



Land Governance in an Interconnected World

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THE IMPACT OF INTERVENTIONS TO PROMOTE CLIMATE CHANGE ADAPTATION: DOES STRONGER TENURE SECURITY INCREASE FARMER INVESTMENT IN SUSTAINABLE AGROFORESTRY?

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Abstract

This paper draws on panel data collected from 2413 households and 6234 fields in Zambia to investigate whether stronger property rights related to land might influence smallholder farmer likelihood to adopt agroforestry. The data was collected in the context of a randomized control trial of the Tenure and Global Climate Change (TGCC) program in Zambia. TGCC was developed by USAID to explore the relationship between secure resource tenure and agroforestry extension. The evaluation uses a four-arm randomized design to determine the impact of agroforestry extension and to investigate whether stronger tenure security leads to marginal increases in farmer investment in sustainable agroforestry beyond improvements gained through agroforestry extension alone. Through the first cross-cutting RCT of a customary certification and agroforestry program, this study sheds light on the relationship between perceived land tenure security and likelihood of agroforestry adoption in a customary land context in sub-Saharan Africa.

Key Words: land tenure, agroforestry, randomized control trial, customary, certification



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1 Introduction

Agroforestry, the cross-cropping of nitrogen-fixing trees with traditional field crops, is an innovation that keeps soil fertile and prevents field erosion. The expected long term benefits include improved crop yields, greater food security and more effective adaptation and mitigation responses to climate-change impacts. Agroforestry is widely perceived as a long-term sustainable land use practice that can help small-scale farmers meet food and livelihoods needs (Verchot, Van Noordwijk et al. 2007; Mbow, Van Noordwijk et al. 2014; Luedeling, Smethurst et al. 2016)Mbow, Van Noordwijk, et al., 2014).

In Zambia, agroforestry has long been seen as a potential development solution to help mitigate the persistent poverty and food security challenges faced by rural smallholders who struggle with declining soil fertility, stagnant crop yields, and emergent deleterious climate change effects. Favorable Zambian agricultural policy has encouraged Climate Smart Agriculture (CSA), and the development community has actively promoted conservation agriculture and agroforestry to encourage food security, especially in Eastern Province. However, despite the expected benefits and decades of development programming, uptake of agroforestry remains limited and understanding how to promote sustainable agroforestry adoption represents a key development challenge.

Many studies provide empirical evidence of the factors driving low uptake across Africa. Primary constraints include insufficient access to inputs, lack of knowledge by target beneficiaries, and the long time frame to realize benefits (Mbow, van Noordwijk et al. 2014; Luedeling, Smethurst et al. 2016). Growing these trees requires getting the proper seedlings, the knowledge of how to grow them, and 5 to 8 years of care. Insecure land tenure is also hypothesized to constrain smallholder investment in agroforestry. Households may be unwilling to plant a tree if they fear other households are likely to encroach or that land will be reallocated or expropriated (Besley, 1995). Indeed, there is a rich body of scholarship on the benefits of tenure security for promoting greater field investment outcomes (Deininger et al., 2011; Holden et al., 2009; Jacoby, Li, and Rozelle, 2002; Rozelle and Swinnen, 2004, Place 2009, Persha et al. 2014).

However, there remains a lack of strong evidence on the causal impact of tenure security on land investment outcomes (Lawry et al. 2014; Place 2009). It is difficult to attribute changes in land investment to property rights because of an endogenous relationship between tenure and investment. Stronger tenure might incentivize farmer decision-making and pursuit of different land investment strategies on their farms, or represent the outcome of those investments (Besley, 1995; Fenske 2011; Lawry et al. 2014)

This paper provides the first experimental evidence for whether improving tenure security makes households more willing to adopt sustainable agroforestry. We evaluate the Tenure and Global Climate Change intervention funded by the US Agency for International Development (USAID) in Zambia

The aim of TGCC and the corresponding impact evaluation was to explore the relationship between strengthening customary resource tenure and farmers' decisions to undertake longer-term land investments that support climate change adaptation and mitigation. To achieve this objective, TGCC cross-randomized an agroforestry extension with a program that strengthened customary land tenure through field demarcation and certification. While the agroforestry extension was a standard intervention that reduced the cost of planting trees, to our knowledge the tenure intervention is unique among programs to be evaluated by randomization.

In particular, TGCC cross-randomized the following two interventions in the customary context of Zambia's Eastern Province through a four-arm village-level randomized control trial (RCT).

- (1) **Land Tenure:** centered on a village-level land tenure intervention consisting of participatory mapping, village headperson land administration support and the facilitation of customary land use certificates for households;
- (2) **Agroforestry:** centered on agroforestry extension in villages to facilitate tree planting adoption and survivorship on smallholder farms; and

Villages were randomized into four treatments (Agroforestry, Land Tenure, Agroforestry and Land Tenure and Pure Control) across four chiefdoms in the Chipata District of Eastern Province. The implementation of TGCC as an RCT enables the evaluation to rigorously assess whether stronger tenure security increases farmer investment in sustainable agroforestry. Since the intervention was exogenously assigned to villages, it avoids the endogeneity problem that prohibits other empirical studies from confidently assessing the causal impact of tenure security on agricultural investment.

In this paper, we analyze qualitative and quantitative data to assess land tenure impacts on three short term agroforestry outcomes: extent of seedlings planted, percent of field planted and seedling survival rates. We assess these outcomes for the overall treatment sample, as well as explore the heterogeneous intervention effects across female-headed, youth, land constrained, elderly and poor households.

To our knowledge, this is the first experimental evidence on whether granting customary documentation to a smallholder makes her or him more likely to adopt new technology. The study aims to advance the literature and inform future programming on the impacts of tenure security on CSA practices and generate new knowledge around the impacts of customary land documentation on household-level development outcomes.

The paper follows the following structure. Section 1 provides brief background on agroforestry as a risk-smoothing activity and form of climate smart agriculture, along with a discussion on barriers to agroforestry adoption.

2 Background

Agricultural production supports the livelihood of over 70 percent of Zambia's population, including 78 percent of women. Relative to other countries in the region, Zambia, and in particular Eastern Province, has an abundance of fertile land, water, and a favorable climate for agricultural production. Yet, despite these favorable conditions, 80 percent of rural Zambians live in extreme poverty, and stunting and malnutrition impact rural communities at much higher rates than their urban counterparts. Individual land holdings are, on average, small and a quarter of the rural population nationwide farms own only one hectare of land. The primary crop grown is corn, and for most farmers it is the only crop they grow, which makes them highly vulnerable to weather conditions or pests that damage the crop. Yields for crops in Zambia are well below global averages, and despite efforts by the Zambian government and NGOs, adoption rates for chemical fertilizer, hybrid maize seeds, herbicide, and other agricultural investments remain low (Sitko et al., 2011).

Agroforestry is widely perceived as a longer-term sustainable land use practice that can not only improve farmers' livelihoods but also enable more effective adaptation and mitigation responses to climate-change impacts in already food-insecure regions of the continent (Mbow et al., 2014). Agroforestry increases soil fertility through nitrogen-fixing legumes that provide additional nutrients to the soil and reduces the need for fertilizer inputs. Since agroforestry trees are intercropped on fields, they do not significantly reduce the area of fields dedicated to crops. Thus, the expected results include improved crop yields, reduced variability in yields, and greater crop diversification with the ultimate objective of higher and more reliable farm income.¹ A large body of empirical work highlights these realized and expected benefits of agroforestry (Franzel et al., 2001; Mbow et al., 2014; Mercer, 2004).

¹ Mature trees also provide fuel, wood or fodder - although some of these direct benefits may be counter to climate resilient development objectives.

However, agroforestry adoption rates continue to be low across Africa (Franzel et al., 2001; Mercer, 2004), including in Zambia. Notwithstanding favorable Zambian agricultural policy encouraging CSA and agroforestry promotion among a number of organizations, statistics analyzed from the 2012 Rural Agricultural Livelihoods Survey (RALS) from Chipata District show agroforestry species were planted on 6 percent of fields (N=84) and in 8 percent of households (n=31) surveyed.² Baseline results for the study area covered by this research effort indicate only 11% (N=383) of households practicing agroforestry across 5% (N=404) of fields.

A large body of research explores the barriers to agroforestry adoption (Feder, Just et al. 1985; Pattanayak, Mercer et al. 2003; Knowler and Bradshaw 2007; Marennya and Barrett 2007). Some of the primary constraints cited include absence of capital for inputs, lack of labor, no access to seedlings, and low technical knowledge and skills to successfully establish seedlings and ensure their survival. Furthermore, secure land tenure alone is hypothesized to be a necessary condition for individuals to undertake productivity-enhancing investments on their land. Numerous studies have suggested positive impacts of greater land tenure security on agricultural outcomes and investment in rural land (Deininger et al., 2011; Deininger and Chamorro, 2004; Feder et al., 1988; Holden et al., 2009; Jacoby, Li, and Rozelle, 2002; Rozelle and Swinnen, 2004). In their 2003 meta-analyses of barriers to agroforestry adoption across 32 empirical case studies, Pattanayak et al. identified tenure security and extension support as two of the most important determinates of increased agroforestry uptake (finding tenure security significant in 72 percent and extension support significant in 90 percent of cases that included these factors in their analyses) (Pattanayak et al., 2003).

There are several reasons resource tenure may have a negative influence on farmers' decision to plant trees. First, planting trees requires a long time horizon in planning and investments. Compared with annual crops, trees require longer periods to produce mature crops — five to eight years for the Msangu and Gliricida trees that are the focus of the TGCC intervention. Uncertainty about access to and control over land will disincentivize an investment in agroforestry that requires a significant amount of financial and labor investments but with future payoffs delayed for many years (Mbow, Smith, Skole, Duguma, & Bustamante, 2014). Increased tenure security is also thought to reduce the need for smallholders to expend resources to defend their land claims, which can be particularly important for women and other vulnerable groups whose rights may not be sufficiently protected under traditional practices (Joireman, 2008).³

² If missing responses are included at the field level, the RALS data shows agroforestry planted on only 5 percent of fields.

³ On the other hand, the literature also theorizes that undertaking visible land investments-especially the planting of trees - on customarily held land can also in some contexts strengthen a farmer's claim to that land (Brasselle, Gaspard et al. 2002; Bromley 2009).

In Zambia, a number of legal and customary practices related to resource rights could be acting as disincentives to smallholder investment. Customary lands in Zambia are administered by local chiefs, outside the statutory and official realm of Zambian government. Traditional leaders grant use and occupancy rights, regulate transfers of land, control use of communal land, and hear disputes (Tetra Tech, 2014). Under Zambia's system of customary land tenure the vast majority of households do not own their land. They farm it by custom, meaning they have farmed it in the past and consider it theirs to farm in the future. Individual smallholders commonly have no documentation of their rights to land, which can result in complex land disputes over boundaries or defense of rights in the event of divorce, death of a family member or arbitrary reallocation of land by chiefs or headman.

