

# Customary Tenure and Agricultural Investment in Uganda

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## Abstract

Customary tenure in Uganda often features land rights being held by different individuals in a community, creating complex incentives for long-term agricultural investment. I introduce a theoretical model of these incentives, exploring farmers' strategic responses to changing land pressures, which may change the social determinants of tenure insecurity. Empirically, I find results consistent with the model in Uganda. As land pressures rise, long-term input use responds more on freehold than on customary parcels. This can be explained by elite incentives for expropriation, which intensify with external demand for land, creating insecurity on customary parcels. This study offers a nuanced conceptualization of the relationship between tenure systems and agricultural investment, incorporating qualitative social dynamics in both theory and empirics.

## 1 Introduction

Secure property rights are fundamental to investment and prosperity, and land tenure in particular is critical for poor farmers to make long-term investments and improve agricultural productivity (Place, 2009). In much of Sub-Saharan Africa, customary tenure, a socially-created and enforced, typically undocumented traditional form of land rights, predominates (Alden Wily, 2011). Economists have traditionally focused on the undocumented and therefore theoretically less secure nature of customary tenure when compared with freehold land, where the owner enjoys all rights in perpetuity (Fenske, 2011). Large-scale formalization

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policies across much of the continent have aimed to address this insecurity to allow farmers to make transformative investments in their own farms (Ali et al., 2016). However, empirical work has been more mixed than theory; customary land is not always less secure in farmers' own estimation (nor under-invested relative to freehold land), and formalization has not always unlocked investment (Bambio and Bouayad Agha, 2018; Lawry et al., 2017; Fenske, 2011; Higgins et al., 2018; Boxho et al., 2022; Bellemare, 2013). By contrast, qualitative work has emphasized the socially-constructed nature of customary tenure, where multiple individuals may hold overlapping rights over a single piece of land, and in particular, local elites such as chiefs or lineage heads hold transfer rights (Cotula et al., 2007; Ensminger, 1997; Alden Wily, 2011; Van Leeuwen, 2014; Barry and Danso, 2014).<sup>1</sup> The distribution of rights can therefore influence the (perceived) security of tenure (Goldstein and Udry, 2008), as other rightsholders may claim the land. Often framed around issues of elite capture, these patterns have been difficult to document in quantitative survey data, although their importance is highlighted in qualitative work on land disputes and dispossession (Kandel, 2022).<sup>2</sup>

I incorporate the social dynamics of land rights, where multiple rightsholders interact strategically, into a theoretical model of agricultural investment and empirical tests using data from Uganda. My model's primary contribution lies in capturing not just different investment incentives under different tenure regimes, but how these incentives change in response to external land pressures. As land pressures increase, liquidity constraints should relax, but local elites may face more incentive to expropriate customary land for sale to outsiders (Cotula et al., 2007; Ubink, 2008; Berry, 2018).<sup>3</sup> If farmers begin to worry about elite expropriation,<sup>4</sup> this should impact their investment decisions. In particular, I find that farmers under-invest in long-term agricultural inputs on customary parcels (when compared with freehold) as land pressures rise.

Working from an endogenous model of customary tenure and agricultural investment where farmers can make socially-recognized investments in their land to enhance their tenure security, I incorporate a liquidity constraint. Long-term investments are weakly lower on (relatively insecure) customary land than on freehold land, although the customary system may provide sufficient investment incentives (Brasselle et al., 2002). The liquidity constraint implies that optimal investment is an (increasing) function of land values on freehold

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<sup>1</sup>A hallmark of the customary is its very localized, negotiated nature; this enables its adaptability to changing circumstances but can also marginalize those in weaker bargaining positions (Cotula et al., 2007). Ensminger (1997) argues that “a common characteristic in almost all African customary systems is for use rights to be assigned at the household level, whereas transfer rights are assigned at a higher level such as the lineage, clan, or chiefdom.” This means that although individuals may be quite secure in their ability to use a particular plot of land in their lifetime, adaptive reallocation within the community could occur in response to changing circumstances. Customary leaders also are able to allocate (often unused) land to migrants into an area as well as adjudicate any conflicts that may occur between members of the community. Although the particular ways these rights are divided may vary considerably across the region (Hasanbasri et al., 2022), this ‘dis-bundling’ of property rights is common and adds a strategic dimension to any decisions about land.

<sup>2</sup>This more localized dispossession is distinct from the large scale land acquisitions that have received international attention, although the phrase ‘land grabs’ is used as a catch-all term (Van Leeuwen et al., 2023).

<sup>3</sup>Kandel (2022) documents that those with off-farm salaried income are “increasingly acquiring rural land in order to invest in small-scale commercial agriculture or as speculative investments.”

<sup>4</sup>Traveling around Uganda, it is common to see signs on properties especially agricultural land stating “this land is not for sale”: an indication that farmers are indeed worried about elite expropriation for sale to outsiders.

land. However, I explicitly consider a case common in customary tenure systems: one household or individual may hold primary use rights, while another, such as a lineage elder, may hold rights of transfer (Ensminger, 1997; Cotula et al., 2007).<sup>5</sup> This partition of rights means that outsiders may struggle to identify land ‘owners’, finding local tenure systems illegible (difficult to parse without deep knowledge of the area and people nor the socially-recognized investments that demonstrate and secure tenure locally). Elites are then able to sell land used by other members of the community for their own private benefit (Ubink, 2008). Their incentives to do so are greater in contexts with rapidly increasing land values (Barry and Danso, 2014; Cotula et al., 2007). This means that rising land values, driven by sales options to outsiders, may lead local elites to assert their historic right to sell land. This expropriation is a real threat for Ugandans: the Prindex survey of Uganda finds that 22.4% of respondents report personally experiencing any involuntary land loss (Prindex, 2020), and qualitative work finds that dispossession is more likely for the poor and socially vulnerable (Kandel, 2022).<sup>6</sup> The model predicts that the farmer, anticipating elite expropriation, may actually make fewer long-term investments on customary land as land values rise, in contrast to the freehold case.

In order to empirically test the implications of this model, I use data from a survey of 2,189 farmer households in Uganda. My primary empirical specification looks at heterogeneous responses to rising land pressures between customary and freehold land for a variety of investments of long and short duration. In order to capture an exogenous component of land pressures, I use two spatial measures from Muller-Crepon (2021). The first is the inverse travel time to Kampala, the national capital and source of much outsider demand for land, which incentivizes elite expropriation but also relaxes liquidity constraints. The second is the historical decrease in travel time to Kampala due to new or improved roads, relative to the 2005 travel time. This isolates new incentives to expropriate customary land, which play a role in uncertainty and tenure insecurity. These measures should capture the degree to which outsiders are interested in purchasing local land, and therefore the drivers of elite expropriation, but abstract away from other pathways by which land values impact agricultural investment. I also use estimated per-acre rental prices for parcels; with this measure, I control for farmer group fixed-effects to account for unobserved farmer quality characteristics.<sup>7</sup>

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<sup>5</sup>I focus on these two rights given their first-order importance for investment incentives, despite the plethora of other secondary rights that may be held by various individuals.

<sup>6</sup>The public Prindex data does not allow us to empirically examine where these expropriations happen, however, nor the kind of land which was expropriated. Nevertheless, it is a valuable resource for understanding the prevalence of tenure insecurity and land disputes in Uganda: 16.6% of respondents report having experienced a dispute over land in the past, and 26% of the adult population report feeling insecure in their land rights.

<sup>7</sup>These farmer groups were part of the sampling strategy in the data collection process. They extend the intuition of household fixed-effects to control for unobserved heterogeneity as farmer groups are self-selected, but allow for sufficient identifying variation. A household fixed effects specification looking at differences across tenure types (particularly in West Africa) may identify from households with the greatest differences in tenure security (and thus households most likely to invest differently across plots), as only those households who feel insecure about land allocated through customary mechanisms will purchase other plots (Fenske, 2011).

