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DOES STRONGER LAND TENURE SECURITY INCENTIVIZE SMALLHOLDER CLIMATE-SMART AGRICULTURE? UNDERSTANDING DRIVERS OF AGRICULTURAL INVESTMENT IN ZAMBIA'S EASTERN PROVINCE

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Abstract

Land tenure insecurity is hypothesized as an underlying barrier to agroforestry uptake, but few studies have demonstrated a definitive link between improved tenure security and changing agroforestry practices. This paper provides insights into the influence of tenure security on the adoption of climate-smart agriculture in Zambia, with a focus on agroforestry and land-related investment outcomes. We draw on field-level data across 3,437 households and 293 villages in Zambia's Eastern Province, drawn from the 2014 baseline survey of an ongoing impact evaluation of the USAID Land Tenure and Resource Management Office's Tenure and Global Climate Change project in Zambia. We characterize perceived tenure security over household smallholdings under Zambia's prevailing juxtaposition of state and customary tenure systems; identify determinants of stronger tenure security; and assess the role of perceived land tenure security in shaping household-level land investments and agroforestry uptake. Results suggest high tenure security in the study villages overall, but highlight the role of prior field-level disputes in promoting tenure insecurity and the likelihood of agroforestry uptake. Using an assurance-based measure of tenure security we find a small positive effect of tenure security on costly and longer return time land investments, but not on shorter return investments, or agroforestry specifically.

Key Words: agroforestry; climate-smart agriculture; land tenure security; randomized control trial; smallholder land investment

Introduction

As climate change vulnerabilities and impacts continue to accrue in sub-Saharan Africa, the past decade has seen a resurgence in agroforestry efforts – and particularly the planting of fast-growing nitrogen-fixing trees as a form of climate smart agriculture – aimed at contributing to dual food security and climate change adaptation improvements for resource-poor farmers. Small-scale studies have amply demonstrated agroforestry's potential for improving soil fertility, crop yields, and a range of additional benefits on smallholders' farms (Franzel et al 2001; Mbow et al 2014). However, its uptake by smallholder communities across much of sub-Saharan Africa has remained persistently low. An abundance of literature highlights a range of contributing factors, including cash and resource constraints, inaccessibility of agricultural inputs, incompatible land management practices, such as land preparation by fire and livestock browsing, and insecure tenure rights, as well as disincentives driven by cultural practices, such as matrilineal inheritance (Mercer 2004).

The role of land tenure insecurity as a barrier to wider agroforestry uptake has long been hypothesized as a key underlying factor, though there are few studies that have been able to demonstrate a definitive link between improved tenure security and changing agroforestry practices (Arnot et al 2011). It is also unclear to what extent insecure tenure acts as an important barrier to climate-smart agricultural practices across different socio-economic, institutional, biophysical, and related contexts. To date, no clear consensus has emerged from empirical studies across varying sub-Saharan Africa contexts on whether and how stronger land tenure security may, in general, incentivize farmer decision-making and pursuit of different land investment strategies on their farms (Place 2009). However, opportunities to rigorously test this supposition have also been limited, given the substantial challenges associated with piloting tenure interventions on the continent.

This paper aims to provide insights into the role of tenure security on the adoption of climate-smart agriculture in Zambia, with a focus on agroforestry adoption and land-related investment outcomes. We draw on data across 3,500 households and 290 villages to investigate relationships among perceived land tenure security, socio-economic and demographic characteristics, cultural practices, and farmers' willingness to invest in climate-smart agricultural techniques, including agroforestry. Our analyses (1) characterize perceived tenure security over household smallholdings under Zambia's prevailing juxtaposition of dual state and customary tenure systems (2) identify household-level determinants of stronger tenure security; (3) quantify the role of perceived land tenure security in shaping household-level land strategies and preferred land investments under the current status quo; and (4) examine drivers of differences in investment, agroforestry uptake, and conservation farming practices across key subgroups of interest: female-headed and otherwise marginalized households. Study data are drawn from the 2014

baseline survey of an ongoing prospective impact evaluation (IE) of the USAID Land Tenure and Resource Management (LTRM) Office's Tenure and Global Climate Change (TGCC) project in Zambia. The TGCC project pilots a tenure intervention alongside climate-smart agriculture activities in Zambia's Eastern Province to test and quantify the relative importance of secure tenure in promoting the adoption of climate-smart agriculture. The overarching objective of USAID's TGCC pilot in Zambia is to inform policies aimed at promoting the successful uptake and adoption of climate-smart land management techniques and natural resource management technologies.

The ensuing paper is structured as follows: We first present an overview of issues and conceptual framing around land issues, tenure reform and smallholder agriculture in sub-Saharan Africa. We highlight existing empirical evidence and knowledge gaps, particularly around the role of tenure security in incentivizing forms of climate-smart agriculture. We briefly summarize contemporary trends in donor investments into tenure security on the continent and describe the TGCC project. Research questions, data collection methods, and our empirical strategy are described in the methods sections. We conclude with a discussion highlighting our results on determinants of tenure security and the role of tenure security in facilitating land-related investments, new contributions from this study, and engagement with the existing literature around the role of land tenure security in promoting climate-smart agriculture.

Agroforestry Benefits and Factors Influencing Adoption

Agroforestry activities are widely perceived as a longer-term sustainable land use practice that can help achieve a range of rural development objectives related to improved land use and farmer livelihoods. The adoption of nitrogen-fixing trees has been seen as particularly important as a strategy to combat widespread soil fertility declines and declining food production throughout sub-Saharan Africa (Giller et al. 1997; Scoones and Toulmin 1999; Ajayi and Kwesiga 2003). Decades of existing research points to a range of realized or expected farmer benefits from agroforestry investment, including increased crop productivity and reduced variability in yields through such outcomes as increased soil fertility; increased livelihoods from higher and more reliable farm income; risk smoothing through crop diversification; and additional direct benefits provided by trees on farms, such as fuel, wood, or fodder (Franzel, Coe, Cooper, Place, & Scherr, 2001; Mbow, Van Noordwijk, et al., 2014; Mercer, 2004).

Agroforestry can also act as a mechanism for diversification of a farming portfolio. Farmers may use trees to complement rather than replace their crop-planted acreage, for example, through nitrogen-fixing legumes that provide additional nutrients to the soil. They may use trees to improve soil management in order to improve yields or reduce risk. In more recent years, heightened awareness of the projected negative effects of climate change across the region has promoted enhanced interest and effort in

expanding agroforestry efforts in sub-Saharan Africa. Advocates of this approach cite it as a type of longer-term sustainable land use 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, Van Noordwijk, et al., 2014). However, several barriers to widespread agroforestry adoption persist.

The broader literature on farmers' adoption of new technologies indicates that these decisions are influenced by a range of factors, including labor availability, credit, tenure, farm size, risk and uncertainty, human capital, and supply constraints of complementary inputs (Feder et al. 1985). However, prior agroforestry research has tended to emphasize identifying the biophysical properties and benefits of agroforestry systems rather than examining cultural, demographic, and socioeconomic factors, as well as local policies and institutional arrangements that might impede wider adoption (Ajayi, 2007; Place et al. 2001; Sirrine, Shennan, & Sirrine, 2010). Farmers' decisions to adopt agroforestry may also include the financial outlay required, explicit and implicit investments in labor, and the extent to which farmers have the necessary technical knowledge and skills to establish trees on farms and effectively manage an agroforestry production system. Compared with annual crops, trees require longer periods to produce mature crops — five to eight years for some common agroforestry species. These longer time frames may influence the decisions of farmers to engage in such planting, especially given that decisions to plant trees may be influenced by perceived tenure security and expectations about access to and control of the land over longer planning horizons.