In principle the chief can take land from one family to give to another. Though chiefs rarely exercise this right, we show in Section X that a sizable minority of households think it likely their land could soon be reallocated. Even if the chief himself does not reallocate land, other households in the village may act unilaterally. Since there is no official record of anyone's boundaries, neighbors may expand their crops or let their animals graze on land the household considers its own. Finally, even if a plot of land has been farmed for generations by a single family whose rights are commonly acknowledged, there is no guarantee that one household in the family can protect its claim from relatives (especially when someone dies and inheritance must be decided).

Several development programs in SSA have focused on tenure strengthening activities with the objective of improved land investments, productivity and livelihood impacts for rural households. These programs have focused on the formal recognition of individual property rights via land registration and titling programs. The empirical results for the impact of formalization programs is somewhat mixed. In some smallholder contexts in SSA, possession of formal documentation of individual land rights has been linked to a higher likelihood of making land investments on fields that households use (Holden, Deininger et al. 2009; Deininger, Ali et al. 2011). Wiig (2013) reports substantial improvement in female empowerment, particularly with respect to agricultural and land investment decisions, as a result of Peru's joint land registration and titling process. In Ethiopia, Ghebru and Holden (2015) found evidence of increased land productivity as a result of the country's land certification program, which formalizes household use rights to individual parcels of land. However, the overall body of evidence on this for SSA is less definitive. Other research highlights the potential for null effects from formalization (Jacoby and Minten 2007), or identifies a series of deleterious findings, including increasing land conflict, reinforcing elite capture (Deininger et al. 2014), or promoting inefficient resource management in

communal settings. Several important studies suggest that both a strong pre-existing customary land governance system and other contextual factors may also be important moderators (Place 2009; Lawry, Samii et al. 2014).

Indeed, the lack of compelling evidence linking formalization to improved investments in SSA has motivated a shift to research and programming to informal customary systems. In particular, Lawry et al. 2014 argues that informal customary system provide sufficient tenure security to facilitate productivity-enhancing land use decisions on the part of farmers. Correspondingly, donor initiatives have shifted to programming that attempts to work within traditional systems of land governance. These include, for example, communal land certification programs and recognition of collective use rights and land tenure (Persha et al. 2014). However, there is currently little empirical work which has examined the effects of such programs, and how they might differ from the more traditional land titling approaches to strengthening tenure security and agricultural outcomes for rural smallholders (Lawry, Samii et al 2014).

Overall, there remains a lack of understanding about the impact of tenure security on smallholder agroforestry investment (Persha et al. 2014). This paper is designed to reduce the evidence gap by rigorously testing whether a customary land certification program that strengthens perceived land tenure security affects a farmer's decision to practice agroforestry. The paper uses panel data from a randomized control trial of a customary land certification program to disentangle the causal impact of land tenure on agroforestry investment. The use of an RCT represents a methodological improvement for the literature. It enables the study to avoid the methodological pitfall of the endogenous nature of tenure security with respect to land investments in customary contexts (Braselle et al 2002; Fenske 2011).

3 Methodology

The study methodology relies on panel data from an evaluation of a USAID-funded customary land certification program in Zambia. USAID's Tenure and Global Climate Change (TGCC) pilot project is a 3.5-year intervention (2014-2017) that supported agroforestry extension services and an informal customary strengthening intervention at the village and household levels in the Chipata District of Zambia's Eastern Province. Through an innovative field experiment, the TGCC interventions, including a pure control group, were implemented as a cross-cutting RCT across a sample of villages.

The Land Tenure intervention consisted of participatory mapping, village headperson land administration support, and provision of land information and dispute resolution training, including the facilitation of customary land use certificates for households. This intervention was implemented by the Chipata District Land Alliance (CDLA), a community based organization.

In each Land Tenure village, CDLA conducted participatory mapping exercises to develop a common village map, provided households with information on land law and rights, and facilitated the process for households to obtain customary land certificates. We note that such documentation in this Zambian context refers to customary land certificates to confirm use rights, rather than formal land titles associated with the conversion of customary use rights to freehold tenure. The certification process included demarcation of village boundaries and household plots through boundary walks; adjudication and support for land dispute resolution; facilitating an objections and corrections process for field and village boundary review, and distributing customary land certificates. Other village level Land Tenure activities included establishing Village Land Committees that received training from CDLA in land management and customary land certificate administration. After the intervention ended, VLCs would be responsible for resolving conflicts over land, clarifying boundaries, and updating land certificates, as well as serving as a general community resource point for land rights and land management.

Through the agroforestry intervention, an extension agent provided support related to planting and establishment of Musangu (*Faidherbia albida*) trees and/or *Gliricidia* on cropland. The NGO Community Markets for Conservation implemented this intervention (COMACO). Specific activities included conducting awareness meetings with chiefs and headmen, forming village-level Farmer Groups open to any household in the village, and leading trainings on agroforestry with Farmer Groups. Because membership in the Agroforestry group was linked to the amount of inputs received, there were limits to the number of household members who could officially participate in the intervention. For each one lima⁴ of land a household owned, one member was able to join. Although not required, this member was typically the household head.

Each Farmer Group received high-quality *Gliricidia* and Musangu seedlings and supplies to establish a community nursery, which members were required to work in. Seedlings were then given to farmers in the group at no cost. Farmer Groups were trained in nursery management, as well as how to plant seedlings in their fields. This included information on best planting times, sites, and intercropping. Finally, if necessary in a particular village, the intervention provided additional resources such as groundnut seeds or wells to encourage seeding survival.

The two treatments were cross-randomized across villages in the four chiefdoms of Mnukwa, Mkanda, Mshawa, and Maguya (Figure 1). The research team received a village list from chiefs with 246 total villages for inclusion in the study sample (the total number of villages that contained 15 or more households and were accessible by motorbike during the rainy season). Based on draws from a random number generator, each of these villages was randomly assigned to one of the four treatment arms: Control (59 villages), Agroforestry (60 villages), Land Tenure (62

⁴ A lima of land is the equivalent of one-quarter of a hectare.

villages), or Agroforestry + Land Tenure (65 villages). The sample was stratified by chiefdom so that each of these four groups is appropriately represented in each of the chiefdoms. Figure 2 shows the location of the study area and treatment status by village.

A comparison of findings in villages receiving the agroforestry extension or tenure strengthening treatment versus control villages provides the average program impact on each of these interventions. The comparison of the average outcomes in the group receiving *both* the Land Tenure and Agroforestry treatment provides evidence about the additional effect of land tenure certification in promoting agroforestry uptake. Thus, the marginal benefits from this third ‘cross-cutting’ treatment enable the study to show the impact of strengthening resource tenure on actual agroforestry investment.

3.1 Data

The endline analysis relies primarily on a household panel datasets consisting of approximately 2935 respondent observations across 246 villages. To supplement the primary analysis, we analyze several additional sources of data, including key informant interviews with lead farmers and focus group discussions conducted across treatment and control villages, as well as geospatial data collected by the implementing partner.

Baseline data was collected from June to August 2014, prior to the start of the TGCC program. Endline data collection took place between June 2017 and August 2017, following the completion of the program. All quantitative data was collected through a cloud-based mobile data collection effort. At endline, household surveys were conducted as panel surveys, and as many baseline respondents as possible were re-interviewed at endline. If the original respondent could not be interviewed, they were replaced with another adult member of the household. If the entire household could not be tracked, another household in the village was selected.⁵ Altogether, 3522 households were interviewed at baseline, and 3403 households were interviewed at endline. Of the 6925 interviews, 5898 are included in the panel dataset, giving the study an attrition rate of 15%.⁶

The household survey data was collected to measure a series of primary and secondary indicators across changes in household perceptions of tenure security over their smallholdings, the prevalence of land disputes and agroforestry adoption. The primary tenure security indicator represents a measure of field-level security of tenure. Drawing from Persha et al. 2014, we construct this through an index of the household’s

⁵ In Agroforestry, Agroforestry Control, and Land+Agroforestry villages, households who participated in the agroforestry intervention were given preference for replacement. In all other villages, replacement households were selected at random using SurveyCTO.

⁶ The primary cause of attrition is households leaving the study area. The survey firm did not track households who moved outside of the study area, though they did attempt to follow households who moved to another community that was a part of the sample.

perceived risk of dispossession from the field. At both baseline and endline, households were asked to assess the short-term (1-3 years) and long-term (4+ years) likelihood that each plot of land would be reallocated or encroached upon by six different sources: extended family members, other households within the village, households from neighboring villages, village headman, chief, or other elites from outside the village. These short-term and long-term measures were combined to create an index for perception of tenure security.

Secondary indicators for tenure security are constructed by splitting the overall tenure security index into separate short term and long term indexes. We also generate indicators for each of the individual components of the index. These correspond to the six sources of dispossession risk. Finally, we create an outcome measure for the prevalence of land disputes at the parcel level.

We construct two primary agroforestry indicators for the analysis. The first is a measure of the extent of agroforestry on a field as measured by the proportion of fields that have agroforestry trees. The second is an indirect proxy for survivorship that captures whether or not the respondent has any living agroforestry seedlings or trees on any fields.

Table 1 shows baseline summary statistics in the control group and shows how each control group differs from the treatment group. The column labeled “P-value” tests for whether the means in the treatment groups are jointly different from that of the control group. There is balance across most variables, though it appears that households in the control group farm significantly fewer fields than the treated groups. Since treatment status is randomized this difference arose by chance and, as the other outcomes suggest, is not caused by some wholesale difference between groups. The last row of Table 1 tests for differences in attrition from the baseline to the endline survey. Average attrition is 13 percent, not atypical for a three-year follow-up survey. Most important is that the attrition is similar across treatment groups, suggesting treatment did not trigger any sample selection.

As part of endline data collection, the evaluation also conducted 34 focus group discussions in 13 purposefully selected villages in the Agroforestry, and Agroforestry + Land treatments. Using M&E data collected from the program implementation team, villages were selected that would capture a variety of experiences within the Agroforestry treatment arms, with primary interest in the experience of program participants compared to non-participants. These criteria were chosen based on focus group discussions with implementers about various factors that influenced a village’s success with the agroforestry or land-tenure intervention, and on quantitative surveys completed by the implementers. The criteria included variation on agroforestry seedling survival rates, water availability for irrigation, headperson engagement with the program, and

activeness of the farming group. Larger villages were also purposefully selected to ensure enough households in each village to capture our subgroups of interest.

3.2 Empirical Strategy

We first establish that the certification did have the expected impact on tenure security through a comparison of households in the Land Tenure treatment arm to those in the pure control. A main goal of this is to determine whether the land tenure intervention did meet the first stage condition of increasing perceived tenure security. For this analysis, the evaluation relies on the intent-to-treat estimates of household engagement in the process of customary land mapping. Our inferences about the treatment relate to households' *expectation* of receiving a paper certificate because although all chiefs and villages completed the customary land certification *process*, several chiefs had not signed and distributed certificates to households in their villages at the time of endline data collection.