Empirically, I find that long-term input use responds to rising land values more strongly on freehold land than on customary land. Elite incentives to expropriate rise along with land pressures, causing tenure insecurity on customary land, and this attenuates the impacts of increased liquidity. This divergence in input use between freehold and customary parcels is also present (to a lesser extent) on short-term inputs, contrary to the model's predictions. This may be driven by changing cropping patterns, as urban markets increase demand for cash crops that require more intensive input use. Nevertheless, the difference in responses is stronger for long-term inputs, which can be attributed to the tenure-security effect. Additionally, the divergence in investment is more responsive to rising land pressures closer to Kampala.

By incorporating the social nature of customary land rights in a model of agricultural investment, this paper avoids the common conflation of incompleteness of rights with insecurity (Doss and Meinzen-Dick, 2020; Hasanbasri et al., 2022; Place, 2009).<sup>8</sup> Instead, it considers how multiple rights-holders interact in different land value environments to make more nuanced predictions about investment on customary land, reconciling the mixed evidence in the literature (Fenske, 2011). In addition to bringing qualitative insights to an economic framework, I use economic modeling to explore how farmers would strategically respond to changing incentives. This model captures how the potential for elite capture affects individual farmers. It thereby returns the focus to the welfare of smallholders, and by examining a broader population allows me to quantitatively document the effects of (potential) elite capture (which historically has been difficult due to the rarity of observed cases). Unlike many previous papers which have conceptually modeled the impacts of tenure *security* but then empirically used tenure *type* as a (poor) proxy, I consider the particular institutional arrangements of tenure type and the incentives it creates throughout my model, therefore linking more closely to my empirical tests (Fenske, 2011; Abdulai et al., 2011).

The remainder of this paper consists of a description of the context of customary tenure and agricultural investment in Sub-Saharan Africa, with a particular focus on Uganda, followed by a model which captures many of the insights explored. I then discuss the data used, as well as an empirical strategy with several hypotheses laid out. I present results for a variety of short- and long-term inputs, and conclude by discussing their implications for the model's relevance to the Ugandan context.

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<sup>8</sup>'Security' could be composed of multiple elements of duration of tenure, assurance, and completeness of rights. Despite the theoretic clarity of tenure security, "there is no agreed upon way to measure tenure security and results may be related to choice of proxy" (Place, 2009). For example, Bellemare (2013) finds in Madagascar that one measure of tenure security, the presence of title, seems unimportant for investment, while beliefs about rights do matter, while Deininger et al. (2021) in matrilineal areas of Malawi that rights to bequeath and sell land are more important than short-term management rights.

## 2 Context

Importantly, the dispersion of rights in many customary tenure systems across the continent is not in itself a cause of instability or under-investment: “sufficient investment incentives tend to be provided by basic rights of use that, under normal circumstances, are guaranteed to many villagers (including migrants) by the local informal order” (Brasselle et al., 2002). Within a local community, farmers are able to demonstrate their stewardship of the land via socially-recognized investments, such planting trees, that signal socially that the land is being used (Awanyo, 2009). However, the continual adaptation of customary institutions means that such systems are dynamic and see considerable changes over time. My model explores how outside, market-based pressures on land shape customary tenure security and investment incentives.

In particular, I focus on the role of elites in customary tenure. A common feature of customary systems across Uganda and the continent is that elites, representing the family or lineage writ large, serve as trustees or administrators of land owned by the family group (Ensminger, 1997). These elites may be lineage heads, (land) chiefs, elders, or others in positions of social power. Often, they hold transfer rights in order to (re)allocate land within the community in response to shocks (such as the death of a large landholder without heirs or an influx of new migrants to an area), as well as to prevent the alienation of a communal resource without the consent of the community.

However, beginning with colonial administrators, outsiders have attempted to fit notions of ownership based on freehold tenure onto customary tenure systems, and this institutional mismatch has created ambiguity about who the ‘owners’ of land actually are. This ambiguity can be exploited by local elites: “There is a fine line between chiefs as (often self-declared) owners of all land in customary laws, and chiefs as trustee administrators” (Alden Wily, 2011). Elites are able to respond as individuals rather than as guardians of the corporate group, and can thus assert their rights to outsiders unfamiliar with the complexities of local tenure arrangements.

The qualitative literature on customary tenure has documented the tensions and conflicts that emerge as customary systems adapt to external pressures such as rising land values. Most cases have considered land values rising due to *non-agricultural* uses, such as urban and peri-urban expansion, or natural resource extraction. Some large scale land acquisitions have been for agricultural purposes, although generally requiring scale or technologies such that local smallholders are unable to participate. Therefore, this should be thought of as an increase in the *marketable* value of land rather than its value to smallholder agriculture. “As land values rise, farmers may be forced or tempted to sell their land. Where land is still under customary chiefs, these may be tempted to sell off lands ... regardless of the views of those actually farming this land” (Cotula et al., 2007). In Ghana, “many of these multiple sales are by different people in a family lineage,

each contending that they have the status to sell under the customary system” (Barry and Danso, 2014); this reinterpretation of customary law is also documented in Niger by Turner and Moumouni (2019). Despite abundant stories of how “local elites have been able to use their position and the ambiguities of customary law to appropriate land to further their own economic and political interests” (Ubink, 2008), especially in peri-urban areas but also in many rural ones (Ubink and Quan, 2008), this particular facet of how customary tenure adapts to external pressures has been little studied by economists, with the notable exception of Berry (2018)’s work on land governance in these areas.

## 2.1 Land Rights in Uganda

Given the enormous diversity of customary tenure arrangements throughout Sub-Saharan Africa, it is worth delving into the particular case of Uganda. Between 12-14% of land is subject to formal title, so customary tenure remains significant throughout the country (Alden Wily, 2011).<sup>9</sup> Customary authorities still play a major role in Uganda: Gochberg (2021) argues individuals may choose not to title their land given the social costs of leaving the customary system (echoing Honig (2022)’s work in other countries on the continent).<sup>10</sup> This customary land is subject to the kind of elite expropriation I model: Adoko and Akin (2011) frames the likelihood of elite land grabbing as a function of physical or ‘social strength’ in the community and family, and Gochberg (2021)’s qualitative work relates elites can “go so far as to survey another individual’s land at night” (p. 10).

Even within Uganda, there is some variation in the relative strength and allocation of bundles of rights. In the west, where population pressures on the land are higher, there is more individualized customary tenure, while the relatively land-abundant north retains stronger rights for customary authorities (Van Leeuwen, 2014), in part due to historical agropastoral systems and collective rights (although post-war resettlement and return complicates customary systems in the north (Sjögren, 2014) and southwest (Mathenge, 2013)). In the historic Kingdom of Buganda, in the center of the country, the *mailo* system is key, a remnant of British indirect colonial rule.<sup>11</sup> *Mailo* land only exists in the historic kingdom of Buganda, however, in central Uganda, and even there, customary land is still substantial.<sup>12</sup>

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<sup>9</sup>This is slightly higher than for the continent as a whole, in part due to colonial administration which focused on documenting land allocation in Uganda.

<sup>10</sup>In lab-in-the-field experiments, references to traditional authorities such as the *kabaka* (the king of Buganda, one of the major regions in Uganda) induce higher contributions to public goods games (Goist and Kern, 2018).

<sup>11</sup>Much of the academic literature on land rights in Uganda has looked at the *mailo* system. In 1900, the British signed a treaty with the Kingdom of Buganda which allocated square-mile tracts in the center of the country to Buganda elites for their ‘ownership’ as absentee landlords. These tracts were then sub-leased to the actual inhabitants and land users (Deininger and Castagnini, 2004). Ever since, there has been a significant tension over government policy towards *mailo* owners and tenants and how to balance the two parties’ competing interests (Coldham, 2000). The 1998 Land Act attempted to balance these by giving *mailo* owners the powers of a freehold owner, while still recognizing the rights of ‘lawful occupants’ of the land who had used it for more than 12 years (Coldham, 2000). This guaranteed occupants’ tenure security (including inheritance rights and the ability to sub-let with consent of the owner), while requiring continuous possession of the land and a nominal rent payment.

