− 12.19	6.497
Plot owner's age	0.333	0.272	1.036	0.862	0.082	0.034	− 0.084	0.315	0.801	0.530	− 0.177	0.033	− 3.599	4.406	− 409.00	210.28	− 346.56	228.70
Selection correction terms																		
_m0	− 0.446	0.182	− 2.826	2.153	− 0.183	0.050	− 0.183	0.100	0.599	0.336	0.429	0.130	− 111.46	25.65	− 494.35	119.62	− 520.61	400.63
_m1	− 0.076	0.855	1.997	0.755	0.288	0.089	0.288	0.089	2.199	3.454	− 0.249	0.107	61.16	29.69	− 82.64	32.84	− 63.352	33.75

Table 12 (continued)

Regressors	Soil erosion control						Organic or inorganic fertilizer use						Trees and permanent crops					
	CGROs		CCROs		No certificate		CGROs		CCROs		No certificate		CGROs		CCROs		No certificate	
	Coef.	Robust Std.Err.	Coef.	Robust Std.Err.	Coef	Robust Std.Err.	Coef.	Robust Std.Err.	Coef.	Robust Std.Err.	Coef.	Robust Std.Err.	Coef.	Robust Std.Err.	Coef.	Robust Std.Err.	Coef.	Robust Std. Err.
_m2	− 0.056	0.175	− 0.675	2.374	0.008	0.010	0.008	0.010	− 0.462	0.849	0.085	0.011	− 138.66	112.89	− 215.32	102.56	− 180.64	118.02
_cons	− 0.273	0.068	0.501	0.032	1.015	1.997	0.895	0.674	0.115	0.083	0.115	0.083	450.19	101.01	218.095	90.47	88.11	51.83

Table 13 Endogenous switching regression (ESR) results of the effect of LTF on perceived tenure security, credit access and land-based investment

Outcomes	Factual/Counterfactual type	Mean	ATT	Std.err.	*t* value
Perceived tenure security	$E(Y_1\|T=1)$	0.582	0.125***	0.034	3.677
	$E(Y_0\|T=1)$	0.457			
General credit access	$E(Y_1\|T=1)$	0.534	0.143	0.111	1.288
	$E(Y_0\|T=1)$	0.391			
Formal credit access	$E(Y_1\|T=1)$	0.277	0.019	0.023	1.188
	$E(Y_0\|T=1)$	0.258			
Informal credit access	$E(Y_1\|T=1)$	0.703	0.116	0.076	1.526
	$E(Y_0\|T=1)$	0.587			
Organic/Inorganic manure use	$E(Y_1\|T=1)$	0.106	0.006	0.004	1.507
	$E(Y_0\|T=1)$	0.100			
Soil erosion control	$E(Y_1\|T=1)$	0.151	0.014	0.009	1.555
	$E(Y_0\|T=1)$	0.137			
Number of trees or permanent crops planted/acre	$E(Y_1\|T=1)$	54.22	5.629*	2.949	1.907
	$E(Y_0\|T=1)$	48.59			

*, **, and *** represent statistical significance at 10%, 5%, and 1% levels, respectively

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Author contributions
HAM: study design, conceptualization, literature search and review, write-up of original draft, data processing and statistical analyses, and research fund acquisition. DWN; BW; KL and SS: study design approval, conceptualization, review and approval of literature search protocols, critical review and editing of the manuscript, research fund acquisition. All authors read and approved the final manuscript.

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Availability of data and materials
The data sets used in this study are secured versions and not publicly available due to data protection policy of the Tanzania's National of Statistics and the World Bank but are available upon reasonable request from the mentioned organizations authorities. The unsecured versions of the data sets are publicly available and can be downloaded from the World Bank micro-data portal using the this link https://microdata.worldbank.org/index.php/catalog/2862.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

Author details
[1]Leibniz-Centre for Agricultural Landscape Research (ZALF), 15374 Müncheberg, Germany. [2]Department of Agricultural Economics and Agribusiness, Sokoine University of Agriculture, 67104 Morogoro, Tanzania. [3]Department of Business Administration and Marketing, College of Business Education, Dar es Salaam, Tanzania. [4]International Institute for Applied Systems Analysis (IIASA), Schlossplatz 1, 2361 Laxenburg, Austria. [5]Department of Resource Economics, Humboldt-Universität Zu Berlin, Berlin, Germany.

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