Next, to address the primary research question, we focus on a comparison of the impact of the Agroforestry + Land Tenure intervention to the Agroforestry only intervention. This estimation of the joint effect of strengthening land tenure in areas receiving agroforestry extension represents the primary objective of the study. It enables the research to determine whether or not the village and household land-tenure interventions under TGCC strengthen the security of land tenure and resource rights for smallholders, thereby increasing farmer investment in sustainable agroforestry and uptake of other CSA practices.

Based on the program theory and literature, we also expect to find variation in the treatment effect across a number of sub-groups. Wealth-based and gender aspects of agroforestry uptake are also reported in a number of studies across the sub-Saharan region, as these groups experience additional disadvantages around access to labor, capital and knowledge for agricultural investment (Kiptot et al., 2014; Phiri et al., 2004). Due to the challenges facing women, youth, and poor households in the Zambian context, we might expect to see these groups be less likely to engage in agroforestry, or be less successful if they do take it up. Agroforestry is particularly labor-intensive, and female-headed households may struggle to find the resources to care for seedlings in the nursery, transport their seedlings the sometimes long distances to their fields and to plant the seedlings. Seedling transportation and planting occurs simultaneously with the most laborious weeding work of the season, which also traditionally falls to women. Poor households face similar constraints on land, labor, and resources as women, and may not be able to sacrifice labor or land to agroforestry, even when the inputs are provided for free. Youth households, though more willing to adapt new technologies than older households, struggle to access land and often work the fields belonging to their parents, on which they have limited decision making power.

As a result, for each primary and secondary indicator, the regression analysis tests for the average treatment effects, in addition to heterogeneous treatment effects across several household sub-groups, including women (male-headed households versus female-headed households), youth (under 35) and poor households (lowest quartile on continuous asset-based wealth index).

Our empirical strategy relies on the following model specifications. The first specification is for estimation of the average treatment effect, whereas the second specification is used for the sub-group analysis.

The effect of each treatment arm of interest are estimated with the following specification for household outcomes:

$$[1a] \quad Y_{ij} = \beta_0 + \beta_1 T_{ij}AGRO + \beta_2 T_{ij}TENURE + \beta_3 T_{ij}TENURE * T_{ij}AGRO + \beta_4 X_{ij} + Y_{ij0} + \phi_d + u_{ij}$$

where Y_{ij} is the outcome measure of household i in village j . T_{ij} is the treatment dummy for each of the three treatment arms of interest. X_{ij} is a vector of control variables, described in section 5.0 Indicators, and included imbalanced covariates. Y_{ij0} is the baseline vectors for the outcome measure, ϕ_d is chiefdom-fixed effects, and u_{ij} are robust standard errors clustered at the village level, using Huber-White sandwiched standard errors (Lin et al., 2013).

This specification enables us to strip out the direct effect of agroforestry and tenure before assessing whether the two together have an even larger effect. It also accounts for correlation in the error term and has more power than other specifications.

To test for heterogeneous treatment effects across these subgroups, we estimate the following equation:

$$[4a] \quad Y_{ij} = \beta_0 + \beta_1 T_{ijk} + \beta_2 T_{ijk} * Het_{ij} + \beta_3 Het_{ij} + \beta_4 Y_{ij0} + \beta_5 X_{ij} + \phi_d + u_{ij}$$

T_{ijk} represents the treatment dummy for treatment indicator k , where k represents which treatment arm we are assessing from Groups 1–3. Het_{ij} is the indicator variable for the subgroup of interest. β_2 is the marginal increase in treatment effect in villages in the subgroup under evaluation. All other parameters are the same as those described above for Group 1.

4 Results

4.1 Perceived Tenure Security

The tenure status for nearly all fields in this study sample is overwhelmingly a customary arrangement, where households do not have formal land documentation (N=8,765, or 99% of fields). Prior to the intervention, the baseline findings indicated that households felt relatively secure that their fields would not be taken away from them from: family members, the village headman or neighboring villages. This expectation held true for the short-term and the future. The general security of land is demonstrated by less than 1% of households indicating having any land reallocated in the past. Additionally, the total number of disputes over fields were low with only about 11% (N=1,007) of fields reported as disputed. At the same time, households worried about their future security. Forty percent of households believed it likely that the chief or government would give up at least one of their fields for investment purposes. Over 90% expressed they would like to obtain paper documentation for their farmland.

The analysis finds strong evidence that the TGCC Land Tenure intervention's process of boundary demarcation and the expectation of receiving paper documentation substantially increased perceptions of tenure security. The regression results indicate a positive statistically significant treatment impact on perceived tenure security for all primary and secondary perception indicators. Treatment households perceive that their fields are more secure from reallocation or unauthorized expropriation in the short and long term, as well as from internal and external threats. This includes a lower perceived risk of reallocation by the headperson or chiefs, as well as encroachment by family members or neighboring villages. The weakest program impact is perceived security against field reallocation by chiefs.

In contrast, there is no evidence that TGCC had an impact on the prevalence of land disputes. This null finding for disputes may be driven by the low level of disputes in the study area, which reduce the power of the sample to identify treatment effects. Another explanation that emerges from the qualitative analysis is that—while the boundary demarcation eventually reduced disputes—it may have motivated an uptick in disputes during the actual process.

Figures 3,4 5 illustrate the program effect across tenure security indicators. The corresponding regression results are displayed in Table 2 below.

In addition, we find positive sub group treatment impacts for female-headed households receiving the Land Tenure intervention. These findings are presented in [Tables XXXX](#)

Overall, the empirical findings indicate that the land tenure intervention successfully promoted perceived security from internal and external sources of reallocation.⁷ Given this important first stage precondition, we now examine the results of the agroforestry extension and whether improving perceived resource tenure motivated higher adoption rates. These findings speak to the fundamental research question driving the study - whether stronger property rights affect a farmer's decision to practice climate smart agriculture, including agroforestry.

4.2 Agroforestry adoption

In addition to the regression results, this section provides contextual and descriptive data and findings on the factors driving program participation, expected benefits and the main challenges to agroforestry, in order to better understand uptake and seedling survival.

The ecological benefits of agroforestry, including soil fertility and crop productivity appear to be well-known to households in Chipata district. The most common expected benefit cited by treatment groups both now and in the future is improved soil fertility (36 percent, N=339 for Musangu; 38 percent, N=364 for Gliricidia).⁸ Similarly, improved crop growth around trees is another oft-cited benefit for both species, particularly in the future. Between 17 percent and 21 percent of households say they expect to see improved crop growth in the future for Musangu trees, as do 15 to 19 percent of households for Gliricidia. This is a lower percentage than we would expect, since higher yields and/or improved crop growth should be the ultimate benefit to households. Almost no households believe that planting agroforestry trees reduce the fear of their land being taken, or raise the value of their land for collateral, either now or in the future.

Focus group participants easily articulated the benefits, even if they did not participate in the Agroforestry extension program. A participant in the women's FGD in Maguya chiefdom described how she expects to benefit from agroforestry. "Growing little food has troubled us here in this village. If you don't have fertilizer and at home you have a big family including grandchildren and the field is not productive so to hear that there are trees that can make soil fertile... so when fertility returns to the soil, people can grow enough food for their families. That is why we want agroforestry trees. Most of us can't afford to buy fertilizer. So we want fertility to return to the soil so that we can reduce hunger in our homes."

⁷ Please see Huntington et al. 2018 for more in-depth discussion of the land tenure findings.

⁸ A benefit emphasized in focus group discussions is the increased availability of fuel wood. It appears that at least some households view their agroforestry trees as an opportunity for a woodlot as opposed to caring for their trees to improve their field's agricultural productivity. This is further supported by the number of households who do not believe that there are any yield-related benefits to the trees. The household statistics are less striking than the qualitative analysis, but are worth noting—8 percent (N=71) of households believe their Musangu trees will increase the availability of fuelwood in the future. The percent of households who believe that Gliricidia trees will increase the availability of fuelwood in the future is slightly higher (10 percent, N=88).

In communities where the agroforestry program was offered, roughly a third of households had at least one household member participate in the extension program. Despite understanding the benefits, a sizeable minority of households who participated and adopted agroforestry see no present benefits from their trees (24 percent, N=228 for Musangu; 24 percent, N=224 for Gliricidia). This is not surprising given the long time frame required to receive the benefits from agroforestry adoption. As expected, this number drops substantially when households are asked about benefits they expect in the next 3-5 years (8 percent, N=79 for Musangu; 9 percent, N=91 for Gliricidia).

The regression results show a positive aggregate treatment impact for the agroforestry extension program for our two primary agroforestry uptake measures (Table 6). The agroforestry extension intervention increased the amount of agroforestry trees and shrubs planted. Households given the agroforestry extension treatment were roughly 30 percentage points more likely to practice agroforestry on a plot. By contrast, households given the tenure treatment alone had essentially a zero effect. The most common tree species planted in every treatment group is the Musangu tree.⁹ A third of households (33 percent, N=227) receiving the Agroforestry treatment and (42 percent, N=315) of households receiving the Agroforestry + Land Tenure treatment planted Musangu trees. Uptake for the control group is substantially lower (14 percent, N=93). Less common than Musangu trees are Gliricidia, a shrub that is particularly sensitive to water shortages. Households struggled to keep the seedlings alive in the nursery, which may explain the slightly lower rates of Gliricidia adoption. Households in Agroforestry communities have the highest rate of Gliricidia adoption (40 percent, N=270), followed closely by Agroforestry +Land Tenure (38 percent, N=288). Again, the rate for control villages is significantly lower (14 percent, N=93).

The percentage of fields covered with agroforestry trees and shrubs increased as well, and these results are statistically significant. Correspondingly, all sub-groups - female-headed, youth and poor - show significant uptake in agroforestry and increased agroforestry planting across fields for villages receiving extension services (Table 7).¹⁰

4.3 Joint effect on adoption rates- Agroforestry and land certification

In line with the research objective of this paper, land tenure is hypothesized to shape farmer likelihood to make agroforestry investments. It is argued that farmers with undocumented customary use rights to land could be less willing to make risky land investments that take time to provide

⁹ Musangu trees are grown from seedlings. It is intercropped with the field's main crop, and is best suited to being planted in a 5-by-5 meter grid.

- Female headed households in treatment communities are slightly less likely to have planted Gliricidia trees than male headed households (FHH: 35 percent, MHH: 40 percent). Based on Monitoring and Evaluation (M&E) conversations with the Agroforestry extension team, female-headed households were more likely to struggle to transport their seedlings from the nursery to their fields, and the large number of Gliricidia seedlings (100 Gliricidia vs 25 Musangu) may have been too much of an obstacle for female-headed households.

benefits, such as agroforestry, because of lower certainty over their continued right to use the land in the future. To address our primary research question, we also test the impact of the agroforestry extension work in communities that received the customary land strengthening intervention.