Despite decades of agroforestry research advancements, low adoption rates across the tropics continue to serve as a substantial barrier to wider realization of agroforestry benefits, as well as to theorized improvements in rural development outcomes (Franzel et al., 2001; Mercer, 2004). Existing syntheses of agroforestry adoption studies focus on five broad categories of factors: farmer preferences, resource endowments, market incentives, biophysical factors and risk/uncertainty (Pattanayak, Mercer, Sills, & Yang, 2003). Farmer uncertainty over land security has particular implications for the likelihood of undertaking investments with future payoffs, especially those that rely on a long time horizon to realize benefits. Thus, it is hypothesized that a lack of security effectively serves as an agroforestry adoption disincentive for farmers, who must factor in the required upfront financial, labor, and other investments, as well as delays of several years to realize expected soil fertility, yield, livelihoods, and other benefits (Mbow, Smith, Skole, Duguma, & Bustamante, 2014).

Tenure Security and Agricultural Investment

There is a small but growing empirical evidence base linking secure tenure to increased productive investment and agricultural productivity, including in sub-Saharan Africa (Deininger, Ali, & Alemu, 2011; Deininger and Jin 2006; Goldstein and Udry 2006). However, several other studies in a range of African countries have found no relationship between the two (Place 2009). The overall knowledge base remains inconclusive, and results differ widely across different contexts and measures of tenure security that are used. In broad terms, secure property rights are theorized to contribute to economic development primarily through three potential mechanisms, although the evidence base for each varies: (1) reduced risk of encroachment and expropriation, which in turn lowers a smallholder's cost to protect property and enables increased productive investment; (2) facilitating market transactions through land transfers to more efficient users; and (3) allowing land to be used as collateral in financial markets (Feder 1988). In this paper, we are primarily concerned with the first of these pathways.

We also note that there is considerable debate regarding what constitutes 'secure tenure' and acknowledge that this may be represented through a range of de jure or de facto forms across different country, socio-cultural and policy contexts. A detailed discussion of this is outside the scope of this paper, however we highlight that for sub-Saharan Africa, several scholars have argued that existing customary tenure systems may already provide a high degree of tenure security (Lawry et al. 2014), thus raising a particular debate around the role and impact of new tenure interventions on the continent. Indeed, much existing work suggests that the pre-existing informal and typically customary systems provide a relatively high degree of tenure security, as defined by long-term use rights accompanied by important transfer rights, such as inheritance (Adams 2001; Bruce and Migot-Adholla 1994; Sjaastad and Bromley 1997). However, intra-community and even intra-household rights often vary substantially within these systems.

To date, no clear consensus has emerged across widely varying contexts on whether and how stronger land tenure security may, as a whole, incentivize farmer decision-making and pursuit of different land investment strategies on their farms (Lawry et al. 2014; Place, 2009). It is also unclear to what extent insecure tenure acts as an important barrier to climate-smart agriculture practices across different socio-economic, institutional, biophysical, and related contexts. Early tenure interventions often focused on formalizing customary land systems through titling. In sub-Saharan Africa, recent literature has paid particular attention to the role of land titles as a means to strengthen smallholder perceptions over security of tenure and to alter their land use decision-making strategies towards longer-term land investments (Smith, 2004). Some studies have found strong evidence of positive impacts in particular locales, such as recent tenure reforms in Ethiopia and Rwanda (Holden et al 2009; Deininger, Ali, & Alemu, 2011; Bezu and Holden 2014; Santos et al 2014). However, despite best efforts, evidence suggests that at least some early tenure intervention efforts on the continent, particularly around land titling, led to unintended

negative consequences, such as reinforcing elite capture of land and land governance processes at the expense of more disempowered groups, such as women and migrants (Baland and Francois 2005; Firmin-Sellers and Sellers 1999; Sjaastad and Bromley 1997).

While such outcomes might suggest a need to carefully examine the assumptions and theory underlying tenure interventions, and perhaps a dampening of such approaches, at the same time, there is also considerable evidence that emerging global forces may be undermining existing property rights dynamics in sub-Saharan Africa in ways that could further marginalize vulnerable groups. These include, for example, land disputes around intra-family inheritance rights and between owners and tenants attempting to increase their land claims (Adams 2001; Deininger 2003). Evidence from Zambia suggests that as many as one-fifth of households have been involved in a land dispute (Place 1994). Furthermore, Deininger (2003) notes that many households on the continent continue to expend resources to defend their land claims, such as by planting trees on boundaries and fencing. On the whole, much work suggests that many landholders on the continent desire stronger tenure security than they derive under existing tenure systems. There is also growing concern that existing informal tenure systems (and, indeed, many formal systems) in Africa may be unprepared to manage the current move towards greater privatization of land, nor its associations with increased land competition in the presence of emerging macro-trends, such as population growth, growing food and fuel demands, rapid urban expansion, and tighter global teleconnections around markets, financial flows, and population movements (Deininger et al. 2011; Meyfroidt and Lambin 2011).

Contemporary Trends in Donor-Supported Land Tenure Interventions

To that end, the United States Agency for International Development (USAID) and other development partners, including the World Bank, have more recently supported a new generation of tenure interventions that aim to strengthen the existing informal and often customary tenure rights of individuals, families, and communities, particularly in sub-Saharan Africa. These interventions have moved away from the early emphasis on traditional freehold titles and instead typically aim to formally recognize and document existing informal, often customary, rights, including through the provision of "certificates" that recognize the land use rights of households and communities but typically cannot be used as legal collateral or to permanently alienate the land. Many of these interventions, for example in Ethiopia, Ghana, Rwanda, Tanzania, and elsewhere, have also focused on building the capacity of local formal or informal institutions to effectively govern land and other natural resource rights.

Given the recent nature of many of these interventions, and the current state of knowledge on impacts, questions remain around the efficacy of several activities hypothesized to strengthen farmer tenure

security over their farmholdings. In addition, the extent to which strengthened land tenure security incentivizes farmers to undertake longer-term sustainable land use investments, such as agroforestry, also is currently unresolved.

Zambian land tenure and administration context

While it does not specifically define property rights in land, the Zambian Constitution of 1991 does recognize individual property rights and protects those rights against deprivation by the government, except in cases authorized by law. The 1995 Lands Act of Zambia vests all land in the Zambian President and recognizes only two types of land: state and customary land. State land includes all land occupied by the national government, as well as land held privately by individuals, who lease the land from the state, including those lands that previously were freehold estates. In contrast, customary lands are not registered with the government and are largely administered outside the statutory and official realm of Zambian government by customary chiefs and their representatives. State land is estimated to cover as little as 6% of all land in the country, while customary land represents the remainder. Estimates of customary land extent in Zambia range from 66 to 95% of total land; however, the exact area is unknown, as there has been no comprehensive land rights mapping exercise in the country since Independence (Evtimov and Muzyamba 2014).

Although legally all lands in Zambia are vested in the President, in practice and by law under the Lands Act, customary lands in Zambia fall under the authority of customary chiefs (Adams 2003). The chiefs exercise this authority through their headmen/women (often more than 300 per chiefdom) and are advised by a council of indunas consisting of a dozen to a few dozen individuals. At the local level, the headmen/women, who administer land on behalf of the chief in the village within their domain, make local land administration decisions, including by granting use and occupancy rights, regulating transfers of land, controlling the use of communal land, and hearing disputes (Mulolwa 2006).

While the Lands Act does legally recognize customary land rights, it does not directly provide for their formal documentation (though neither does the Act explicitly forbid any such documentation) (Kajoba 1998; Sambo 2015). Customary lands can, however, be converted into statutory lands eligible for private leasehold with the consent of chiefs (Adams 2003).