<sup>12</sup>My survey includes one district with a substantial share of *mailo* land; 20% of parcels there are reported as *mailo*, with

Qualitative work has documented throughout the country that rights to the land in perpetuity are differentiated from responsibility for managing the land (Adoko and Akin, 2011). Specific land rights regimes can be incredibly precise: Howard and Nabanoga (2007) document that rights are determined for individual people over individual plots on different types of land under different circumstances.<sup>13</sup> I leave these particularities to the side, focusing on the first-order rights of land use/management and transfer rights, which have the most direct impacts on agricultural investment. The precise institutional details shape the identities of the different rightsholders in a region (whether Basoga chiefs in the Busoga region in the south-east of the country or Rwots in Acholiland in the north, or other traditional leaders), how elites are selected (hereditary or elected), and in what other domains they have power (whether primarily on land or also other areas such as maintaining social order). Nevertheless, the fundamental distinction I model is common across the country: on customary land, although the farmer has use rights, a customary elite will hold transfer rights.

Deininger and Castagnini (2004)'s examination of land-related disputes in Uganda can illustrate how customary tenure functions and the margins at which it breaks down. They estimate that up to 5% of the rural population is involved in a pending land-related conflict at any given time, mostly between neighbors because boundaries have been exceeded. More recent estimates from Prindex find that 16.6% of the population report ever having experienced a dispute, with 22.4% reporting having personally experienced the involuntary loss of land (Prindex, 2020). The prevalence of boundary disputes has led to many farmers planting trees to demarcate their land; "boundary trees are useful evidence when the land can be visited during a case by customary authorities, but they are less useful when the case is heard in a court of law far away from the land" (Adoko and Akin, 2011). There has been a push to incorporate customary leaders into statutory court systems, with mixed success (Van Leeuwen, 2014).

Historically, proclamations of state ownership of all land under the dictatorship of Idi Amin in 1975 were largely unenforced and ignored by the population (Hunt, 2004). The Land Act of 1998, by contrast, regarded land as the property of the citizens of Uganda and recognized four tenure types: freehold, leasehold, customary, and *mailo* (Joireman, 2007). The law provides for an extensive and decentralized land administration (Tripp, 2004) that could issue titles as well as 'certificates of customary ownership.' These certificates registered rights held by multiple people and could, in time, be converted into freehold titles (Coldham, 2000). Unlike compulsory registration in other countries in the region, registering rights was voluntary. This leads Coldham (2000) to observe that "where the grant of certificates of title is based on individual applications, there is always a risk of land-grabbing, that is, that an applicant may lay claim to a larger area of land less than 1% reported similarly in any other surveyed district. However, a nearly identical share of parcels in that district are reported as under customary tenure.

<sup>13</sup>For instance, that a woman who is pregnant or sick is allowed to pick certain medicinal plants from someone else's river plot, but not from a home garden.

than that to which he is customarily entitled.” Furthermore, the widely-lauded land reform has been largely unfunded and thus little-implemented (Deininger and Castagnini, 2004; Joireman, 2007). Individuals do seem receptive to titling: Cherchi et al. (2019) found in Uganda that 91% of households chose to title their land when offered a fully-subsidized freehold title.

Two previous economic analyses have looked at the impacts of tenure on agricultural investment in Uganda. Deininger and Castagnini (2004) focus on land conflicts, but argue that the intensive multi-cropping system prevalent in much of Uganda implies individual crop production functions are inappropriate for productivity measures or investment. Deininger and Ali (2008) use household fixed effects to control for unobservables such as farming skill and find that households invest in both long-term and short-term inputs significantly more on plots they own outright rather than plots they have only customary rights over. Furthermore, they find that registering customary rights (by acquiring a certificate of customary ownership) has little impact on investment, but legal efforts to strengthen occupancy rights do increase investment.<sup>14</sup>

### 3 A model of tenure and investment

Broadly, land tenure has been thought to encourage investment through three possible mechanisms, going back as far as the discussion in Feder (1988, cited in Place (2009)). These have been termed the assurance, collateralizability, and realizability mechanisms: stronger land rights should provide assurance that the farmer will be able to reap gains from investment, increase access to capital by leveraging the land as collateral, and allow the farmer to sell the land and realize gains sooner (as well as transferring land to those most able or likely to invest) (Besley, 1995, cited in Fenske (2011)).

Each of these mechanisms is the subject of an extensive theoretical and empirical literature, and their relevance to customary tenure in Africa has been long debated. Credit markets have been shown to be thin, farmers may be credit rationed for other reasons, and land markets are often missing or face other restrictions (Tabetando et al., 2023; Higgins et al., 2018).<sup>15</sup> This discussion will focus on the first of these mechanisms, which does not rely on the existence of functioning complementary markets.

The simplest theoretical models of land tenure and investment attempt to capture tenure as an exogenous probability of losing the land, along with any fixed investments, before the profits of those investments can be fully realized. These models often make this assumption to instead focus attention on other features of the investment context (Jacoby and Minten, 2006), such as intra-household bargaining (Dillon and Voenen, 2015). However, much qualitative evidence on customary tenure regimes in Sub-Saharan Africa has stressed

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<sup>14</sup>They find that investment increases with length of occupancy, with a discontinuity at the 12 year mark when rights become recognized by law.

<sup>15</sup>In China, Li and Zhu (2023) for example find that a legal reform recognizing transfer rights increases investment, although land concentration seems to be an important mechanism, which may be less possible in Africa.

the endogeneity of tenure security, which has been incorporated into quantitative models. Actions taken by the farmer, particularly certain investments in the land, demonstrate responsible use and defend against expropriation by others in the community who recognize these investments as land stewardship (Awanyo, 2009; Bambio and Bouayad Agha, 2018). Deininger and Jin (2006) emphasize the visibility of an investment to others in the community as key to its efficacy in securing tenure rights, for tenure security is fundamentally about social recognition of rights. Place and Otsuka (2002) explore this concretely by contrasting three possible investments: planting trees, which is visible and thus reduces the probability of losing the land (a primary input in my model below); management effort, which is invisible and thus has no effect on tenure security; and fallowing, which in a tenure system predicated on land *use*, may actually increase the risk of expropriation.<sup>16</sup>

I now turn to my own theoretical model of tenure and investment, explicitly incorporating changing incentives for expropriation on land under different tenure systems. Consider a two-period model. In the first period, a farmer chooses to purchase and apply a short-term input, fertilizer,  $F_1$ , and a long-term one, trees,  $T$ ,<sup>17</sup> to his or her exogenously given land  $L$  under tenure system  $h$  in order to produce according to  $f(F, T)$ .<sup>18</sup> The farmer also has some wealth endowment and can choose to borrow  $B_1$  against the value of the land (depending on the tenure system), to be repaid at the end of the period. The farmer faces an exogenous interest rate  $r$  (paid in period 1) and has a discount rate  $\beta$  for second period returns (the optimized expected second-period total profit is given by  $\pi_2^*$ ). There is some probability that the farmer's land will be expropriated before the second period, in which case fixed investments (trees) would also be lost. This probability is given by  $(1 - \phi(T, h, vL))$  (where  $v$  is the per-unit value of the land) and may be a function of tree investment, tenure systems, and the value of the land. For convenience, I use the word 'expropriate' to capture both 'horizontal' expropriation (where others in the community take over the farmer's use rights), as well as the exertion of sales rights by local elites without the permission of the land

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<sup>16</sup>Goldstein and Udry (2008) focus on this latter effect in their work on tenure security in Ghana, where fallowing is the primary investment in land productivity. They focus on how an individual's social status interacts with these incentives: "farmers who lack political power are not confident of maintaining their land rights over a long fallow. As a consequence, they fallow their land for much shorter durations than would be technically optimal, at the cost of a large proportion of their potential farm output." This effect is driven by non-elite households on their land obtained through customary tenure. Social elites do not face the same disincentives to fallow, as they would be the ones to transfer unused land, so empirically they fallow land similarly regardless of how a parcel was acquired.

<sup>17</sup>These inputs stand in for bundles of short and long-term investments, although trees may have particular tenure-enhancing effects not seen for other long-term inputs.