Significantly, the regression results show that land certification did not encourage any marginal improvements in agroforestry uptake. Households given both interventions were no more likely to practice agroforestry than households given only the extension (if anything the effect was smaller). Thus, as Figure 6 shows for the *overall household sample*, there is no evidence to support a link between tenure security and agroforestry uptake.

In contrast, the *sub-group* findings described in Table 7 for female-headed households indicate marginal benefits to linking land tenure and agroforestry. This lends some limited support to the argument that, at least for more marginalized groups, stronger property rights affect a farmer's decision to practice agroforestry.

4.4 Seedling survival

Within areas receiving agroforestry extension services, seedling and tree survival rates are low. Across all years of the program, over one-third of households who engaged in agroforestry reported that less than one-quarter of their Musangu and Glyricidia seedlings survived (Figures 7,8). For Musangu, the rate of survival is even lower. These low survival rates do not appear to correlate with the geographical location of the villages, or with the location of wells or water points.

Seedling survival declines over time and is the lowest in 2016, after the agroforestry intervention withdrew support. The map below shows average survivorship rates by village across all intervention groups (Figure 9). It is a positive sign that treatment households have slightly higher survival rates than control households. In 2014, the first year of the agroforestry intervention, just under 25% of households in treatment communities report that between 76%-100% of seedlings are alive today. In control communities the rate is lower at 18%. Nine percent of households in treatment communities have a 0% survival rate, compared to 16% of control communities. It is important to highlight that the overall sample size of control households who have planted seedlings is low, so the percentages may be misleading.

Survival rates for Musangu trees planted in 2015, the second year of the program, are slightly lower than they were for the first year of the program. This is unexpected given the adaptations the Agroforestry extension program made to the agroforestry program to address challenges households faced in the first year, such as building wells and distributing groundnut seeds. Despite these efforts, only 19 percent (N=37) of

treatment households have a survival rate above 75 percent. Still, this is higher than control households, where only 3 households have a survival rate that high.

Survival rates for *Gliricidia* trees are slightly more optimistic, though the majority of households still report survival rates under 50 percent. Of the seedlings planted in 2014, 27 percent (N=65) of treatment households say that more than 75 percent of them are alive today. The figures are nearly identical for seedlings that treatment households planted in 2015 (26 percent, N=50) and 2016 (26 percent, N=31).

Households encountered a number of challenges to agroforestry tree survival. The most common challenges to agroforestry seedling survival include a lack of water for seedlings, fires burning trees, pests killing the trees, and animals grazing in the field. Lack of knowledge was not a prevalent challenge for households. Lack of water for seedlings was the number one challenge for both Musangu and *Gliricidia* seedlings, identified by 37 percent (N=201) of treatment households for Musangu trees, and 23 percent (N=209) of treatment households for *Gliricidia* trees. The Agroforestry extension attempted to address this challenge by installing wells in some water-insecure villages, however, it does not appear that the wells improved seedling survival in subsequent years. An Agroforestry participant from Mnukwa chiefdom commented “The challenge we are facing is lack of water. Even if they brought more seed for us to plant, once the rains stop, we work in vain. So we don’t know how you are going to help us, once you help us with water, aah we will have trees all over here.”

Traditional land management practices also present a challenge to the survival of agroforestry trees, and there is some limited evidence that land management rules related to grazing and fires promote seedling survival. Animals are allowed to graze in fields after crops are harvested, which leaves seedlings vulnerable to being grazed or trampled by cattle, goats, and other livestock. We examined the seedling survival rates for villages that forbid livestock grazing on fields, or allow it only if the livestock are accompanied (68 percent, N=187), and compared to villages that either have no rule about grazing, or allow livestock to graze unaccompanied on fields (32 percent, N=86). Figure 10 shows the results of the comparison. Another traditional practice, setting fires to fields to clear crops after harvest or to harvest mice to eat, resulted in 13 percent of participants (N=72) saying their Musangu seedlings were burned by fires.¹¹ Figure 11 shows seedling survival in villages where there is a village rule that forbids fires on fields at any time in the year (53 percent, N=146). It appears that villages with rules that protect their seedlings from fires do have higher survival rates than villages without these rules.

¹¹ Pests killing and damaging trees was also a large challenge for households growing both Musangu and *Gliricidia*, especially in the control areas. The fact that treatment communities were slightly less likely to have their trees killed by pests may speak to the success of the Agroforestry extension’s training about how to protect their trees.

5. Discussion

The findings indicate that the program successfully increased perceptions of tenure security. The process of boundary demarcation and expectation of receiving paper documentation for fields did indeed make households feel more secure in their property rights. As the Zambian government prepares to revise Zambia's Land Act with anticipated technical support from USAID, the positive tenure findings support a scale-up of the TGCC model in Zambia and intervention piloting in other customary land systems in Africa.

The cross-randomized extension program lowered the cost of agroforestry adoption by giving farmers agroforestry seedlings and training on how to keep them alive. Indeed, we see that the agroforestry extension program had a significant impact on agroforestry adoption rates. If tenure insecurity is a major barrier to investment, getting the tenure intervention should make households more willing to adopt agroforestry than getting the extension program alone. However, the regression results show that households given the combined intervention were equally likely to adopt agroforestry as those given only the extension program without any tenure intervention. Households that received both the Land Tenure and Agroforestry interventions were 15 percentage points more likely to use agroforestry on their plots—an effect almost identical to that on households that received *only* the Agroforestry intervention. The tenure intervention appears to have had precisely zero effect for the overall household sample.

The exception to this is evidence of positive sub-group treatment impacts for female-headed households in villages that received the Land Tenure intervention. In the short term, strengthening customary land tenure did have a positive effect on agroforestry adoption for a vulnerable sub group.

The overall results suggest several explanations:

1. Tenure insecurity might not actually deter households from adopting agroforestry;
2. Only after households have felt secure for some time do they begin adopting time and labor intensive investments; and
3. The difficulty and demands of agroforestry - combined with perceptions of relatively small and distal benefits - suggest a need to reconsider agroforestry as a key CSA development intervention in this context. Indeed, this explanation may be supported by evidence from the analysis that finds low survivorship due to a number of environmental challenges.

Contextual quantitative and qualitative data do not reveal a strong link between tenure and agroforestry adoption. Instead, the most common challenges to agroforestry seedling survival include lack of water for seedlings, as mentioned by 37% of treatment households for Musangu trees and 23% for Gliricidia trees. Despite the Agroforestry extension's efforts to construct wells and boreholes, focus group discussion

participants continuously noted the lack of water. The qualitative data highlights also highlights the need for significant labor investments during the harvest season and constant threats from fire, pests and livestock.

However, there is strong reason to expect that TGCC effects in the long run may differ from those in the short run. It may take time for households to trust that the guarantees of land tenure will be honored. Households that adopt agroforestry may subsequently abandon it. We recommend a third round of data collection in 2 - 3 years that revisits the same households who took part in the baseline and endline surveys in order to investigate the longer term effects of the TGCC program. A third round of data collection will provide further evidence about the program's impact on long-term benefits such as seedling survival, as well as agricultural productivity, livelihoods, and crop yields, as well as the impact of certification on seedling survival. This will promote a better understanding of the TGCC's program full policy potential and value for money, and inform other stakeholders' decisions to take the program to scale in Zambia and other African countries with similar customary land systems.

Findings about the impact of the Agroforestry extension intervention are also important, as donors and the government continue to promote climate-smart agricultural practices while seeing relatively little increase in uptake. Although agroforestry extension did promote an increase in agroforestry uptake, seedling survival rates are less than 40% and on the decline. The qualitative data highlights a number of contextual and environmental challenges to keeping seedlings alive. These include water shortages, the need for significant labor investments during the harvest season and constant threats from fire, pests and livestock.

Given the large labor investment and challenge to keeping seedlings alive, agroforestry may not be the best climate-smart agricultural investment to offer. Households may be more responsive to a program that promotes reforestation or growing community woodlots, as many respondents mentioned the need for trees for fuelwood and climate resilience. Other CSA possibilities with greater benefits to farmers include minimal tillage and crop rotation. Minimal tillage requires greater labor than traditional tillage, but can be done in the farming offseason where labor is less constrained. Crop rotation requires no additional labor, but does require a change in farming inputs that may need to be provided. If programs choose to continue with agroforestry, several issues should be addressed. Seedling death prior to planting is often explained by lack of water and inconsistent care in the nursery. It may also be worthwhile for the implementer to provide seedlings at the point of planting, reducing the amount of labor households must invest in agroforestry while increasing the number of seedlings available to plant. This is less sustainable than a village-run nursery, but as each field should only need to be planted once, may be effective at increasing the number of trees surviving. Moreover,

land management rules in a village play an important role in the success or failure of agroforestry. Rules about setting fires and grazing livestock are particularly important, since seedlings are susceptible to being grazed or trampled by livestock or burned by fires. Future programs should incorporate improved land management rules in communities with the aim of increasing seedling survival rates. One potential rule in the Zambian context is to prohibit livestock from grazing on fields at any point in the harvest cycle.

Another possible option for future agroforestry programs is to incorporate incentives to motivate better survival rates. In another RCT of an agroforestry program in Eastern Province, Jack et al. (2016) found that paying cash incentives to farmers who kept at least 70% of their trees alive after one year increased the seedling survival rate in the short term, as well as increasing program participation and the number of trees planted. The same study also found that weekly monitoring visits from program officers improved seedling survival, which, though costly, could be incorporated into future programs. In Zambia, given a long history of radio broadcasts and agroforestry activities, improving farmer's knowledge of agroforestry might not need to remain an intervention focus. The ecological benefits of agroforestry are widely known, even at baseline and across control groups, and the evaluation found no evidence that lack of knowledge is a barrier to uptake. For future programming, baseline data can be used to assess farmers' knowledge of agroforestry in areas like Eastern Province.

Greater participation might be possible if the program modifies its approach to recruitment, perhaps by doing greater outreach before signups began, or allowing for multiple rounds of program signups as news of the program permeates the villages. Some households wanted to participate in the Agroforestry intervention, but were reportedly refused. Other households signed up expecting a different type of COMACO program, or were not clear about who in their household was allowed to attend trainings. To promote greater participation and reduce confusion, future programs could increase the number of sensitization visits they make to each village and permit households to join the program until the end of the final sensitization visit. Additional sensitization will spread information about the program and give households additional time to decide if they would like to participate. The meeting should clearly lay out the expected time commitments, number of household members who are permitted to join and/or attend trainings, and the types of inputs the households would receive, all things which generated confusion during the Agroforestry intervention.