Threats to customary land tenure security

Once converted to statutory tenure, leasehold titles in Zambia can be used as legal collateral. Interest in such conversions, which reflect the growing recognition of land as an economic asset, has been particularly driven by large landholders (Roth 1995), including the growing class of African elites

residing in urban centers. Other threats to customary tenure include the perceived weakening of customary authorities vis-à-vis the state and of ties between urban populations and rural customary authorities (Adams 2003). Recent household surveys in Zambia suggest that such processes, including the sale or transfer of customary lands to urban elites, may represent a dominant threat to agricultural growth in the country (Jayne et al. 2014).

Uncertainties over land allocation processes within villages are also hypothesized to contribute to ongoing land conflicts and tenure insecurity. Insufficient access to arable land has been shown to be a driver of continued impoverishment in rural areas of Zambia (Jayne, T.S., B. Zulu, G. Kajoba, 2009). Prior research points to large variation in farmer landholdings among village households, significant numbers of land-constrained households even in villages where unallocated land is present, and widely varying perceptions around land availability and ease of acquisition of land for farm expansion. Although many factors are likely to feed into such variations, key characteristics have been found to include relations to local headmen; distance to markets, roads and district administrative centers; and whether a household is female-headed (Jayne, T.S., B. Zulu, G. Kajoba, 2009).

The Tenure and Global Climate Change (TGCC) Project and Impact Evaluation

USAID's Tenure and Global Climate Change (TGCC) project is piloting a set of tenure and agroforestry interventions that aim to increase adoption of climate-smart agriculture (CSA) practices by strengthening customary land governance and agroforestry extension over two years (2014-2016) in five chiefdoms of Chipata District, in Eastern Province. TGCC's activities in Zambia contribute to the broader USAID goals of improving the enabling governance environment and reducing rural poverty through increased smallholder agriculture productivity, improved natural resource management, and improved resilience of vulnerable households.

The TGCC activities in Zambia aim to increase tenure security at the chief, village, and household level, as well as increase farmer knowledge of agroforestry practices and access to agroforestry seeds and related inputs. The pilot is designed as a randomized control trial, with villages across four chiefdoms selected randomly to receive one of four treatment groups (agroforestry only, land tenure only, combined agroforestry and land tenure, and control). Since the village and household level tenure activities require basic engagement with the chiefs, a fifth treatment arm was added in a fifth chiefdom to explore the impact of the agroforestry interventions alone.

Tenure Intervention

TGCC's tenure intervention targets 138 randomly-assigned villages in four chiefdoms in the Chipata District of Eastern Province. The chiefdom level tenure activities aim to increase transparency of land allocation, administration, and decision processes and to strengthen smallholder rights to land and trees. Specific activities include facilitated dialogues on land use management and improved tenure governance with chiefs and their indunas (advisory councils); promotion of transparency over decision-making related to land allocation and land disputes; and providing basic training in administrative support.

Village level tenure activities consist of establishing Village Land Committees, conducting participatory mapping, and facilitating the issuance of customary land certificates. Specific activities include increasing the democratization of customary land management process through the establishment of Village Land Committee institutions within villages; documenting rules and regulations and strengthening land management systems through Village Land Committees (VLC); participatory mapping to develop a common village map to aid headmen when allocating land; support into dissemination of land management rules that are agreed at the chief level; and building the capacity of headmen, indunas, and VLCs to implement basic land administration processes, including the fair adjudication of land disputes and the administration of customary land certificates.

In chiefdoms where the chief has given consent for customary land certification, the project will encourage households within villages selected for the tenure intervention to obtain customary land certificates and give them the opportunity to receive information on land administration and dispute resolution services. Although the customary land certificates are issued to households, based on existing experience in Zambia, it is anticipated that once a village has been selected for the tenure intervention most, if not all, households belonging to that village will pursue land certificates. These household-level activities include NGO paralegal extension agents to provide households with information on their land rights, land certification, and dispute resolution and documentation of land rights through a parcel-based process led by VLCs with support from NGO paralegal extension agents and traditional authorities.

Agroforestry Intervention

TGCC's agroforestry intervention targets roughly 200 randomly-assigned villages across five chiefdoms in the Chipata District of Eastern Province, four of which overlap with the tenure intervention chiefdoms. Through the TGCC agroforestry intervention, an extension agent provides support related to planting and establishment of three different nitrogen-fixing plants on croplands: Msangu (Faidherbia albida), an Acacia tree native to the region; Gliricidia sepium, a fast-growing leguminous shrub; and pigeon pea (Cajanus cajan).

The agroforestry intervention is primarily focused on activities at the village level but also includes basic interactions with chiefs at the chiefdom level in the four chiefdoms where tenure interventions are also implemented. In these four chiefdoms, the project couples chief level agroforestry involvement with tenure interventions at the chiefdom level related to land use management and transparent land administration. Thus, by default, all four of the chiefdoms involved in the tenure intervention are subject to some high-level chiefdom intervention. At the sub-chiefdom level, extension agents are expected to visit treatment villages at least three times throughout the first year and at least twice in the subsequent year, at least once prior to the rainy season and at least once after planting. Under the extension agent structure, the agroforestry partner will be able to reach any interested farmers at the village level that would like to participate in trainings and/or benefit from high-quality agroforestry seeds.

The impact evaluation of the TGCC program is also funded by USAID and implemented under the Evaluation, Research and Communication (ERC) project, with baseline data collection completed in August 2014 and an endline survey expected to be completed in August 2017. Given the small number of chiefdoms targeted by TGCC's pilot interventions in Zambia, the impact evaluation focuses on identifying the effects of the village and household level interventions.

Methods

TGCC Project and Baseline Data Collection

TGCC is designed as a four-arm cross-cutting randomized control trial (RCT) implemented at the village level. Study arms consist of (1) a village-level agroforestry intervention that seeks to sensitize farmers on the potential economic gains of agroforestry and to improve access to extension services and inputs; (2) a village-level land tenure intervention designed to strengthen tenure security, including by improving access to customary land documentation; (3) a joint intervention consisting of villages that receive both the agroforestry and land tenure intervention; and (4) a control group.

Baseline data collection for the TGCC IE consists of a household survey conducted across 3,500 households across 290 villages in five chiefdoms located in the Chipata District of Zambia's Eastern Province; a headperson survey; and key informant interviews of agricultural extension officers and individuals with extensive involvement in local land issues (e.g. Indunas and village elders). In addition, we draw on data from focus group discussions conducted with women, youth, and land-constrained households in the same communities. A multi-stage sampling technique was used to select household respondents, with sample stratification by female-headed respondents, wealthier households, and households at higher risk of social marginalization.

Research Questions and Outcome Indicators

Four overarching research questions drive our analyses:

1. How secure are the rights of Eastern Province smallholders over the land they use under Zambia's prevailing dual customary and state tenure system, and what are key characteristics associated with more land-secure households?
2. What are household level determinants of stronger tenure security?
3. What role does tenure security play in shaping household land use strategies and CSA investments (particularly with respect to agroforestry uptake and other land-related investments)?
4. How do these results differ for female-headed and poorer households?