<sup>18</sup>I leave this production function general, only assuming diminishing marginal returns to each input ( $\frac{\partial^2 f}{\partial F^2} < 0$ ,  $\frac{\partial^2 f}{\partial T^2} < 0$ ) and that the cross-partial of trees and fertilizer is positive (

$$\frac{\partial^2 f}{\partial F \partial T} > 0$$

), as fertilizer helps sustain an intercropping system with trees and the shade provided by trees helps retain soil moisture (van Asten et al., 2012). These assumptions allow me to use the implicit function theorem to predict how investment will respond to changing land values, which is the empirically relevant hypothesis, even without estimating a full agronomic production function which is beyond the scope of this model.

user ('vertical' expropriation). After working through the main features of the model (a fuller, more formal treatment of the model, including assumptions and full solutions, is presented in the appendix), I consider what different forms of this  $\phi$  function could imply for the farmer's decisions as land pressures increase.

The first period optimization problem faced by the farmer is therefore

$$\begin{aligned} \max_{F_1, T, B_1} & p_a f(F_1, T) - p_F F_1 - p_T T - r B_1 + \beta \phi(T, h, vL) \pi_2^*(F_1, T, B_1) \\ & p_F F_1 + p_T T \leq w_1 + B_1 \\ \text{subject to:} & \\ & B_1 \leq s(vL, h). \end{aligned}$$

In the second period, the farmer only chooses fertilizer ( $F_2$ ) and therefore maximizes according to the following:

$$\begin{aligned} \max_{F_2} & p_a f(F_2, T) - p_F F_2 \\ & p_F F_2 \leq w_2 \\ \text{subject to:} & \\ & w_2 = w_1 + (1 - r) B_1 + p_a f(F_1, T) - p_F F_1 - p_T T. \end{aligned}$$

### 3.1 Land Values and Investment

To begin with, consider the case where the farmer is certain their land will not be expropriated before the second period (that is, the land is under freehold ( $h = 1$ ), and  $\phi(T, vL|h = 1) = 1 \forall T, vL$ ).

Figure 1 follows Carter and Olinto (2003) in depicting the constrained solution to the model. The width of the horizontal axis represents the available liquidity,  $w + s(vL, h)$ . Parameters  $\gamma$  and  $\tau$  represent the total expected marginal productivity of inputs  $F$  and  $T$ , respectively. Fertilizer is modeled to only last for one period, while trees continue to produce in both periods, therefore:

$$\begin{aligned} \gamma &= p_a \frac{\partial f}{\partial F_1} - p_F \\ \tau &= p_a \frac{\partial f}{\partial T} - p_T + \beta \frac{\partial \phi}{\partial T} \pi_2^* + \beta \phi \partial \pi_2^* \partial T \end{aligned}$$

However, as mentioned above, for the moment  $\phi$  is constant with respect to trees, so  $\frac{\partial \phi}{\partial T} = 0$ .

As in Carter and Olinto (2003), the liquidity-constrained farmer will choose inputs  $F$  and  $T$  such that the expected rates of return are equal between the two, labeled  $A$  in figure 1. These input levels will be necessarily lower than the unconstrained optima (where  $\gamma$  and  $\tau$  each cross the dashed line representing the marginal cost of the inputs and summing to more than the available liquidity). Given the lumpy nature

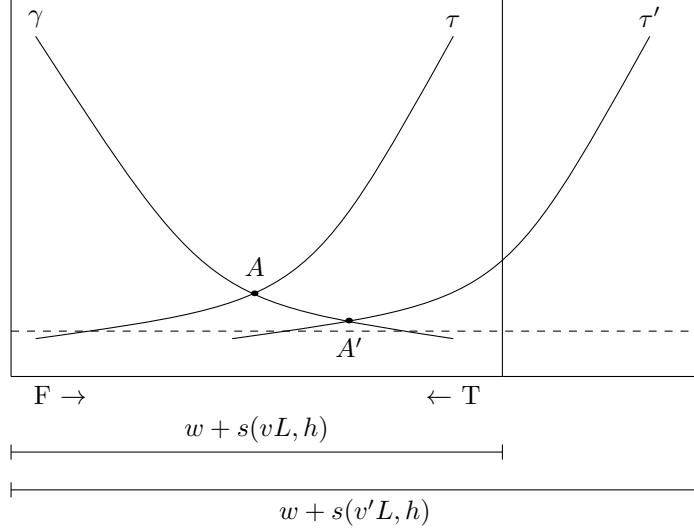


Figure 1: Increasing land values increase investment on freehold land. Fertilizer application (a short-term input) is measured from the left-hand axis; trees (long-term) are measured from the right, with the available liquidity represented by the width of the box,  $w + s(vL, h)$ . Expected total marginal productivity of fertilizer depicted with  $\gamma$ , and of trees depicted with  $\tau$ . In the absence of a binding liquidity constraint, optimal investment would be where each curve crosses the dashed line, representing the price of the input. Instead, optimal investment is at  $A$ , which equates the marginal productivity of the two inputs. As land values rise from  $v$  to  $v'$ , the available liquidity increases to  $w + s(v'L, h)$ , expanding the size of the figure. The marginal productivity curve for trees shifts along with the right-hand axis to  $\tau'$ , and in turn, optimal investment is at point  $A'$ , with higher fertilizer use (measured from the left) and tree planting (measured from the right).

of investment in trees, the farmer may optimally choose not to plant trees on their plot.

If there is an exogenous increase in the value of the land,  $v' > v$ , then the available liquidity provided by that land will increase, illustrated as an expansion of the horizontal axis to  $w + s(v'L, h)$ . This does not necessarily stem from using the land as collateral, but may instead be a function of output markets for crops grown, such as demand for cash crops.  $\tau$  is measured from the right-hand axis, and so as the available liquidity space expands, this curve graphically shifts to the right (to  $\tau'$ ). The marginal productivity curves now cross at  $A'$ , indicating higher investments in both fertilizer and trees. Therefore, increasing land values will allow for increased investment in both short and long-term inputs for liquidity-constrained farmers.

### 3.2 Customary Tenure and Investment

The threat of future expropriation of the land is real for many farmers, particularly on customary land. This expropriation can happen with little to no advance notice, as it takes the form of the sale or physical expropriation of the land by someone other than the use rights holder, rather than the non-renewal of a contract. The model captures this risk in two ways, as illustrated in figure 2.

Oversimplified models of customary tenure and investment merely consider customary land to have a

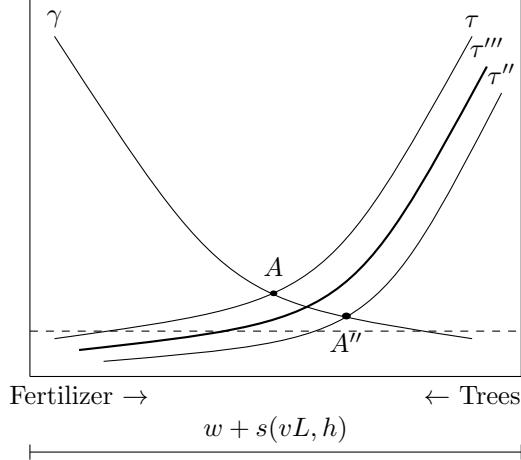


Figure 2: Long-term investment is influenced by customary tenure. Fertilizer application (a short-term input) is measured from the left-hand axis; trees (long-term) are measured from the right, with the available liquidity represented by the width of the box,  $w + s(vL, h)$ . Expected total marginal productivity of fertilizer depicted with  $\gamma$ , and of trees on freehold parcels depicted with  $\tau$ . In the absence of a binding liquidity constraint, optimal investment would be where each curve crosses the dashed line, representing the price of the input. Instead, optimal investment on freehold parcels is at  $A$ , which equates the marginal productivity of the two inputs. However, on customary parcels, the risk of expropriation before the second period could lower the total marginal productivity of trees to  $\tau''$ , which would shift optimal investment to  $A''$ , implying (in a liquidity-constrained context) lower investment in trees and higher investment in fertilizer on customary parcels relative to freehold. If trees have a security-enhancing effect on customary parcels, this shift towards the axis is attenuated, represented by  $\tau'''$ .

higher risk of alienation than freehold land:  $\phi(T, vL|h = 0) < \phi(T, vL|h = 1) \forall T, v, L$ , with  $\frac{\partial\phi}{\partial T} = 0$ . That is, for any level of investment in trees or land values, the risk of expropriation is higher on customary land, and this risk does not change in response to investment in the land. This lowers the expected total marginal productivity of investment in trees, as shown by a shift right (towards the origin for  $T$ ) from  $\tau$  to  $\tau''$ , decreasing the investment in trees to the equilibrium shown at  $A''$ .