5 Conclusion

Land tenure security and CSA extension have long been a central focus for a range of rural development initiatives in sub-Saharan Africa (SSA) that address poverty reduction and agricultural livelihoods. The aim of this paper was to contribute knowledge that may be useful for land

and agroforestry policy and programming efforts to facilitate wider adoption of climate-smart agricultural practices and their intended household benefits, particularly in contexts with relatively strong existing customary rights to land.

Our analyses are important for their contributions towards understanding the potential role that enhanced tenure security may play in incentivizing farmer decisions to engage in agroforestry land investments. Such knowledge – particularly from a customary land context prior to efforts to strengthen customary use rights *in situ* - is critical for practical applications amid contemporary land programming efforts by country governments, donors, and NGOs on the continent. Ultimately, our results contribute towards a better understanding of how land tenure strengthening and agroforestry extension programs as a whole may be shaped to increase their likelihood of eliciting intended development outcomes for rural smallholders in customary land settings in sub-Saharan Africa.

Overall, we find that the TGCC Land Tenure intervention had a positive impact on perceived tenure security and Agroforestry extension had a positive impact on agroforestry uptake. These positive impacts were also experienced by women, youth, and poor households. However, there is no evidence that the combination of the two led to more agroforestry uptake or long-term seedling survival for the average treatment sample. That farmers attempted to plant agroforestry trees in the Agroforestry only intervention indicates that there is interest in agricultural improvements even without increased tenure security. Analogously, that farmers desired increased tenure security even though it did not lead to high levels of long-term sapling survival or more agricultural investments in the combination treatment shows farmers desire the immediate protection of certification apart from any potential agricultural investment benefits.

The difficulties with seedling survival show that despite interest in, and knowledge of, agroforestry, sufficient labor and time inputs remain an essential missing piece of the inclusive agricultural transformation strategy for smallholders. That said, the long-term results may differ from those in the short-term. We may see more long-term investments that are easier for households to accomplish as, over time, all households finish receiving certification and begin to trust that the guarantees of land tenure will be honored.

Significantly, our findings are not in agreement with several recent studies from West Africa, Central Asia and Southeast Asia that call attention to land tenure and land policy constraints to agroforestry, including in customary land systems (for example, see Persha and Huntington 2015; Djalilov et al 2016; Fouladbash and Currie 2015; and Simelton et al 2016). These other studies point to a stronger impact of land tenure security and land documentation for household decisions to invest in agroforestry. Our study's deviation from this work may be due to several

factors. The first is our use of an experimental approach that better assesses the directionality of the relationship between tenure and investments. There are significant selection bias issues for observational studies (Persha and Huntington 2015).

To this point about longer term research efforts, the dataset generated by this study through an RCT has important long term consequences for agroforestry research. Few studies have rigorously quantified field or household level impacts from agroforestry at scale, or show unequivocal improvements (Sileshi, Akkinifesi et al. 2010; Persha and Huntington 2015), while existing work highlights the complexity of data needs and analytic approaches required to do so. Consequently, this dataset and underlying design opens the door to more rigorous research in the future about the true productivity and livelihood impacts of agroforestry.

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Tables

Table 1

Balance at Baseline

	Control Mean	Difference from Control			P-value
		Tenure	Agro	Both	
Agroforestry on Any Field	0.10 (0.02)	-0.00 (0.02)	0.00 (0.02)	0.03 (0.02)	0.461
Left Any Field Fallow	0.10 (0.01)	0.01 (0.02)	-0.01 (0.02)	0.02 (0.02)	0.222
Have Paper Document for Field*	0.01 (0.00)	0.00 (0.01)	-0.00 (0.01)	0.00 (0.01)	0.844
Number of Fields Farmed	2.32 (0.06)	0.34 (0.08)	0.19 (0.08)	0.21 (0.09)	0.001
Have At Least 1 Field	0.99 (0.00)	-0.00 (0.00)	-0.00 (0.01)	-0.01 (0.01)	0.349
Female-Headed HH	0.25 (0.02)	0.04 (0.03)	0.03 (0.03)	-0.01 (0.02)	0.089
Total Area Owned (ha)	2.56 (0.52)	-0.13 (0.62)	-0.60 (0.53)	0.60 (0.86)	0.127
Had Land Reallocated?	0.02 (0.01)	-0.00 (0.01)	-0.00 (0.01)	-0.01 (0.01)	0.895
Can write name?	0.66 (0.02)	-0.03 (0.03)	0.01 (0.03)	-0.01 (0.03)	0.732
Can read newspaper?	0.52 (0.02)	-0.04 (0.03)	-0.01 (0.03)	-0.03 (0.03)	0.575
Likelihood Other HHs Encroach*	1.88 (0.06)	0.09 (0.09)	0.23 (0.09)	0.14 (0.08)	0.080
Likelihood Elites Encroach*	1.66 (0.05)	-0.05 (0.07)	0.07 (0.07)	0.01 (0.07)	0.495
Likelihood Neighboring Villages Encroach*	1.60 (0.06)	0.09 (0.08)	0.12 (0.08)	0.06 (0.08)	0.440
Likelihood Family Encroachs*	1.71 (0.06)	-0.02 (0.08)	-0.06 (0.08)	-0.13 (0.07)	0.309
Likelihood Chief Reallocates*	2.04 (0.06)	-0.23 (0.09)	-0.19 (0.09)	-0.13 (0.08)	0.059
Likelihood Head Reallocates*	1.61 (0.05)	-0.10 (0.07)	-0.12 (0.07)	-0.13 (0.07)	0.267
Attrit from Baseline to Endline	0.13 (0.02)	0.03 (0.02)	0.05 (0.02)	0.03 (0.03)	0.296

*Outcome is household's response for the first field reported by the household (see text for explanation)
Note: For likelihood questions households were asked to use a Likert scale (1 is impossible, 6 is currently occurring). The p-value reports a test on the hypothesis that the means in the three treatment groups are jointly different from the control. Inference is clustered by village (the unit of randomization).

Table 2

Table 2: Tenure Security – All households

Variables	tensec_index_h h_pca	tensec_index_hh hh_long_pca	tensec_index_hh_s hort_pca	fallow_seasons_c s_mean	fallow_seasons_cs cs_min	fallow_seasons_lo g_mean	fallow_seasons_l og_min	tensec_intern al_pca	tensec_extern al_pca
Lagged	0.0656*** (0.0146)	0.0544*** (0.0139)	0.0716*** (0.0151)	0.0265 (0.0168)	0.0177 (0.0172)	0.0209 (0.0159)	0.0140 (0.0163)	0.0647*** (0.0152)	0.0551*** (0.0147)
Saili	0.105** (0.0528)	0.113** (0.0512)	0.0946* (0.0540)	0.0758 (0.0822)	0.0329 (0.0857)	0.0943 (0.158)	0.0120 (0.166)	0.0971* (0.0538)	0.102** (0.0508)
Land tenure	0.151*** (0.0514)	0.148*** (0.0507)	0.145*** (0.0524)	0.0705 (0.0825)	0.0595 (0.0851)	0.126 (0.161)	0.109 (0.168)	0.144*** (0.0518)	0.139*** (0.0501)
Agroforestry	-0.0418 (0.0591)	-0.0339 (0.0574)	-0.0479 (0.0600)	0.0231 (0.0723)	-0.00515 (0.0767)	0.0381 (0.139)	-0.0163 (0.149)	-0.0413 (0.0582)	-0.0400 (0.0591)
Agroforestry + Land tenure	0.100** (0.0486)	0.0998** (0.0474)	0.0977* (0.0498)	0.0862 (0.0741)	0.0865 (0.0781)	0.172 (0.141)	0.173 (0.151)	0.104** (0.0496)	0.0866* (0.0471)
Constant	0.147*** (0.0372)	0.128*** (0.0366)	0.160*** (0.0378)	0.280*** (0.0581)	0.240*** (0.0621)	3.545*** (0.121)	3.479*** (0.129)	0.137*** (0.0377)	0.139*** (0.0362)
Observations	2,863	2,866	2,863	2,837	2,837	2,837	2,837	2,865	2,864
R-squared	0.018	0.016	0.018	0.003	0.002	0.002	0.002	0.017	0.014

Notes: Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 3: Tenure Security – All households

Variables	disputecoun t	villhh_encroac h	elite_encroac h	neighvill_encroac h	chief_reallocate h	headman_reallocat e	family_encroac h	dispute
Lagged	0.108** (0.0531)	0.0675*** (0.0140)	0.0463*** (0.0148)	0.0378** (0.0147)	0.0565*** (0.0147)	0.0304* (0.0159)	0.0428*** (0.0157)	0.127*** (0.0192)
Saili	0.182 (0.176)	0.138** (0.0535)	0.0849* (0.0444)	0.0742 (0.0493)	0.0874 (0.0632)	0.0646 (0.0449)	0.0159 (0.0703)	-0.00592 (0.0131)

Land tenure	-0.0965 (0.111)	0.122** (0.0581)	0.106** (0.0450)	0.122** (0.0470)	0.113* (0.0601)	0.104** (0.0438)	0.112* (0.0618)	0.000383 (0.0142)
Agroforestry	-0.00882 (0.101)	-0.0382 (0.0604)	-0.0473 (0.0546)	-0.0298 (0.0529)	-0.0397 (0.0682)	-0.0314 (0.0492)	-0.0530 (0.0644)	0.00891 (0.0143)
Agroforestry + Land tenure	0.212 (0.163)	0.0991* (0.0545)	0.0544 (0.0438)	0.0871* (0.0453)	0.0926* (0.0553)	0.0611 (0.0422)	0.0974* (0.0586)	-0.00873 (0.0146)
Constant	1.054*** (0.0879)	5.238*** (0.0878)	5.394*** (0.0880)	5.429*** (0.0912)	5.246*** (0.0894)	5.486*** (0.0940)	5.324*** (0.0954)	0.0642** (0.0101) *
Observations	187	2,868	2,868	2,868	2,866	2,868	2,867	2,862
R-squared	0.065	0.019	0.011	0.010	0.012	0.007	0.009	0.025

Notes: Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4: Tenure Security – Female headed household