Empirical Strategy and Analyses

We use three sets of mixed multi-level models to address the above research questions, focusing on determinants of tenure security, intensive land investment, and agroforestry, respectively. Existing studies employ several different ways to measure tenure security, and inconsistencies across definitions and measurements have been noted to contribute at least in part towards barriers to stronger knowledge around the role of tenure in smallholder land use decision making. Following Arnot et al (2011), we focus on characterizing tenure security via a household's perceived risk of dispossession, measured through their expectation of losing access to the parcel via reallocation or similar processes. We employ two measures to capture this risk at the field level and test both of them. The first measure is an index of the household's perceived risk of dispossession over the field, both in the immediate (next 1-3 years) and longer term (beyond 4 years) future, from six different groups: extended family members, other households within the village, households from neighboring villages, village headman, chief, or other elites from outside the village. The second measure reflects the number of seasons a household (HH) felt they could let the field lie fallow without worrying about it being reallocated to another household. Continuous responses were converted to an ordered categorical variable that reflects 0 (HH does not feel it can leave the field fallow without worrying about reallocation), 1 – 5 years (HH feels it can leave the field fallow for the short term future), or more than 5 years (continuous data ranged from decades to hundreds of years, reflecting that a HH feels it can leave the field fallow indefinitely without worrying about reallocation).

To test the relationship between tenure security and agricultural investments, we distinguish between and test three different types of investment outcomes separately. Our strategy is informed by the diverse effects of the role of tenure security that have been found on these different types of investment categories in existing studies across sub-Saharan Africa, even within a given a study location (Place 2009), which

suggests that tenure effects could be masked by indexing such investments together. We first draw on data regarding household use of live fencing, drip irrigation, or planting basins to indicate the field level presence of high cost or labor intensive field-level land investments with somewhat longer returns (Place 2009). Guided by existing literature, we hypothesize that resource intensive, long-term investments are more likely to occur on fields that households view as more tenure secure (Smith 2004; Place 2009). We distinguish these investments from other important field-level conservation agriculture investments that are not as time or labor intensive and tend to have shorter pay-off time frames (manuring, zero tillage, ridging or mounding), and we test those shorter term activities separately. Lastly, we explicitly test for determinants of a binary indicator of agroforestry adoption on the field.

Given the clustered nature of the data, with fields nested within households, and households within villages and chiefdoms, we use multi-level mixed effects regression models in order to correct for dependence among observations within the same cluster and exploit the variance within and across levels to more accurately determine the effects of key covariates on our outcome variables of interest (Rabe-Heskith and Skrondal 2008). We include household and village as random effects in our models, in order to explicitly take into account variation within and across these units. Given that our sample is drawn across a small number of chiefdoms, we control for chiefdom effects by including chiefdoms as fixed effects dummies. We run a mixed effects linear model for our continuous tenure outcome (tenure security index), and a random coefficient proportional odds model for the binary (agroforestry uptake) and ordered categorical (fallow length; long term investment; short term investment) outcomes.

We control for field level biophysical characteristics, location with respect to household, and farming practices and include a set of household-level socio-economic, demographic, and landholding factors and (where applicable) indicators for land disputes on the field, household connections to village and chief elites, method of field acquisition, farming practices, and extension exposure, as well as household level indicators of satisfaction, trust, and fairness around the land governance and leadership context in the village. We also test for heterogeneity of effects by three key groups of interest: female-headed households (we code households led by women who are widows, divorced, or separated as female-headed), land-constrained households (defined as households with < 1 ha of land), and poorest households (the bottom quarter of households according to an asset-based wealth index based on a principle components analysis of landholdings, house construction, livestock, and selected household assets).

We undertake several diagnostic steps to test our model specifications and determine final models, including use of likelihood ratio tests to guide covariate removal, and Bayesian information criteria to

select between similar models. We use the Durbin-Wu-Hausman test to assess the appropriateness of a random versus fixed effects model for the tenure security index. We did not find evidence for misspecification, indicating that the random-intercept model is appropriate for our data. We use residual diagnostics to examine potential outliers and assess normality assumptions for the village and household random intercepts and estimated field level residuals. Histograms and normal quantile-quantile plots of the estimated residuals were used to check for normal distribution of the random intercept and estimated field level residuals. Lastly, we note that conditional on the fixed effects covariates, we find that the tenure security index is only slightly correlated within the same village, and moderately correlated with the same village and household. We estimate that village and household random effects compose approximately 20% of the total residual variance.

Results

Data Description

We present broad socio-economic and demographic characteristics of households in the sampled villages and key summary statistics in Table 1. Table 1 also indicates key patterns around tenure security and related outcomes in our analyses across the sampled villages. Very few households (n=63, or < 2% of surveyed households) in the sample have actually experienced land dispossession (i.e., reallocation of a parcel for use by others outside the household), although the perceived risk of dispossession expressed by households, and measured in our tenure security index, is much higher. Actual dispossession events were fairly widely distributed across villages in the sample (55 villages, or 19% of those sampled), rather than clustered as common events within a small number of villages. Thus, it may be possible that the occasional dispossession event in a village, though rare, is sufficient to maintain some level of concern across households in the village. Concerns that field dispossession was likely or very likely ranged from 15 to > 25% of surveyed fields across the six different sources of dispossession on which respondents were surveyed. Across these different groups, households were most concerned about dispossession by chiefs for investment purposes, as well as from boundary disputes with other households within the village. In terms of actual land-related dispute experience, 26% of households had experienced at least one land conflict on one of their fields in the past 3 years (n=707 households), and prior disputes were recorded for 10% of fields surveyed (n=1007 fields).

In terms of land rights documentation, implementation of customary land certificates is currently very low, with only 1% of households holding some form of documentation over customary land that they use. Households also currently hold some form of paper documentation for 1% of fields (n=106). At the same time, the data reveal that households clearly desire more widespread documentation than the current status quo. Respondents state that they would like to acquire some form of documentation for 80% of

fields in the study (n= 7035). At the household level, 91% of households stated they would like to obtain such documentation.

With respect to field-level land investments, and agroforestry uptake specifically, the data in our sample indicate a currently low rate of agroforestry uptake. 11% of households (n= 383 respondents) currently practice agroforestry, and this is implemented across 5% of fields sampled in the study (n= 404 fields). Costly upfront land investments with longer time to returns were also generally uncommon, with planting basins being implemented on 10% of fields (n=910), live fencing on 1% of fields (n= 88), and drip irrigation on less than 1% of fields. For shorter return, less costly CSA investments, zero tillage was practiced on 8% of fields (n=748), manuring on 18% of fields (n=1569), and fallowing on 7% of fields (n=656). Other field-level shorter return land investments in this category were much more common, particularly the use of ridging (n=7530 fields, or 85%) and crop rotation (n=7266 fields, or 82%).

Determinants of tenure security

The results for the tenure security models are presented in Table 3 (Model 1). Using the indexed perceived risk of expropriation at the field level as an indicator of tenure security, we find significant effects of several field and household level variables on tenure security. The time length holding the field and main field use for subsistence rather than cash crops are both positively associated with greater tenure security. The association with subsistence fields could simply reflect that farmers in the study area are still primarily reliant on subsistence crops, and tend to plant crops on which they most depend on fields where they perceive their rights to be most secure. We find a strong negative effect of prior land conflict on perceived tenure security, and the existence of a prior dispute on the field has the largest effect size of any significant variable in our model. All other variables controlled for, the tenure security index score is increased by 0.43 points (indicating higher tenure insecurity) for households who experienced a prior dispute on the field. Field acquisition by allocation rather than family inheritance, more steeply sloped land, and poorer quality soils are also all associated with reduced tenure security. At the household level, greater total landholdings is associated with a slight increase in tenure insecurity. This result is somewhat counterintuitive, but given household concerns regarding expropriation by chiefs and outside investors, one possibility may be that households with larger holdings feel somewhat more vulnerable to such risks, or that farmers with access to more land are more likely to experience some form of conflict or other security reducing event on at least some of that land.