Drawing upon qualitative understandings of customary tenure, though, more subtle models have sought to capture the endogenous nature of tenure security on customary land. Place and Otsuka (2002), for instance, model the probability of losing land as a decreasing function of planting trees, a visible investment in the land. In my model, this implies that  $\frac{\partial\phi}{\partial T} > 0$ , which would attenuate the rightward shift of the  $\tau$  curve (and could perhaps even lead to an ‘overinvestment’ in trees relative to the unconstrained optimum if the tenure-enhancing effect is large, although empirically this is rarely documented). This combined effect leads to the marginal productivity of trees indicated by  $\tau'''$ .

The equilibrium determined by the marginal productivity of trees under (less-secure) customary tenure, then, likely sees under-investment in trees relative to the allocation under freehold tenure. I will empirically test this using data from Uganda.

### 3.3 Expropriation Risk under Customary Tenure

Customary tenure is not simply insecure tenure. Earlier, I showed that an attention to the complexities of how customary tenure functions can have important implications: visible investment decisions such as planting trees can demonstrate responsible land use (a condition of tenure), thus endogenously strengthening tenure rights. Recall that by planting trees on a plot, a farmer demonstrates to the community that it is under use. If another member of the community tries to encroach on the plot, these visible investment decisions can be used as evidence of responsible land use, and thus make it more likely that disputes within the community will be resolved in the farmer's favor.

The model so far has ignored the particular bundles of rights and their distribution among individuals that are hallmarks of customary tenure systems. That is, many customary tenure systems in Sub-Saharan Africa, and those in Uganda in particular, do not vest all types of rights over a given piece of land in the same individual or household. Primary use rights may be held by one household, while other members of the lineage or extended family have access rights or even claims to certain plants (Howard and Nabanoga, 2007). Importantly for this analysis, local elites (such as lineage heads or traditional chiefs) often hold transfer rights over large areas of customary land.

These decentralized rights do not in themselves cause major tenure insecurity (Bruce and Migot-Adholla, 1994); indeed, they can provide much-needed flexibility to adjust to changing populations. Mechanisms, such as planting trees, have developed to allow use-holders to demonstrate tenure against other claimants, with local elites serving as arbiters and rights-holders for the community.

However, there has been recent concern in policy spheres about the potential for local elites to make deals with outsiders (often national or international investors) that alienate local rights-holders. While the details of such deals, termed 'Large-Scale Land Acquisitions' (Smalley and Corbera, 2012; Purdon, 2014), are beyond the scope of this model, they represent but one example of local elites using their traditional rights to the land for their own gain.<sup>19</sup> Outside investors often find it difficult to navigate the complex realities of customary rights, and thus they may not realize that they are expropriating land from existing users without their consent.

In the context of this model, it suffices to note that increasing land values may not only increase the value of the asset for the primary land user, but also for other rights-holders. This could increase the value of expropriation for these other individuals (namely, local elites with transfer rights). Local elites may not have found it profitable to exercise their traditional rights in an inactive land market, preferring instead to maintain the traditional status quo. However, as land values rise (whether due to offers from outside

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<sup>19</sup>It could be argued that this is in fact a reinterpretation of their customary rights, shifting from custodian of the land to 'owner' in a more Western, exclusive, sense.

investors, population pressures from growing urban areas, or other exogenous forces that introduce potential outside buyers who are less familiar with the customary) they may be more likely to expropriate from the land user in order to alienate the land to others.<sup>20</sup>

Within the model, then,  $\phi$  is written as a function of  $vL$  as well as  $h$ , the tenure system, and  $T$ , tree investment. In particular,  $\phi(T, h, vL)$  could have the following properties (laid out in more detail in the appendix):

$$\phi(T, h, vL) = \begin{cases} 1 & \text{if } h = \text{Freehold}, \\ g(T, vL) & \text{if } h = \text{Customary}. \end{cases}$$

where  $\frac{\partial g}{\partial T} > 0$ , as in Place and Otsuka (2002), and  $\frac{\partial g}{\partial v} < 0$  following the intuition outlined above.

The land user (farmer/decision-maker) can anticipate these changing incentives for their co-rights-holders, as captured in  $\frac{\partial \phi}{\partial v} < 0$ . Rising land values may mean that no matter the level of their own investment in production, the risk of expropriation increases. Figure 3 illustrates this: the higher risk of expropriation could outweigh the liquidity constraint-relaxing effects of increasing land values, and perhaps even on net decrease longer-term investments in the land. The shift from  $A$  to  $A'$  reflects the effect of increasing land values on investment on freehold land: although still bound by the liquidity constraint, investment in both fertilizer and trees increases. For customary land in Figure 3, increasing the value of the land and relaxing the liquidity constraint does not simply shift the marginal productivity of trees rightward, but changes the shape due to the effect of  $\frac{\partial \phi}{\partial v}$  discussed above.<sup>21</sup> Graphically, the farmer has actually left the liquidity-constrained case, but investment in trees has decreased to  $T_C^{*'}.$

## 4 Data

To test this model empirically, I use data from the baseline survey I conducted for a proposed impact evaluation of Uganda's Agriculture Cluster Development Project (ACDP).<sup>22</sup> This baseline survey was conducted

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<sup>20</sup>An alternate, complementary, understanding of this process (explored in Honig (2022)) is that in isolated communities, returns to elite are primarily social – respect and prestige from their community. But as outsiders penetrate the community, that social prestige may be less valuable or obtainable from a community in flux. This may make the monetary benefits of expropriation seem even more valuable.

<sup>21</sup>In the formal model in the appendix, this can be seen by comparing the matrix products from the implicit function theorem in equations (53) and (62), or by comparing the equilibria conditions for freehold (equation (45)) and customary (equation (54)), where the marginal productivity of tree investment is higher in the customary case, indicating fewer trees are planted.

<sup>22</sup>This project, supported by the Government of Uganda and the World Bank, aims to provide farmers in five crop-specific ‘clusters’ (maize, rice, beans, cassava, and coffee) with the resources needed to move from subsistence farmers to commercialized producers. To that end, the project provides subsidized farm inputs to selected farmers, improves agricultural infrastructure, and supports post-harvest handling technologies. The impact evaluation was planned as part of the pilot phase of the project, focusing on the provision of electronic vouchers for subsidized inputs that are redeemable at certified local agro-input dealers. The impact evaluation was planned in 4 districts throughout Uganda, each assigned one of 4 target crops (maize, rice, beans, and coffee; cassava was omitted as it has a longer growing season). The impact evaluation randomly assigned farmer organizations