Variables	tensec_index hh_pca	tensec_index_hh long_pca	tensec_index_hh short_pca	fallow_seasons cs_mean	fallow_seasons cs_min	fallow_seasons_ log_mean	fallow_seasons log_min	tensec_inter nal_pca	tensec_exter nal_pca
Lagged	0.0670*** (0.0147)	0.0552*** (0.0140)	0.0735*** (0.0152)	0.0242 (0.0169)	0.0161 (0.0174)	0.0193 (0.0160)	0.0121 (0.0164)	0.0661*** (0.0152)	0.0562*** (0.0147)
fhh_baseline	-0.0329 (0.0731)	-0.0236 (0.0690)	-0.0390 (0.0755)	0.0677 (0.0886)	0.0834 (0.0921)	0.0772 (0.176)	0.107 (0.183)	-0.0394 (0.0742)	-0.0219 (0.0749)
Saili	0.108* (0.0600)	0.116** (0.0584)	0.0970 (0.0610)	0.0798 (0.0919)	0.0506 (0.0999)	0.103 (0.174)	0.0422 (0.191)	0.104* (0.0626)	0.101* (0.0563)
Linear combination - Saili	0.102 (0.0884)	0.107 (0.0845)	0.0936 (0.0907)	0.0333 (0.119)	-0.0237 (0.120)	0.0201 (0.243)	-0.0945 (0.247)	0.0848 (0.0879)	0.105 (0.0901)
Land Tenure	0.133** (0.0581)	0.137** (0.0559)	0.125** (0.0598)	0.0421 (0.0920)	0.0381 (0.0976)	0.0595 (0.179)	0.0502 (0.192)	0.122** (0.0591)	0.133** (0.0559)
Linear combination - Land tenure	0.197** (0.0846)	0.174** (0.0835)	0.196** (0.0864)	0.135 (0.111)	0.113 (0.111)	0.288 (0.223)	0.257 (0.224)	0.203** (0.0831)	0.155* (0.0866)
Agroforestry	-0.00153 (0.0667)	0.00809 (0.0639)	-0.0105 (0.0685)	0.0250 (0.0789)	-0.00507 (0.0858)	0.0278 (0.151)	-0.0355 (0.165)	-0.00254 (0.0657)	-0.00123 (0.0673)
Linear combination - Agroforestry	-0.139 (0.118)	-0.136 (0.112)	-0.137 (0.121)	0.0107 (0.114)	-0.00265 (0.118)	0.0534 (0.220)	0.0274 (0.230)	-0.134 (0.115)	-0.135 (0.118)
Agroforestry + Land tenure	0.0727 (0.0555)	0.0718 (0.0530)	0.0716 (0.0579)	0.137 (0.0834)	0.140 (0.0898)	0.247 (0.159)	0.249 (0.174)	0.0798 (0.0560)	0.0581 (0.0547)

Linear combination - Agroforestry + Land tenure	0.183** (0.0880)	0.184** (0.0850)	0.176** (0.0889)	-0.0664 (0.112)	-0.0616 (0.113)	-0.0534 (0.213)	-0.0422 (0.217)	0.176* (0.0904)	0.173** (0.0854)
c.nonrandom#c.fhh _baseline	-0.00563 (0.0990)	-0.00941 (0.0948)	-0.00339 (0.101)	-0.0465 (0.129)	-0.0742 (0.137)	-0.0829 (0.260)	-0.137 (0.279)	-0.0195 (0.101)	0.00396 (0.0988)
c.t_tenure#c.fhh_ba seline	0.0643 (0.0937)	0.0371 (0.0895)	0.0710 (0.0971)	0.0927 (0.116)	0.0744 (0.122)	0.228 (0.233)	0.207 (0.245)	0.0805 (0.0930)	0.0226 (0.0949)
c.t_agro#c.fhh_base line	-0.137 (0.134)	-0.145 (0.125)	-0.126 (0.138)	-0.0143 (0.120)	0.00242 (0.128)	0.0256 (0.231)	0.0629 (0.248)	-0.132 (0.130)	-0.133 (0.134)
c.t_agroXtenure#c.f hh_baseline	0.110 (0.1000)	0.113 (0.0945)	0.104 (0.103)	-0.203 (0.123)	-0.202 (0.127)	-0.300 (0.237)	-0.291 (0.247)	0.0963 (0.101)	0.115 (0.0993)
Constant	0.156*** (0.0426)	0.134*** (0.0410)	0.171*** (0.0441)	0.263*** (0.0658)	0.216*** (0.0721)	3.529*** (0.132)	3.453*** (0.145)	0.148*** (0.0436)	0.145*** (0.0413)
Observations	2,865	2,868	2,865	2,839	2,839	2,839	2,839	2,867	2,866
R-squared	0.020	0.019	0.020	0.005	0.005	0.005	0.004	0.019	0.017

Notes: Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 5: Tenure Security – Female headed household

Variables	disputecount	villhh_encroach	elite_encroach	neighvill_encroach	chief_reallocateh	headman_reallocate	family_encroach	dispute
Lagged	0.105* (0.0536)	0.0671*** (0.0140)	0.0464*** (0.0148)	0.0392*** (0.0149)	0.0563*** (0.0147)	0.0315** (0.0160)	0.0445*** (0.0158)	0.127*** (0.0192)
fhh_baseline	0.0263 (0.215)	0.0247 (0.0819)	0.000203 (0.0689)	-0.0826 (0.0754)	0.0332 (0.0777)	-0.0323 (0.0738)	-0.0742 (0.0803)	-0.00274 (0.0225)
Saili	0.242 (0.208)	0.127** (0.0643)	0.102** (0.0507)	0.0532 (0.0539)	0.0942 (0.0704)	0.0670 (0.0525)	0.0407 (0.0768)	-0.00277 (0.0158)
Linear combination - Saili	-0.00875 (0.280)	0.160* (0.0863)	0.0438 (0.0858)	0.135 (0.0894)	0.0669 (0.0970)	0.0629 (0.0844)	-0.0334 (0.115)	-0.0131 (0.0225)
Land Tenure	-0.126 (0.0979)	0.118* (0.0691)	0.103** (0.0512)	0.109** (0.0519)	0.109 (0.0697)	0.0779 (0.0519)	0.103 (0.0644)	0.00109 (0.0166)
Linear combination - Land tenure	-0.0322 (0.324)	0.129 (0.0931)	0.114 (0.0761)	0.161* (0.0863)	0.123 (0.0882)	0.173** (0.0767)	0.140 (0.105)	-0.00282 (0.0252)
Agroforestry	-0.0356	-0.0100	-0.00521	-0.0155	-0.0142	0.000764	-0.0110	0.00946

	(0.101)	(0.0738)	(0.0635)	(0.0615)	(0.0795)	(0.0580)	(0.0670)	(0.0169)
Linear combination - Agroforestry	0.0614	-0.111	-0.153	-0.0564	-0.107	-0.109	-0.151	0.00775
	(0.278)	(0.114)	(0.111)	(0.112)	(0.106)	(0.103)	(0.120)	(0.0270)
Agroforestry + Land tenure	0.281	0.0762	0.0319	0.0507	0.0904	0.0462	0.0783	-0.00676
	(0.189)	(0.0657)	(0.0523)	(0.0518)	(0.0652)	(0.0492)	(0.0627)	(0.0167)
Linear combination - Agroforestry + Land tenure	-0.0563	0.170*	0.124	0.195**	0.101	0.105	0.152	-0.0150
	(0.250)	(0.0869)	(0.0775)	(0.0849)	(0.0867)	(0.0799)	(0.107)	(0.0237)
c.nonrandom#c.fhh_baseline	-0.251	0.0334	-0.0584	0.0820	-0.0272	-0.00407	-0.0741	-0.0103
	(0.335)	(0.105)	(0.0982)	(0.0966)	(0.106)	(0.0988)	(0.120)	(0.0273)
c.t_tenure#c.fhh_baseline	0.0940	0.0106	0.0115	0.0517	0.0138	0.0953	0.0364	-0.00391
	(0.334)	(0.112)	(0.0856)	(0.0941)	(0.102)	(0.0904)	(0.104)	(0.0296)
c.t_agro#c.fhh_baseline	0.0970	-0.101	-0.147	-0.0409	-0.0928	-0.110	-0.140	-0.00172
	(0.288)	(0.140)	(0.129)	(0.129)	(0.124)	(0.121)	(0.124)	(0.0321)
c.t_agroXtenure#c.fhh_baseline	-0.337	0.0939	0.0916	0.145	0.0108	0.0589	0.0733	-0.00822
	(0.314)	(0.108)	(0.0937)	(0.0967)	(0.104)	(0.0927)	(0.112)	(0.0268)
Constant	1.052***	5.234***	5.393***	5.443***	5.238***	5.489***	5.334***	0.0650***
	(0.0883)	(0.0913)	(0.0910)	(0.0916)	(0.0930)	(0.0950)	(0.0947)	(0.0127)
Observations	187	2,868	2,868	2,868	2,866	2,868	2,867	2,864
R-squared	0.080	0.020	0.013	0.012	0.013	0.010	0.013	0.025

Notes: Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 6

Table 6: Agroforestry - All households

Variables	% of field planted with agroforestry trees	% of field planted with agroforestry trees - bin
Lagged	0.287*** (0.0330)	0.422*** (0.0269)
Saili	0.0886*** (0.0209)	0.215*** (0.0415)
Land tenure	0.00814 (0.0174)	0.00400 (0.0377)
Agroforestry	0.139*** (0.0205)	0.303*** (0.0413)
Agroforestry + Land tenure	0.146*** (0.0188)	0.301*** (0.0381)
L.agroforest_bin	-	-
Constant	0.0844*** (0.0113)	0.198*** (0.0270)
Observations	2,853	2,870
R-squared	0.097	0.154

Notes: Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 7

Table 7: Agroforestry -Female headed households

Variables	% of field planted with agroforestry trees	% of field planted with agroforestry trees - bin
Lagged	0.287*** (0.0334)	0.421*** (0.0270)
fhh_baseline	-0.00545 (0.0155)	-0.00893 (0.0336)
Saili	0.0945*** (0.0229)	0.237*** (0.0473)
Linear combination - Saili	0.0753 (0.0753***)	0.164 (0.164***)
Land Tenure	0.0103 (0.0179)	0.0182 (0.0409)
Linear combination - Land tenure	0.00316 (0.0267)	-0.0314 (0.0503)
Agroforestry	0.139*** (0.0229)	0.313*** (0.0454)
Linear combination - Agroforestry	0.141*** (0.0287)	0.281*** (0.0580)
Agroforestry + Land tenure	0.135***	0.291***

	(0.0202)	(0.0411)
Linear combination - Agroforestry + Land tenure	0.181*** (0.0315)	0.329*** (0.0539)
c.nonrandom#c.fhh_baseline	-0.0191 (0.0239)	-0.0730 (0.0533)
c.t_tenure#c.fhh_baseline	-0.00714 (0.0249)	-0.0495 (0.0495)
c.t_agro#c.fhh_baseline	0.00211 (0.0305)	-0.0318 (0.0594)
c.t_agroXtenure#c.fhh_baseline	0.0464 (0.0330)	0.0371 (0.0536)
Constant	0.0858*** (0.0118)	0.200*** (0.0285)
Observations	2,853	2,870
R-squared	0.098	0.156

Notes: Robust standard errors in parentheses
: *** p<0.01, ** p<0.05, * p<0.1





Figures

Figure 1

Figure 2. Visual of the Randomization of TGCC Treatment Groups

Four chiefdoms eligible for chiefdom-level tenure security intervention.