We find no effect on the tenure security index of household wealth status, education, residency in village, or connection to local or chief elites, nor is tenure security significantly different for female-headed households in our sample. Lastly, we find that one of the chiefdoms in the sample is associated with

significantly lower tenure security, although the magnitude of difference relative to other chiefdoms is small. This chiefdom is similar to others across many covariates, but it has a much higher proportion of neither strongly matri- or patri-lineal inheritance patterns amongst surveyed households. We suggest the significant chiefdom effect is likely due to this higher proportion of mixed or less strongly traditional inheritance patterns amongst households in that chiefdom, which may be associated with somewhat greater tenure uncertainty. As an additional indication of support, we note that the presence of a mixed inheritance pattern is significant in our model when we do not control for chiefdom, but drops out once the fixed chiefdom effects are added to the model.

We find a similar pattern of predictors when we use a proxy tenure security variable based on fallow time length for the field (Table 3, Model 2), which lends further consistency to our findings around key determinants of field-level tenure security in the sampled villages. The fallow length outcome variable indicates the categorical number of fallow seasons the household is comfortable implementing on the field before worrying about dispossession (categories are: no tenure security (0 fallow seasons); low tenure security (1-5 fallow seasons); and high tenure security (6 seasons to indefinitely, without worrying about risk of dispossession)). In that model, household relationship to the chief has the strongest positive effect on tenure security, corresponding to a 1.2 times greater odds of a field being in high tenure security category (meaning, the household is comfortable leaving the field fallow for 6 seasons through indefinitely, without worrying about dispossession) relative to the two lower tenure security outcome categories, when holding all other variables in the model constant. The household time length holding the field also has a positive effect on tenure security, with each additional year associated with a 1.01 increase in the odds of moving to a higher tenure category for the field, holding other variables constant. Prior disputes on the field again have a strong negative effect on tenure security. In our model, we find the odds of obtaining the highest tenure security category is 0.79 times lower when there has been a prior dispute on the field. More sloped fields, often an indicator of poorer quality land, are also negatively associated with tenure security in this model.

In contrast to Model 1, however, we find a negative effect of subsistence field use on the odds of obtaining a more secure tenure category in the fallow model, and a positive effect of poorer soil quality. A change to a poorer quality soil category at the field level is associated with a 1.06 increase in the odds of obtaining a more secure tenure category response for that field. It is possible that this result may also reflect household knowledge of fallowing needs and benefits for poorer quality soils, as well as the possibility that household responses here reflect a view that poorer quality land is less likely to be desirable for reallocation, irrespective of other factors.

Determinants of intensive land investments

The results for the long and short return time land investment models are presented in Table 4. The high upfront labor and cost investment model uses a binary outcome to indicate whether households undertake either live fencing, planting basins, or drip irrigation on the field (Table 4, Model 3). We find a strong positive effect of field size, and weak positive effects for household labor availability (as indicated by head or spouse hiring their labor out) and education level of the household, on the likelihood of these investments being implemented. The largest field in the household's portfolio is expected to have a 2.5 times higher odds of having any of these investments than other fields used by the household, indicating that households are more likely to undertake these investments on their largest field. A one unit increase in the household's labor availability (as indicated by hiring labor out), and in the years of education across all household members, are both associated with a 1.2 and a 1.05 times higher odds of investment implementation, respectively. Thus, all else being equal, households with more labor availability or formal education are slightly more likely to undertake these labor-intensive investments. Our results also indicate that households are less likely to undertake these investments on fields over which they perceive lower tenure security, though the effect is relatively small. In our model, the odds of intensive land investments are 0.91 times lower for each one unit increase in the tenure security index score for the field. Lastly, we find no association between indicators of household satisfaction around land governance in the village; a household's extension exposure, connections to elites, or residency time in the village; or head age, wealth status, or female-headedness, on the likelihood of undertaking these up-front intensive land investments.

For the less costly and shorter return time investments (Model 4), we again find a positive effect of field size, education level of the household and labor availability, though these effects on likelihood of investment are much smaller than for the long return investment model. We also find the likelihood of these shorter return and less costly investments is slightly lower for land-constrained households, and if the household has prior exposure to extension knowledge around climate smart agriculture. We find no effect of tenure security over the field on the likelihood of household implementation of the shorter return investments that we test in this model.

Determinants of agro-forestry

The results for the agroforestry adoption model are presented in Table 4, Model 3. Here, we explicitly model the likelihood of obtaining agroforestry on the field using a binary outcome variable for agroforestry planting. We include a similar set of field level predictors, household level socio-economic and demographic factors, as well as the household's perceived tenure security over the field, household satisfaction around land governance in the village, and agricultural extension exposure. We find four

significant predictors of increased likelihood of agroforestry uptake, all of which are household level factors. We find a strong positive effect of the field size on likelihood of agroforestry, with the largest field in the household's portfolio expected to have a 3.1 times higher odds of agroforestry planting. Other factors associated with a small but significant increase in the odds of obtaining agroforestry on the field are the amount of household labor available, head age, and the highest education level obtained by any household member. For each of these factors, a one unit increase is associated with a 1.09, 1.02, or a 1.05 times higher odds of obtaining agroforestry, respectively.

In terms of negative effects on agroforestry uptake, our results indicate that land-constrained households have a significantly lower likelihood of agroforestry uptake, while the household head's residency time in the village also has a negative though much smaller effect. In our model, land-constrained households have a 0.72 times lower odds of agroforestry uptake on any of their fields relative to non-land constrained households (those with total landholdings greater than 1 hectare). We find no significant effect of perceived tenure security over the field on the likelihood of agroforestry uptake in these baseline data, nor do we find any effect of governance indicators, agricultural extension exposure, female headedness, or asset-based measures of household wealth.

Discussion & Conclusion

Our results from this large-N sample contribute new insights into the status of tenure security among smallholder Zambian households and the influence of tenure security on the adoption of climate-smart agriculture in Zambia, with a focus on land-related investment outcomes and agroforestry adoption, specifically. In this discussion, we aim to highlight key messages emerging from our results, situate our findings within the existing empirical work around these issues, and delve into potential explanations for some of our key findings of interest. Our results contribute new information towards understanding whether and how documenting property rights and strengthening customary land governance might improve smallholder tenure security and, in turn, farmer decisions to engage in agricultural practices that may better meet dual food security and climate challenges forecasted for sub-Saharan Africa in coming decades.

Determinants of tenure security

We begin by noting that while smallholder tenure security has long been conceptualized as an important factor driving smallholder behavior across a range land use decisions and investments, the empirical evidence supporting this claim across wide-ranging contexts has been much less conclusive. Studies also use a wide range of definitions and measures – often driven by data availability and which are often not directly comparible - to characterize security of tenure (Arnot et al 2011), which likely contributes to

uncertainty over its key determinants. Following Arnot et al's (2011) guidance, we focus on using measures of the assurance of land rights to characterize tenure security – in our case, expropriation risk – and we include as predictors measures that characterize the substance of land rights in our study context, such as the method of land acquisition and land inheritance patterns followed by the household. In that sense, our results are likely to be more comparable to empirical work that also draws on assurance data around land rights (such studies comprise the minority of tenure work according to Arnot et al's recent synthesis), than that which is based on the existence of particular rights. We also benefit in this study from the ability to model tenure security at the field level, rather than solely at household level, which allows us to take into account the possibility that smallholders with multiple land parcels situated in different biophysical, spatial, and acquisition contexts may perceive different expropriation risks on the basis of some of these factors.