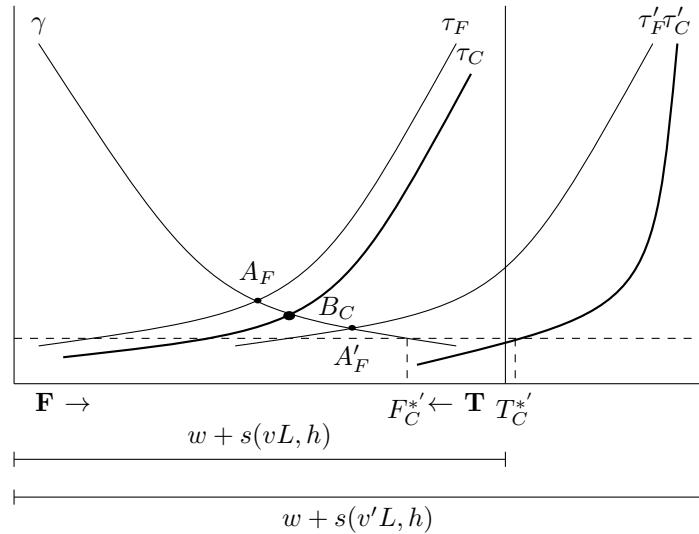


Figure 3: Rising land values, and the strategic interactions they create on customary parcels, shape investment in long-term inputs. Fertilizer application (a short-term input) is measured from the left-hand axis; trees (long-term) are measured from the right, with the available liquidity represented by the width of the box,  $w + s(vL, h)$ . Expected total marginal productivity of fertilizer depicted with  $\gamma$ , and of trees on freehold parcels depicted with  $\tau_F$ . In the absence of a binding liquidity constraint, optimal investment would be where each curve crosses the dashed line, representing the price of the input. Instead, optimal investment on freehold parcels is at  $A_F$ , which equates the marginal productivity of the two inputs. However, on customary parcels, the risk of expropriation before the second period could lower the total marginal productivity of trees to  $\tau_C$ , which would shift optimal investment to  $B_C$ , implying (in a liquidity-constrained context) lower investment in trees and higher investment in fertilizer on customary parcels relative to freehold. As land values rise from  $v$  to  $v'$ , the available liquidity increases to  $w + s(v'L, h)$ , expanding the size of the figure. The marginal productivity curve for trees on freehold parcels shifts along with the right-hand axis to  $\tau'_F$ , and in turn, optimal investment on freehold parcels is at point  $A'_F$ , with higher fertilizer use (measured from the left) and tree planting (measured from the right). On customary parcels, however, the higher land values increase the likelihood of elite expropriation, which lowers the total marginal productivity of the long-term input trees even further, to  $\tau'_C$ . This means that although optimal fertilizer use on customary parcels increases to  $F_C^{*'}$ , optimal tree planting does not increase with higher land values and is instead depicted by  $T_C^{*'}$ .

in early 2019 in four districts throughout Uganda. Respondents were chosen in a two-stage process: first, we randomly selected 133 registered farmer organizations that had at least 20 members in the target districts, and membership rosters were drawn up. Member households were then randomly selected to be interviewed, with a total of 2,189 interviews in the baseline survey used here.

The districts selected for the impact evaluation are located throughout the country and thus encompass some of the diversity of customary tenure arrangements in Uganda. Selected districts are located in the east, southwest, center (where *mailo* land predominates), and north (where instability has led to many internally displaced people).

As part of the impact evaluation, the Ministry of Agriculture, Animal Industry and Fisheries and a team from UC Davis conducted an extensive baseline survey,<sup>23</sup> which has data well-suited to the structure of this model. Given that the program was designed to induce investment in agriculture, the survey has an exhaustive plot-level elicitation of all inputs and outputs as well as continuous measures of the value of investment. Furthermore, the survey asks detailed questions about the tenure status of each agricultural parcel farmed by the respondent household. These questions ask about the tenure system the parcel is under; which individual members of the household are owners; what kind(s) of documentation exist for the parcel, if any, and whose names are on the documentation; who within or outside the household holds particular rights (such as transfer rights); and questions on perceived tenure security. Finally, the survey asks about land rental prices in the region and contains GPS coordinates for the household, allowing me to match households to other geospatial datasets. For most specifications, I use a dataset of 3,076 parcels; most were observed over two seasons, for a total of 5,760 parcel-season observations which I pool.

To some extent, this sample is positively selected in comparison to all farmers in Uganda: they are members of farmer groups, indicating a higher likelihood of participating in output markets and perhaps higher farming skill, although farmer groups are relatively common in Uganda.<sup>24</sup> This positive selection can be seen in rates of input use in the ACDP data when compared with the nationally-representative Living Standards Measurement Survey (LSMS) conducted by the Uganda Bureau of Statistics and the World Bank: only 4.6% of parcels have organic fertilizer applied and 2.6% inorganic fertilizer in the 2019 LSMS, as compared with 11.5% and 10% of parcels in the ACDP data, respectively. This higher rate of input use provides a key advantage over the more widely used LSMS data: I can estimate the interacted models that

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eligible for the ACDP subsidy to one of two treatment groups (defined by the timing of benefits) or to a ‘downstream’ control group. Approximately 36 farmer organizations were assigned to each treatment arm, from each of which an average of 20 members were selected to be surveyed throughout the four districts.

<sup>23</sup>Subsequent mid-line and end-line surveys were planned but were cancelled along with the implementation of the Impact Evaluation in November 2020, due to compliance issues and COVID-19. The baseline data I use was entirely collected pre-intervention, so there should be no impacts of the intervention on input use.

<sup>24</sup>In the 2019 Living Standards Measurement Survey, 28% of communities report having a farmers’ group; 43% report a savings & loan group that was identified by subcounty extension workers as serving as a farmers’ group for the purposes of ACDP targeting.

emerge from my model due to the variation in the outcome. However, it comes at a potential cost of external validity.

I use two measures of the external pressure on land values modeled above. First, I use the inverse travel time to Kampala, the national capital, adapted from Muller-Crepon et al. (2021) and Muller-Crepon (2021). This measure is constructed using historical road maps from Michelin, which Muller-Crepon et al. (2021) digitized and created a road atlas for all of Africa from 1966 to 2015, akin to a historical Google Maps. In Muller-Crepon (2021), he then estimates the shortest travel time via roads of different qualities to the national capital for each 5x5 km grid cell.<sup>25</sup> Both Muller-Crepon (2021) and Muller-Crepon et al. (2021) use the inverse of travel time to the capital as proxy of state reach in a local geography, but it also represents the degree to which outsiders such as urban residents of the capital may be interested in purchasing local land: precisely the concern of customary landowners that creates insecurity. Figure 4 plots the average travel time to Kampala in each parish of the country, with ACDP districts highlighted in yellow.<sup>26</sup>

I match households to a grid cell using GPS locations collected during the survey (taken at the household residence, not at agricultural fields which could be at some remove). Following Muller-Crepon et al. (2021), I then compute the ‘access’ to the national capital in 2015 for each household as  $(1 + time_j)^{-1}$ .<sup>27</sup> The correlation between per-acre rental prices and access to Kampala is low (.08) but increases to .21 when I winsorize several outliers in estimated rental prices (among those who own their land and are estimating how much they could rent it out for) and to a very high .93 when I consider district median rental prices, suggesting that it captures broader pressures than individual prices which may be influenced by soil quality or other agricultural value considerations.

The second measure I use attempts to isolate changing pressures on local land, which is a more direct representation of the pressure on local elites to expropriate and sell customary land to outsiders. I use the historical (10-year) decrease in travel time to Kampala, due to the construction or upgrading of roads, relative to the 2005 travel time to Kampala. This measure, also constructed using historical spatial data from Muller-Crepon et al. (2021), captures the extent to which elites face *new* opportunities to expropriate, which should have a strong impact on perceptions of tenure insecurity. I match this measure spatially in the same way as the inverse travel time variable described above.

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<sup>25</sup>This is approximately 2.5 arc-minutes at the equator, which Uganda spans.

<sup>26</sup>I focus on travel time to Kampala rather than to regional capitals in this analysis, as I want to isolate away from the politically-driven administrative unit proliferation that has occurred in Uganda in the recent past. Although a new district capital may be identified close to respondents, these new centers do not yet have the population to support substantial outsider demand for land.

<sup>27</sup>This represents the most recent year for which Muller-Crepon (2021) has data on travel time to national capitals, regional capitals, and distance to markets, and thus the closest to the ACDP baseline survey in 2019.