Villages within the chiefdoms were randomized into four treatment arms.

-  Agroforestry Intervention
-  Land Tenure Intervention
-  Agroforestry + Land Tenure
-  Control

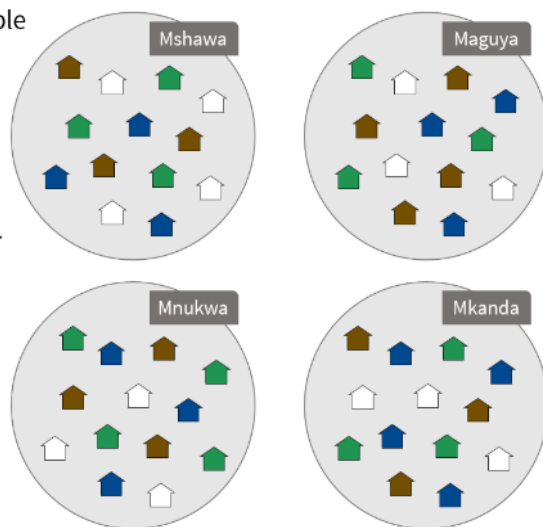


Figure 2

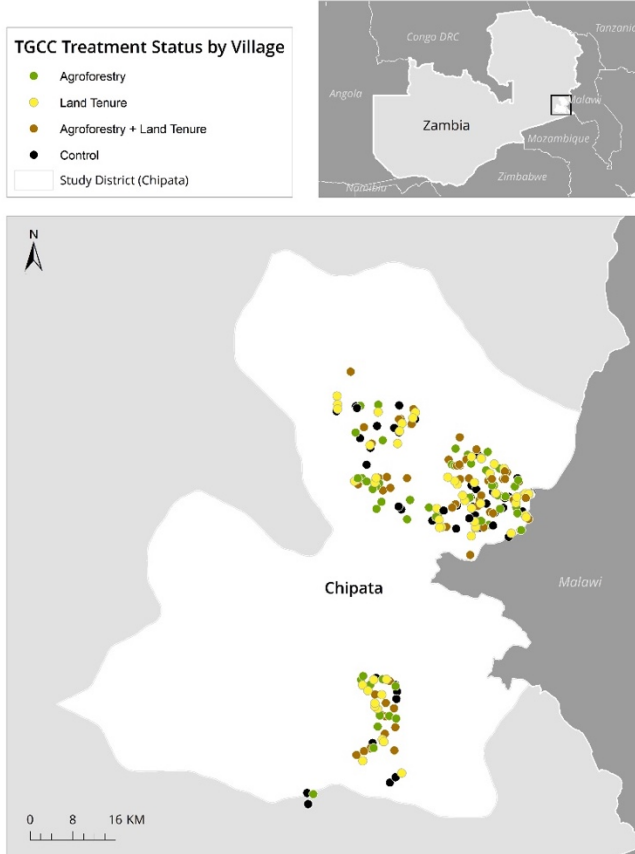


Figure 3

Figure 3: Treatment effect on tenure security—Pca indices

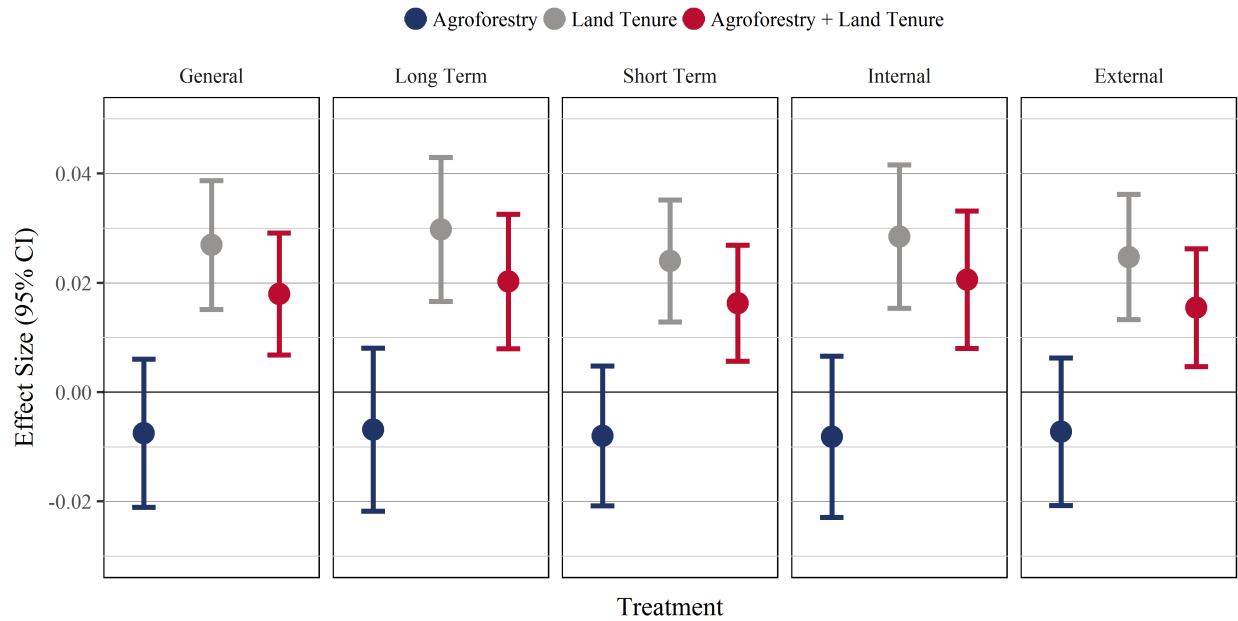


Figure 4

Figure 4 Treatment Effect on Tenure Security—Encroachment Actors

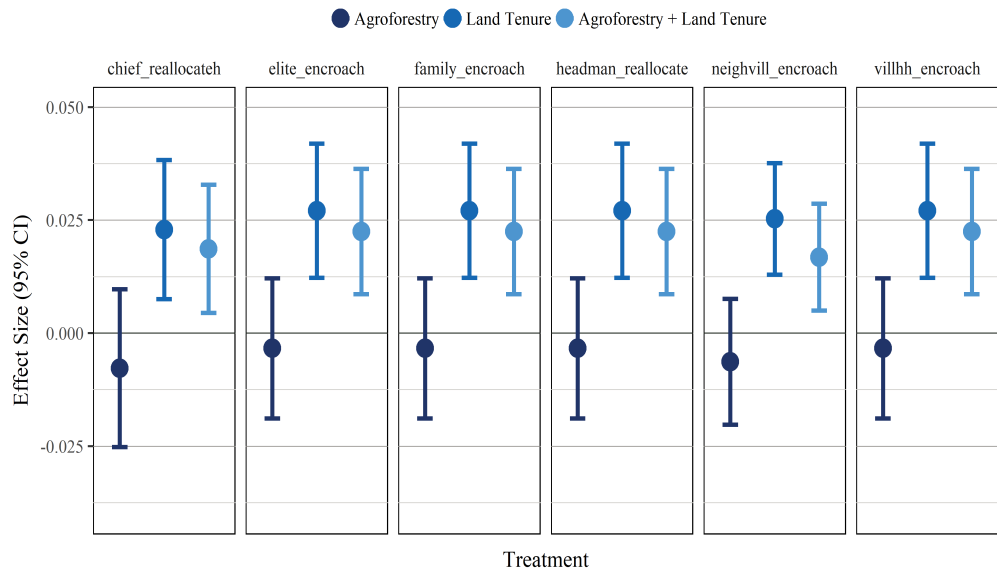


Figure 5

Figure 5 Treatment Effect on Tenure Security—Dispute

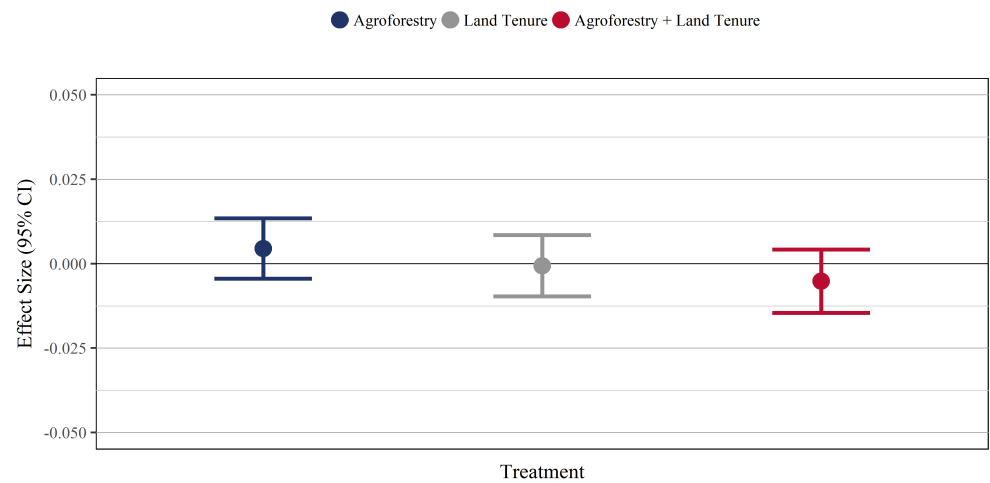


Figure 6