Across both of our models for tenure security, our results do suggest that at least some of those factors are relevant, although they point most strongly to the presence of prior disputes on the field as a key determinant of insecurity of tenure, and longer time length holding the field as a key determinant of stronger security. Field acquisition by inheritance, and stronger ties to elite networks, are also important determinants of stronger security. Although an abundance of literature across sub-Saharan Africa, as well as in Zambia, highlights links between stronger land tenure security and household status, as well as particular vulnerabilities for traditionally disempowered groups, such as the poorest and female-headed households, we find little evidence in our data for these variables as strong drivers of higher perceived tenure security by households. Instead, the picture that emerges from our data appears to suggest that tenure security in theis long-existing customary system is fairly high, and largely driven by a collective understanding of cultural norms which constitute the strength of a household's customary claim to land. That is, collectively acknowledged and respected elements of the customary system, such as time length of holding the parcel and parcel acquisition by inheritance rather than by village or chief allocation are two key influences on increased tenure security in our study data.

We find the lack of association between traditionally vulnerable groups and tenure security in our sample to be puzzling, and one that bears more scrutiny in future work. We note that we included a number of alternative indicators of wealth status in our preliminary modeling, including income and asset-based measures of household wealth, a binary indicator for off-farm income to identify wealthier households, and a dummy for household land constraints. However, the lack of effect across sub-groups of interest is also somewhat consistent with the overall relatively strong security of tenure that emerges from the survey data, and is bolstered by key informant interviews and focus group discussions from our study in which households paint a relatively equitable ability to access and use land in the study villages. We also

note that our study is restricted to five chiefdoms in Eastern Province, and it may be that our sample happens to draw on chiefdoms with particularly strong governance and leadership around land issues. Because we have no additional information regarding other chiefdoms in the Province, we do not have a strong sense of how land governance issues in our study chiefdoms may differ from other areas of Zambia.

Similarly, and also contrary to expectations, we also find little influence of village-level governance context – for example, trust and transparency in land allocation, land-based rule application, and dispute resolution processes – on household perceived security over their landholdings. This result is puzzling, as well; however, we point to the same arguments as above and also note that we had relatively little variation in these measures across the villages in our sample. In general, households largely expressed trust and satisfaction in village governance and leadership processes around land. Nevertheless, it is also possible that households did not feel comfortable fully expressing opinions on this issue in the household survey. While most households indicated they felt land was distributed fairly in their villages, with little discrimination towards vulnerable groups, such as women, the poorest, or the elderly, results from focus group discussions in several of the villages suggested that households who are immediately related to headmen tend to be preferenced in land-related decisions. Thus, while we have little evidence that vulnerable groups are systematically and negatively targeted in such decisions, there may instead be positive preferences at work for more connected households that are not as well captured in our empirical findings.

Theory implications around the relationship between land tenure security and farmer investment in climate-smart agriculture

The literature around the relationship between land tenure security and farmer decision making and agricultural investment is similarly complex, and rife with divergent findings. Although the conventional assumption is that increased tenure security will lead to greater investment, there is also clearly some feedback between these two processes, and few studies are able to explicitly account for this potential endogeneity in empirical work (Brasselle et al 2002; Place 2009; Arnot et al 2011). We encounter the same challenges in our analyses, though we take diagnostic steps in our modelling to test for endogeneity in our model specification, and find no strong indication of its presence in our investment models. Our study is also well situated to do this more explicitly once endline data are collected, as the large sample size and panel data will enable more robust modeling of this dynamic than we are able to do here.

Irrespective of these challenges, our current results are fairly consistent with comparative existing econometric work which aims to disentangle the relationship between land tenure security and

agricultural investment (in which agroforestry is one of several potential forms of investment that tend to be tested). Using an assurance-based measure of tenure security we find a small positive effect of tenure security on costly and longer return land investments, though not on less costly and shorter return investments, or on agroforestry specifically. These findings are consistent with a number of studies from sub-Saharan Africa around longer term fixed investments (Hayes et al 1997; Place and Hazell 1993; Smith 2004 ;Arnot et al 2011). Of the few studies we are aware of that use a similar measure of tenure security as ours (focused on expropriation risk), and also focus on a similar set of short return investments, our results also appear to agree with the majority of those studies in finding no effect of tenure security on these investments.

Nevertheless, the literature which is oriented towards understanding agroforestry adoption explicitly, in which tenure security is considered as one of many potential determinants, suggests there is strong reason to continue to consider tenure issues. For example, in their 2003 meta-analysis of barriers to agroforestry adoption across 32 empirical case studies, Pattanayak et al. (2003) 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). Wealth-based and gender aspects of agroforestry uptake are also reported in a number of studies across the sub-Saharan region, suggesting a particular need for monitoring, as well as targeted activities to support women's access to and representation within such extension activities (Kiptot, Franzel, & Degrande, 2014; Phiri et al., 2004). Additional disadvantages emerge around women's frequently greater insecurity over land and tree resources, as well as their access to labor, capital, and knowledge services (Kiptot et al., 2014).

Thus, as Arnot et al highlight in their comprehensive survey of existing work and theoretical challenges around accounting for the role of tenure security in smallholder investment, some of the few examples of rigorous work that have been able to account for these complicated feedbacks have found no evidence for a strong role of tenure security on smallholder investment (Brasselle et al 2002). However, the body of work is small, and clearly there is more nuanced work to be done around this issue. Our results appear to be most consistent with the few existing studies that use similar measures of tenure security, focus on a similar set of land investments, and are also conducted in similar sub-Saharan rural agrarian contexts, where credit and land markets are currently extremely nascent or nonexistent, and traditional informal and customary norms over land tenure are still strongly held.

Key Messages

Taken together, our results point to at least four key messages: (1) actual land expropriation is fairly uncommon in our sample; however, households remain concerned about this possibility, as expressed through relatively high concern over expropriation and strong interest in obtaining customary certificates. This suggests that households in the study area are currently relatively land secure, but perhaps less certain of the strength of their claims under changing land dynamics or new kinds of expropriation. (2) The strongest determinants of stronger perceived tenure security reflect elements that have long been recognized and reinforced through Zambia's customary system, such as inheritance patterns and time holding the parcel – rather than household characteristics such as wealth, education, or elite status. This may suggest that this long-standing informal system currently continues to function well in distributing land equitably across households in villages and upholding household claims to land. (3) The presence of land disputes plays a clear role in determining tenure security, as well as dampening the likelihood of agricultural investment. In addition, increased frequency and new kinds of land disputes may test the ability of the customary system to grapple with emerging challenges in ways that have been effective for more traditional disputes. This may be reflected, for example, in the greater concern that households expressed around land expropriation by chiefs for investment purposes, than from more immediate or traditional sources of disputes or reallocation risks within villages; and in the near universal desire for greater documentation of their customary land claims expressed by more than 90% of surveyed households in the study, even while actual land expropriation instances are currently low. (4) Tenure security does appear to play a small role in incentivizing some high direct cost but longer return land investments, though we do not find evidence of its direct role in incentivizing agroforestry in the uncommon instances where agroforestry occurs in these baseline data.