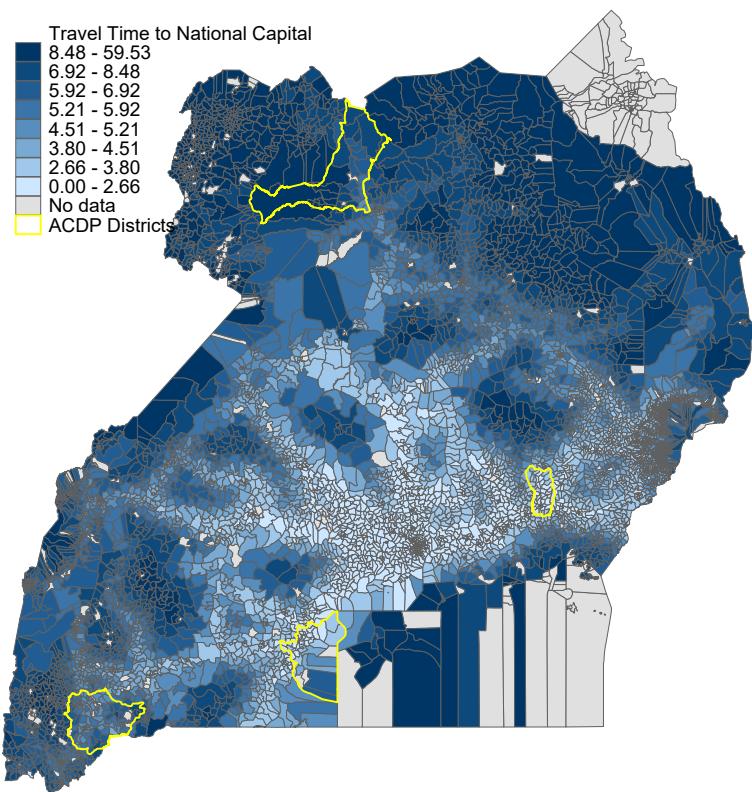


Figure 4: Map of the average travel time in 2015 to Kampala in each Parish in Uganda, with ACDP districts highlighted in yellow. Administrative units in Uganda extend into Lake Victoria to the national border, to include several small islands.

## 5 Empirical Strategy

To test the predictions outlined in the model, I examine differential patterns of short- and long-term agricultural investments on parcels under different tenure regimes as land pressures exogenously increase. These predictions go beyond existing models of land tenure and investment by considering how overlapping rights-holders respond to rising land prices, and thus how incentives may change differently on customary land. Commonly-used empirical strategies model tenure *security* (the expected probability of expropriation before realizing the fruits of investment) but then only empirically measure rough proxies such as tenure *type*. Improving over this, I explicitly model the relationship between tenure *type* and investment (operating through tenure security). The theoretical model explored above shows how a rough proxy may be insufficient: in low land-value environments, customary land may be equally secure as freehold, but as land values increase, customary land may become less secure.<sup>28</sup>

Outside this advancement, I use empirical methods generally accepted in the literature. At heart, the empirical specification involves regressing a given investment measure on a continuous measure of land values interacted with a dummy for a parcel being under customary (as opposed to freehold) tenure. Investments should rise with land values on freehold land due to a relaxation of the liquidity constraint; on customary land, however, this effect is attenuated by the escalating insecurity caused by local elites' incentives to expropriate newly-valuable land to sell to outsiders. The coefficient on the interacted term of customary tenure with a measure of land pressure is of primary interest: is the response to rising land pressures statistically different on customary parcels than on freehold ones?

Several concerns are apparent with this strategy. First, the tenure regime of particular parcels may not be exogenous (for example, households may be more likely to pursue titling for higher-quality plots). Deininger and Ali (2008) argue that Uganda has what amounts to an “exogenous historical assignment of land rights... and the absence of readily available opportunities to change the tenure status of occupied land to full ownership imply that the case at hand can be considered akin to a natural experiment.” In the appendix, I explore differences in parcel characteristics by tenure type, and although there are some observable differences in table A33, the results are robust to controlling for these characteristics in tables A34 - A38. Second, there may be unobserved heterogeneity in household farming decisions caused by factors such as household shadow prices or farming skill, which may be correlated with the tenure of parcels farmed by households. Ideally, this would be addressed using a household fixed-effects strategy. Unfortunately, of the 2,189 households surveyed, only 6.5% of respondents reported having parcels under both freehold and customary tenure, which is much lower than the rates observed in the LSMS-ISA in Uganda, a high-quality

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<sup>28</sup>The lack of results in previous studies which elide tenure security and tenure type may be understood, then, as an issue of this poor proxy.

nationally-representative dataset (Deininger and Ali, 2008). Furthermore, these households are concentrated in two of the four surveyed districts. This limits the power of a household fixed-effects model to detect changing investment patterns as land prices increase.

Despite this, the ACDP data sampling strategy involving farmer groups allows me to extend the intuition of household fixed effects to farmer group fixed effects. These farmer groups are co-located, self-selected groups of farmers who can purchase inputs in bulk, share farming methods, and aggregate outputs in order to receive better output prices, in addition to meeting regularly for mutual support. Therefore, it seems plausible that many unobservable characteristics are shared by members of the same farmer group. By including a farmer group fixed effect, I am able to control for a portion of the unobserved heterogeneity while still retaining some identifying variation. However, this does restrict the identifying variation almost to zero for regressions using the inverse travel time. This is measured at a fairly coarse geographic scale, meaning that most farmer groups are all within the same grid square or parish. Including farmer group fixed effects when using these geographically coarse measures of land pressures would mean I am identifying off of within-group noise from the few groups that have members in grid cells with different travel times, which could give misleading estimates. Therefore, my preferred specification includes farmer group fixed effects for regressions using the standardized rental price as the measure of land pressures (column (2) in results tables 1 - 6) but without the fixed effects for regressions using the inverse travel time or changes in travel time (columns (3) - (4) in tables 1 - 6). In interpreting coefficients on rental price with the farmer group fixed effects, I identify off of within-group differences in land pressures; for other measures, the results are more between-groups or regions. All specifications cluster standard errors at the larger parish level, to account for geographic relationships between households. In the appendix, I present results with a more traditional parish fixed effects specification with land values (table A19) for robustness, as well as computing spatially dependent standard errors as in Conley (1999) (tables A5 - A9).

The primary results that I present have land pressures entering linearly, with a constant marginal pressure on either customary or freehold land. This may not be the appropriate specification: it may be that elite incentives to expropriate only begin at intermediate or relatively high land pressures, or alternately that in high land pressure environments, the likelihood of expropriation of customary land has been ‘priced in’ to investment behavior, meaning the marginal effect of increasing pressure is minimal. In order to explore this, I examine whether the relationship differs on either side of a travel time threshold identified in interviews as being relevant for external land demand from Kampala, 2 hours travel time. I separately estimate the responsiveness of investment to land pressures on customary and freehold land on either side of the threshold. In the appendix (tables C.4 - C.4), I also use the Hansen (2000) threshold estimator to statistically identify the location and existence of the threshold. However, because the ACDP data only comes from 4 districts,

I do not have a continuous support of most measures of land pressure, making the threshold detection noisy and prone to overfitting. The detected thresholds are close to the two hour point for all outcomes, but the estimation is more difficult to interpret.

## 5.1 Hypotheses

First, I illustrate the hypothesized comparative statics from the model represented in figure 3 and identify which terms would capture them in regressions. Consider the following cross-sectional empirical specification which closely follows the model discussed above:

$$I_i^Q = \gamma_0 + \gamma_1^Q D_i + \gamma_2^Q \bar{v} + \gamma_3^Q D_i * \bar{v} + \beta' X_j + \eta_f + \epsilon_{fi} \quad (1)$$

where  $I_i^Q$  is a measure of investment of type  $Q$  (either short- or long-term) by household  $j$  (a member of farmer group  $f$ ) on parcel  $i$ ;  $D_i$  is a dummy equal to one if the parcel is customary;  $\bar{v}$  is the exogenous component of land price in the locality;  $X_j$  is a vector of household characteristics (a probability of poverty index, total household landholdings, and dummies for how the parcel was acquired); and  $\eta_f$  controls for farmer-group fixed effects. This equation would be separately estimated for long and short-term inputs.

The particular hypotheses predicted by the model are derived in the mathematical appendix. Here I summarize proposed tests of the predicted signs of the following in cross-sectional data:

1.  $\frac{\partial F}{\partial v} \Big|_{h=1}$  : That is, how does short-term input use vary with respect to land values on freehold land?

The model would predict that *ceteris paribus*, a liquidity-constrained farmer would use more short-term inputs as land values increase. This is tested by examining the sign of  $\gamma_2^S$ .

2.  $\frac{\partial T}{\partial v} \Big|_{h=1}$  : That is, how does long-term input use vary with respect to land values on freehold land?