Figure 6: Treatment effect on Agroforestry Uptake

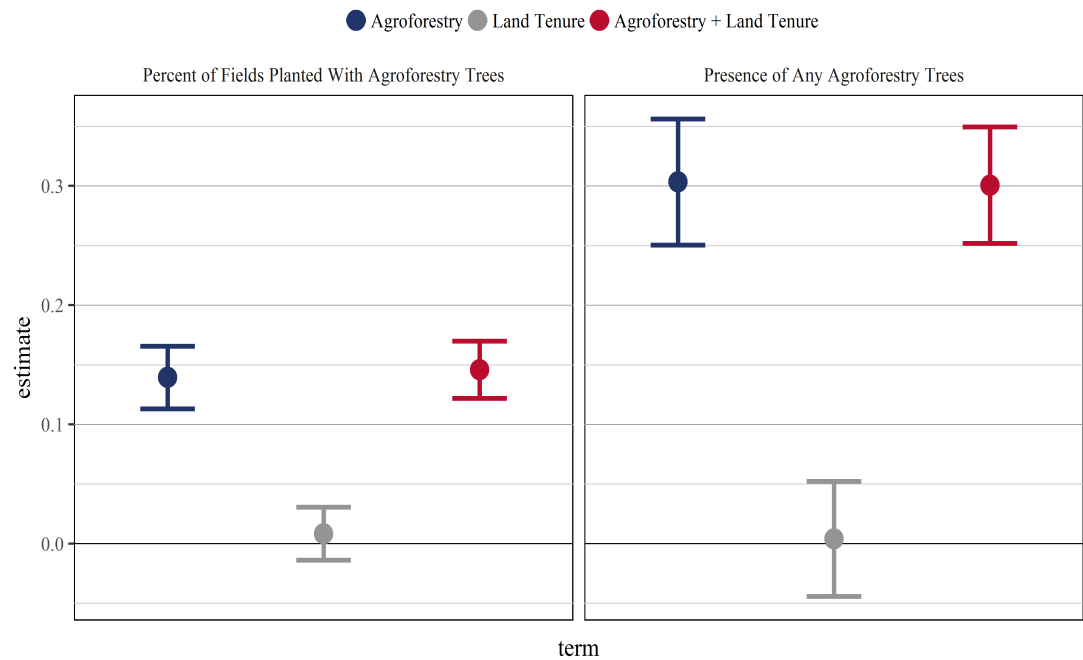


Figure 7

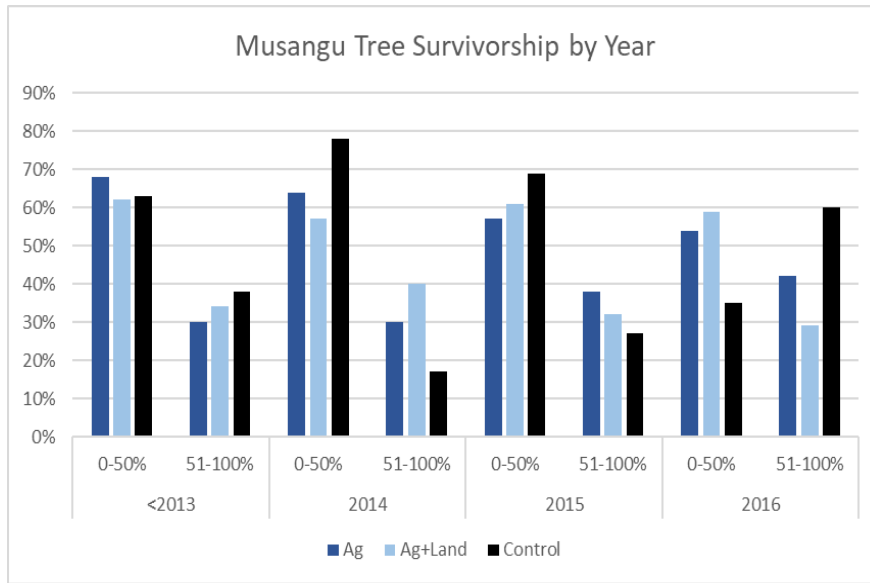


Figure 7: Musangu Survivorship by Year

Figure 8

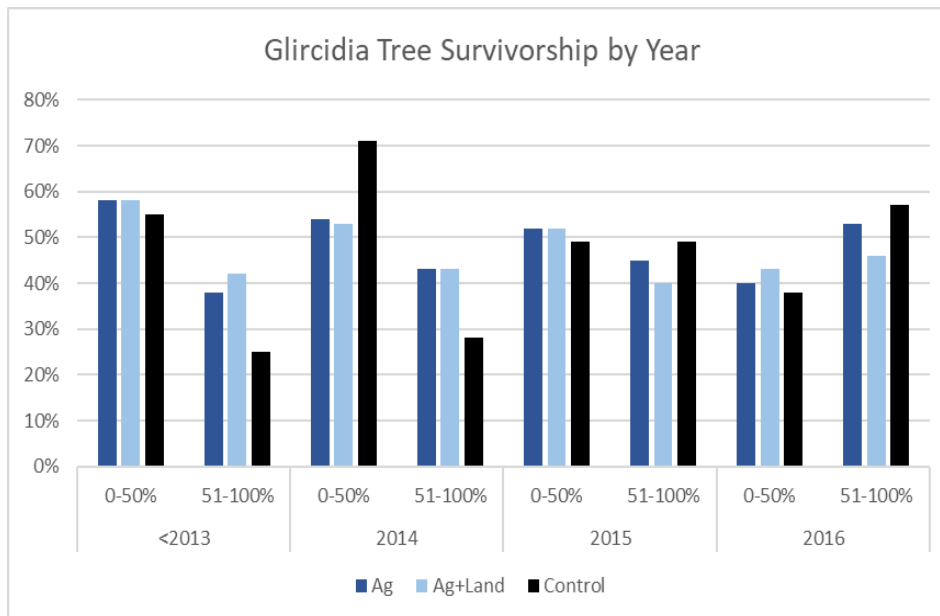


Figure 8: Gliricidia Survivorship by Year

Figure 9

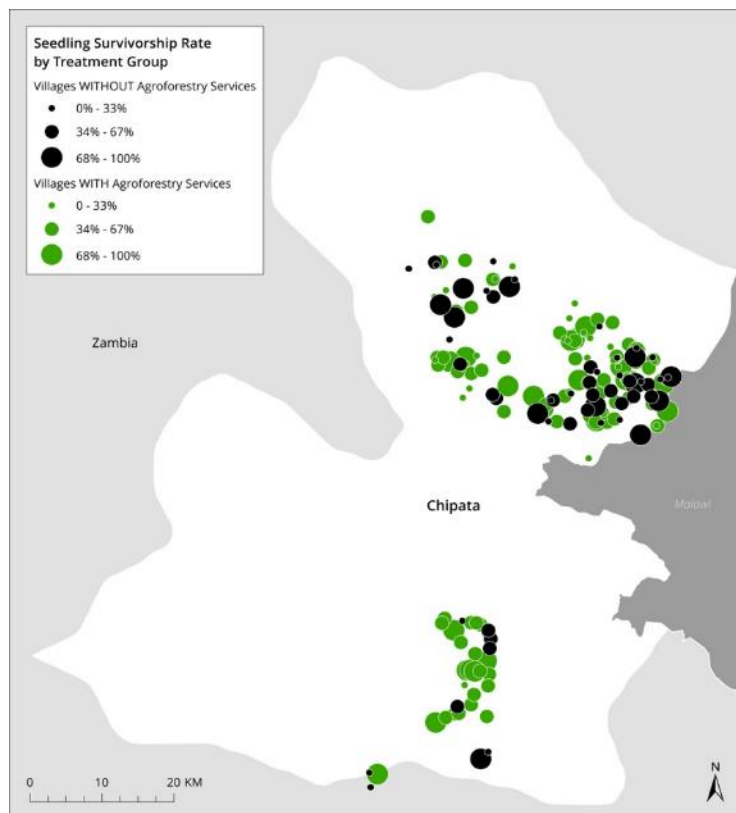


Figure 9: Seedling survivorship rate by treatment group

Figure 10, 11

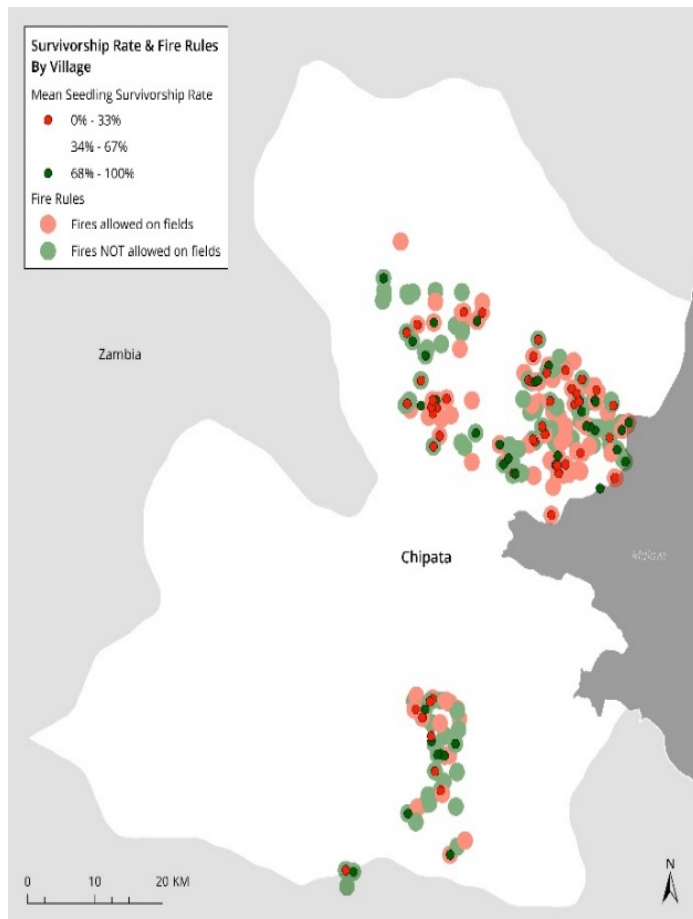


Figure 10: Survivorship rate and fire rules by village

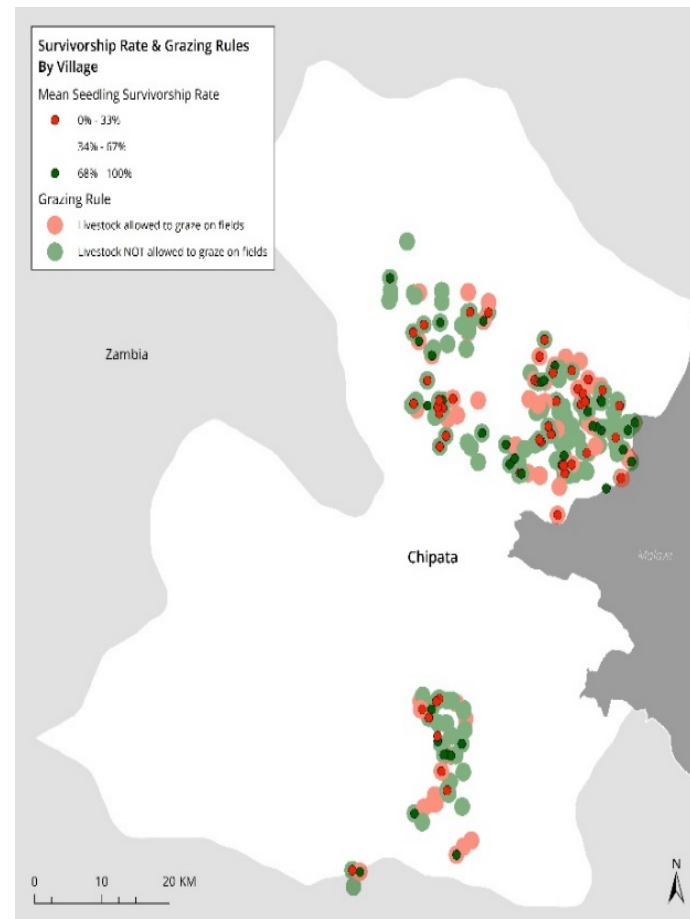


Figure 11: Survivorship rate and grazing rules by village