Policy and Program Implications

Our findings suggest that stronger formal (legal) recognition of customary land rights, such as through customary land certificates, coupled with improvements in the transparency and inclusiveness of land transactions, particularly those involving individuals outside the village, would likely bolster the already high levels of tenure security provided by customary land tenure systems in Zambia while reducing key remaining sources of tenure insecurity. The on-going presence of land disputes and their negative implications for both tenure security and agricultural investment may suggest that the certification process, which includes parcel-level confirmation of boundaries by neighbors and traditional authorities, as well as dispute resolution, could play an important role in identifying and easing sources of field-level disputes and thereby leveraging both tenure security and agroforestry investment objectives. Although important questions remain about the long-term feasibility of administering customary land certificates, there appears to be high demand for written documentation of customary land rights, particularly in the

context of increasing interest in customary land from individuals and groups outside the village and/or customary system. At the same time, increasing the transparency of all kinds of customary land transactions, and potentially the engagement of local rights holders in decisions to convert land out of the customary estate, is likely to be critical given the continued promotion of large-scale private investment in land, whether for agribusiness, mining, and/or forestry- and conservation-related investments, such as those associated with reducing emissions from deforestation and forest degradation (REDD). Customary land certificates could be one mechanism for achieving these objectives, but broader customary land governance reforms to ensure that the decisions of customary authorities represent the interests of all members of the chiefdom will also be important. This program will also test the efficacy of Village Land Committees and Village Land Volunteers, as well as general administration and dispute resolution training for chiefs and indunas, in strengthening customary land governance. Finally, our results suggest that additional investments, such as increasing access to agroforestry seeds and key inputs, such as water, as well as more directed targeting of agroforestry education and extension efforts to households with smaller landholdings, or lower overall education levels across household members, may be needed to scale up agroforestry adoption more widely in Zambia.

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Tables

Table 1. Summary statistics and variable descriptions.

Table 2. Summary statistics disaggregated by Chiefdom.

Table 3. Tenure security model results, using continuous tenure security index (Model 1) and categorical fallow seasons outcome to indicate tenure security (Model 2).

Table 4. Model results for land-related investments (Models 3 and 4), and agroforestry uptake (Model 5).

Table 1. Summary statistics and variable descriptions.

Variable Name	Variable Description	Mean	SD
Dependent Variables			
Tenure Security	Mean score of 12 questions assessing likelihood of encroachment, confiscation or reallocation by 6 sources, over short (1-3 yrs) and longer term (4+ yrs), on a six point Likert scale.	1.727	0.932
Fallow Length	Three point interval variable indicating how many seasons respondent could let a field lie fallow without being worried about the field being reallocated. 0= 0 seasons; 1 = 1-5 seasons; 2 = six or more seasons.	1.143	0.875
Long Return Investment	1 = indicates presence of fencing, irrigation or basin planting on the field.	0.108	0.311
Short Return Investment	Indicates the number of short-term investments households have made on fields, including manuring, zero tillage, ridging or mounding.	2.369	1.165
Agroforestry Uptake	Binary indicator for the planting of agroforestry trees on a field.	0.046	0.209
Independent Variables			
Level 1 - Field			
Slope	An interval variable to assess field steepness; it ranges from flat to steep	1.415	0.535
Soil Quality	A four-point variable based on soil texture ranging from loamy to clay.	2.611	1.023
Prior Land Dispute (Y/N)	1 = a land dispute has occurred on the field.	0.114	0.318
Length of landholding (yrs)	Number of years that the household has owned or used the field.	24.88	23.87
Primary field use for subsistence (Y/N)	0 = crops grown on this field are sold or bartered; 1 = crops grown on this field are used for subsistence.	0.635	0.482
Field acquisition by inheritance (Y/N)	0 = field was acquired through village allocation; 1 = HH inherited the field through parents.	0.672	0.470
Field replanted (Y/N)	1 = field was replanted during previous agricultural season.	0.421	0.494
Field distance to household (m)	Distance in meters from the household to the field.	123.9	304.5
Largest field (Y/N)	1 = field is the largest field used by the household.	0.352	0.478
Level 2 - Household			
Relationship to chief (Y/N)	1 = the head of household or primary spouse is related to the chief.	0.210	0.408
Governance satisfaction index	PCA-based measure of satisfaction with local land governance. Respondent evaluation of leaders on: decision-making transparency, fairness in land allocation, accountability, commitment to protecting community land.	0.000	1.712
Total land farmed by hh (ha)	A measure in hectares of the total land area farmed by a household.	2.027	1.880
Poor household	1= household is in lowest 25% of asset-based wealth index.	0.240	0.427
Education level (yrs)	Highest education level achieved of any household member.	8.816	3.366
Female headed (Y/N)	This is a binary indicator for female-headed households.	0.221	0.415
Head residency time in village	Number of years the head of household has been a resident of the village.	41.63	17.87
Inheritance pattern	A three level indicator for whether the household is defined by a matrilineal, patrilineal or mixed/unclear inheritance regime.	1.837	0.528
Labor availability	Number of adults in the household that are available for field labor.	3.073	1.626
Head hires labor out to other farms (Y/N)	Indicates whether anyone in the household was involved in “ganyu” or hired labor out to another field during past agricultural season.	0.430	0.495
Head age (yrs)	Age in years of the household head.	43.85	16.44
CSA extension exposure	A count of the amount of climate smart agriculture extension exposure received by the household in the year prior to the survey.	2.095	2.639
Agroforestry extension exposure (Y/N)	A measure of whether or not a household received specific exposure to agroforestry extension.	0.313	0.464
Land constrained (Y/N)	1 = household uses less than 1 hectare of land.	0.229	0.420
Level 3 - Village			
Land-related meetings (Y/N)	1 = the village held any land related meetings in the past year.	0.672	0.470
Village N		293	
Household N		3437	
Field N		9745	

Table 2. Summary statistics disaggregated by chiefdom.

	Chiefdom 1		Chiefdom 2		Chiefdom 3		Chiefdom 4		Chiefdom 5	
Variable Name	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Dependent Variables										
Tenure Security	1.820	0.991	1.689	0.902	1.723	0.937	1.677	0.875	1.745	0.959
Fallow Length	1.191	0.841	1.160	0.877	1.143	0.876	1.074	0.900	1.139	0.876
Long Return Investment	0.123	0.328	0.101	0.301	0.108	0.311	0.103	0.304	0.111	0.315
Short Return Investment	2.393	1.169	2.346	1.166	2.360	1.181	2.382	1.138	2.377	1.172
Agroforestry Uptake	0.050	0.218	0.043	0.203	0.049	0.216	0.047	0.212	0.041	0.198
Independent Variables										
Level 1 - Field										
Slope	1.452	0.543	1.419	0.541	1.486	0.549	1.338	0.505	1.384	0.520
Soil Quality	2.728	1.016	2.608	1.022	2.693	1.038	2.462	0.998	2.576	1.025
Prior Land Dispute (Y/N)	0.113	0.317	0.113	0.317	0.111	0.314	0.130	0.336	0.104	0.306
Length of landholding (yrs)	24.67	23.47	25.83	24.23	23.71	13.20	25.12	24.30	24.41	23.82
Primary field use for subsistence (Y/N)	0.636	0.481	0.634	0.482	0.643	0.479	0.640	0.480	0.622	0.485
Field acquisition by inheritance (Y/N)	0.675	0.468	0.656	0.475	0.667	0.471	0.710	0.454	0.661	0.474
Tenure security index	1.820	0.991	1.689	0.902	1.723	0.937	1.677	0.875	1.745	0.959
Field replanted during prior season (Y/N)	0.436	0.496	0.440	0.497	0.448	0.497	0.360	0.480	0.378	0.485
Field distance to hh (m)	88.0	234.3	135.7	354.1	137.9	324.9	127.3	282.9	126.0	282.2
Largest field used by household (Y/N)	0.351	0.477	0.350	0.477	0.352	0.478	0.362	0.481	0.347	0.476
Level 2 - Household										
Relationship to chief (Y/N)	0.229	0.420	0.213	0.410	0.204	0.403	0.208	0.406	0.194	0.396
Governance index	-0.052	1.789	0.033	1.725	-0.075	1.702	-0.047	1.677	0.115	1.646
Total land farmed (ha)	2.169	1.905	2.024	1.993	2.148	1.663	1.724	1.512	2.077	2.131
Poor household (Y/N)	0.257	0.437	0.237	0.425	0.237	0.425	0.254	0.435	0.219	0.413
Education level (yrs)	8.679	3.258	8.704	3.487	8.700	3.556	9.060	3.206	8.997	3.241
Female headed (Y/N)	0.169	0.375	0.216	0.412	0.227	0.419	0.234	0.423	0.265	0.441
Head residency time (yrs)	38.22	18.84	43.45	17.85	40.58	18.47	42.29	16.93	42.59	16.70
Inheritance pattern	1.973	0.613	1.811	0.503	1.746	0.585	1.845	0.485	1.802	0.427
Labor availability	3.114	1.651	3.071	1.668	2.959	1.443	3.119	1.676	3.093	1.635
Head hires labor out (Y/N)	0.474	0.499	0.424	0.494	0.456	0.498	0.401	0.490	0.402	0.491
Head age (yrs)	42.69	16.35	45.42	16.49	43.31	16.93	43.21	16.12	43.70	16.20
CSA extension exposure	2.311	2.736	2.095	2.703	2.005	2.671	1.959	2.405	2.086	2.612
Agroforestry extension exposure (Y/N)	0.325	0.469	0.306	0.461	0.326	0.469	0.329	0.470	0.283	0.451
Land constrained (Y/N)	0.204	0.403	0.238	0.426	0.207	0.405	0.287	0.453	0.205	0.404
Level 3 - Village										
Village holds land-related meetings (Y/N)	0.688	0.463	0.659	0.474	0.685	0.465	0.670	0.470	0.665	0.472
Village Cluster N	59		85		56		49		45	
Household N	641		980		564		631		621	
Field Obs N	1824		2792		1598		1742		1789	

Table 3. Tenure security model results, using continuous tenure security index (Model 1) and categorical fallow seasons outcome to indicate tenure security (Model 2).

	Model 1	Model 2
Independent Variables	**Tenure Security**[a]	**Fallow Length**[b]
Fixed Effects		
Level 1 - Field		
Slope	0.079 (0.020)***	0.895 (0.043)**
Soil Quality	0.023 (0.011)**	1.060 (0.029)**
Prior Land Dispute (Y/N)	0.428 (0.037)***	0.791 (0.069)***
Length of landholding (yrs)	-0.003 (0.000)***	1.01 (0.001)***
Primary field use for subsistence (Y/N)	-0.101 (0.023)***	0.815 (0.047)***
Field acquisition by inheritance (Y/N)	0.073 (0.026)***	1.10 (0.068)
Level 2 - Household		
Relationship to chief (Y/N)	0.009 (0.030)	1.20 (0.101)**
Governance satisfaction index	0.003 (0.007)	0.982 (0.019)
Total land farmed by household (ha)	0.024 (0.006)***	0.982 (0.017)
Household in poorest quartile (Y/N)	-0.016 (0.028)	0.889 (0.069)
Highest education level of any household member (yrs)	0.000 (0.004)	0.997 (0.010)
Female headed (Y/N)	-0.002 (0.032)	0.957 (0.072)
Head residency time in village (yrs)	0.000 (0.001)	1.000 (0.002)
Inheritance pattern		0.943 (0.058)
patrilineal	0.045 (0.029)	
mixed inheritance / unclear	0.077 (0.052)	
Level 3 - Village		
Village holds land-related meetings (Y/N)	0.011 (0.025)	0.904 (0.062)
Chiefdom indicator		0.958 (0.029)
Chiefdom 1 dummy	0.104 (0.045)**	
Chiefdom 2 dummy	-0.051 (0.040)	
Chiefdom 3 dummy	-0.038 (0.046)	
Chiefdom 4 dummy	-0.041 (0.042)	
Random Effects		
Level 2 - Household		
SD/ Var	0.065 (0.028)	1.117 (0.117)
Level 3 - Village		
SD/ Var	0.406 (0.018)	0.149 (0.039)
Residual SD/ Var	0.811 (0.012)	
Wald chi^2	345.03	
Prob > chi^2	<0.0001	
Log likelihood	-9164.8	-7137.4
Village Cluster N	293	293
Field Obs N	9745	9745

Note: Robust standard errors reported in parentheses.
[a] Higher index score indicates greater tenure *insecurity.*
[b] Ordered logit with highest category indicating greatest tenure security. Estimates reported as odds ratios.
** p < 0.10; ** p < 0.05; *** p < 0.01*

Table 4. Model results for land-related investments (Models 3 and 4), and agroforestry uptake (Model 5).

Independent Variables	Model 3 **Long Return Investment**[b]	Model 4 **Short Return Investment**[c]	Model 5 **Agroforestry**[b]
Fixed Effects			
Level 1 - Field			
Tenure security index[a]	0.913 (0.044)*	1.005 (0.005)	0.975 (0.063)
Field replanted during prior season (Y/N)			1.166 (0.142)
Field distance to household (km)	1.000 (0.000)		1.000 (0.000)
Largest field used by household (Y/N)	2.522 (0.225)***	1.062 (0.010)***	3.12 (0.434)***
Level 2 - Household			
Relationship to chief (Y/N)			
Governance satisfaction index	1.003 (0.023)	0.999 (0.002)	0.984 (0.032)
Household in poorest quartile (Y/N)	0.854 (0.086)	0.999 (0.010)	0.987 (0.130)
Highest education level of any household member (yrs)	1.049 (0.014)***	1.003 (0.011)***	1.054 (0.022)**
Female headed (Y/N)	0.903 (0.989)	1.008 (0.011)	0.970 (0.147)
Head residency time in village (yrs)	1.006 (0.005)	1.000 (0.000)	0.990 (0.006)*
Labor availability	1.043 (0.028)	1.008 (0.003)***	1.09 (0.037)**
Head hires labor out to other farms (Y/N)	1.190 (0.107)**	0.991 (0.008)	1.05 (0.130)
Head age (yrs)	0.992 (0.005)	0.999 (0.001)	1.02 (0.007)**
Prior CSA extension exposure (Y/N)	1.011 (0.015)	0.996 (0.002)**	
Prior agroforestry extension exposure (Y/N)			0.975 (0.117)
Land constrained household (Y/N)	0.838 (0.095)	0.956 (0.011)***	0.715 (0.121)**
Level 3 - Village			
Village holds land-related meetings (Y/N)	0.908 (0.081)	1.002 (0.009)	1.004 (0.119)
Chiefdom 1 dummy	1.164 (0.177)	1.006 (0.014)	1.194 (0.224)
Chiefdom 2 dummy	0.884 (0.113)	0.986 (0.013)	1.046 (0.183)
Chiefdom 3 dummy	0.966 (0.162)	1.010 (0.016)	1.215 (0.244)
Chiefdom 4 dummy	0.833 (0.122)	0.983 (0.014)	1.164 (0.223)
Constant	0.051 (0.013)***	2.479 (0.057)***	0.007 (0.003)***
Random Effects			
Level 2 - Household			
SD/ Var	0.888 (0.179)		0.625 (0.364)
Level 3 - Village			
SD/ Var	0.054 (0.048)		0.042 (0.087)
Residual SD/ Var			
Log likelihood	-2759.3	-12227.6	-1377.4
Village Cluster N	293	293	293
Field Obs N	9745	9745	9745

Note: Robust standard errors reported in parentheses; Estimates reported as odds ratios.
[a] Higher index score indicates greater tenure *insecurity.*
[b] Logit model.
[c] Poisson model.
** p < 0.10; ** p < 0.05; *** p < 0.01*