The model would predict that *ceteris paribus*, a liquidity-constrained farmer would use more long-term inputs as land values increase. This is tested by examining the sign of  $\gamma_2^L$ .

3.  $\frac{\partial F}{\partial v} \Big|_{h=0}$  : That is, how does short-term input use vary with respect to land values on customary land?

The model would predict that *ceteris paribus*, a liquidity-constrained farmer would use more short-term inputs as land values increase. This is tested by examining the sign of  $\gamma_2^S + \gamma_3^S$ .

4.  $\frac{\partial T}{\partial v} \Big|_{h=0}$  : That is, how does long-term input use vary with respect to land values on customary land?

The model would predict that *ceteris paribus*, a liquidity-constrained farmer would use fewer long-term inputs as land values increase. This is tested by examining the sign of  $\gamma_2^L + \gamma_3^L$ .

with the last of these being the primary innovation of this model. Without considering the changing incentives

of local elites, the impact of rising land values on customary land would parallel that on freehold. This stems from the qualitative fact that tree planting behavior is effective at securing tenure within the community, but less so to outside investors who find this demonstration of rights illegible.

## 5.2 Measuring Tenure Security

In taking stock of the body of empirical evidence on tenure security and investment, several papers have noted the variety of definitions of tenure security as well as proxies used empirically (Arnot et al., 2011; Deininger and Ali, 2008). Common empirical measures include the existence of legal title, duration of tenure, method of acquisition, tenure type, existence of a conflict over the land, subjective perceptions of tenure security, and existence of particular rights (often transfer rights) (Arnot et al., 2011). It is often left implicit how these proxies are related to tenure *security*, which is the parameter modeled. Fenske (2011) notes that the choice of proxy does seem to be related to the effect found, and therefore this is a crucial choice. I do have a measure of subjective tenure security, which does respond to changing land pressures as in the model; in the appendix, I also show in table A20 that alternate proxies such as documentation and past experiences of disputes have the expected correlations with perceived tenure security.

My model addresses concerns with measures of tenure security by explicitly considering the relationship of the empirically observable tenure type to the fundamental parameter of interest, tenure security. The importance of this consideration is illustrated by the final hypothesis, that customary tenure exists in an institutional context that responds differently to changes in land value, and therefore the relationship between tenure type and security is different in high and low land value areas. Arnot et al. (2011) distinguish between the ‘content’ and ‘assurance’ aspects of tenure, and rather than eliding between those, I consider how the two are related.

## 5.3 Measuring Investment

Another point at which many papers allow their model and empirics to diverge is in the measurement of agricultural investment, the outcome of interest. Because many smallholders operate low-input, even subsistence farms, it is difficult to measure investment well. Therefore, many papers have used binary investment outcomes (Fenske, 2011). I present binary outcomes using a linear probability model in order to allow for farmer group fixed effects (much as Deininger and Ali (2008) do).

However, the ACDF data also allows for continuous measures of investment, although these were measured with some error. Fenske (2011) has argued that measuring investment in a continuous way can make a substantial difference to the results. He argues for the trimmed least absolute deviations estimator to deal

with the prevalence of zeroes in types of investment. This is the panel equivalent of the Tobit estimator (Honore, 1992); as I only have a cross-section of data, I use the Tobit for continuous investment measures; results are in the appendix. Coefficients on a Tobit model are interpreted as in a linear model; however, the linear effect is on the uncensored (non-zero) outcome. Broadly, these results are consistent with those in the binary outcomes case.

## 5.4 Land Values

Importantly, the model presented above takes land values to be an exogenous force shaping the incentives faced by farmers. This modeling choice was driven by the qualitative literature, which has focused on the breakdown of customary institutions caused by outside pressures, such as the rapid urban expansion in much of Africa or international large-scale land acquisitions. In reality, the value of an individual parcel of land is a product of its particular features, including any investments made. In my results, I present some specifications using standardized land rental values (in the appendix, I also use alternate measures of land prices, including predicted prices for all parcels, median village prices, and non-standardized rental value). These results carry the crucial caveat that land prices are likely a result of land quality, which may change optimal investment behavior through pathways other than those modeled.

Therefore, I also present results where I proxy for the exogenous pressures on land values with the inverse travel time to the national capital or the relative 10-year change in travel times to the capital. These measures should impact agricultural investment through the pathways described in the model: certainly, more (peri-)urban areas have more active credit markets, which would relax the credit constraint faced by the household, and a pool of urban buyers is the canonical situation incentivizing local elites to expropriate customary land. The process of urbanization, though, should not impact agricultural investment through other channels, such as via an increase in total factor productivity.

These measures could potentially be used as an instrument for local land values (as seen above, they are correlated with regional patterns in land values and would therefore be valid); however, I choose to treat them as proxies for the underlying phenomenon of interest, external pressures and demand for land. Rental values for individual parcels are perhaps an even more problematic proxy for the forces modeled, so I focus on these more exogenous measures which should be better-identified. Nevertheless, these results may not be strictly causal; however, they can be understood as descriptive of patterns consistent with a theoretical model. I have constructed all measures of land pressures such that higher values represent greater pressure on land: higher standardized rental prices, larger inverse travel times (equivalent to shorter travel times to Kampala), or greater decreases in travel time over the past 10 years relative to 2005 times.

## 6 Results

In this section, I present results for a variety of agricultural investments, following the empirical strategy in equation (1). The model predicts that long-term inputs respond to rising land values more strongly on freehold land than on customary land due to the attenuating effect of increased insecurity on customary land induced by elite incentives to expropriate.

Before turning to the regressions with individual agricultural inputs, consider figures 5 - 7. Each of these presents the difference in the coefficients for (binary) input use between freehold and customary parcels as a function of land values in the area (measured by rental values in figure 5, the inverse travel time to Kampala in 6, and the 10-year relative decrease in travel time in 7).<sup>29</sup> For short-term inputs such as pesticides and inorganic fertilizer, the model would predict equivalent responses to rising land pressures on all parcels, which would appear as a flat line on these graphs. As can be seen, however, there is a slight divergence in short-term input use on freehold vs. customary parcels as rental prices or the accessibility to Kampala rise, reflected by a positive (although shallow) slope in these figures for short-term inputs. This result, explored further below, can be explained by a shift toward pesticide-intensive crops near urban markets.<sup>30</sup> As urban markets expand, so does the local demand for cash crops (such as vegetables and fruits which are difficult to transport long distances). Farmers facing this increased demand therefore shift their production away from staples and towards cash crops. This shift is stronger on freehold parcels, perhaps because such parcels remain secure.<sup>31</sup> Cash crops, in turn, may have a higher return to inputs, and particularly to pesticides, than staple crops (Riwthong et al., 2017).

If the model holds, this effect of changing crop choices on long-term inputs should be compounded by the direct impact of additional insecurity on customary land prompted by rising land pressures. In figures 5 - 7, there is a stronger response for trees, the most long-term of the inputs measured, than for short-term inputs, as shown by the steeper slope in the difference in predicted input use. Visually, the insecurity effect can be seen in the difference in slopes between the short- and long-term inputs in these figures.

Figures 5 - 7 also depict the difference in reported insecurity between freehold and customary land. This measure is discussed in further detail below, but note that at low land pressures, parcels under customary

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<sup>29</sup>I separately regressed input use on the measure of land pressures for customary and freehold parcels, and then plot the difference in coefficients from each of these regressions. This is in contrast to the regression tables below, where I include all parcels and use interactions to model the relationship between land pressures, tenure type, and input use.

<sup>30</sup>An alternate explanation could be different collateralizability of customary and freehold parcels. Farmers may be less able to internalize rising land values to relax their liquidity constraint on customary parcels. This would be less concerning if farmers held parcels under different tenure systems, due to the fungibility of loans. When I examine household credit usage in my sample, those in areas closer to Kampala are actually slightly less likely to take out loans; the relationship between credit usage and normalized individual rental prices is insignificant. This suggests that collateral is not driving the results for short-term inputs.

<sup>31</sup>It may also be that households with freehold parcels are better placed to take advantage of new markets for cash crops; future work with household fixed effects could eliminate this pathway.

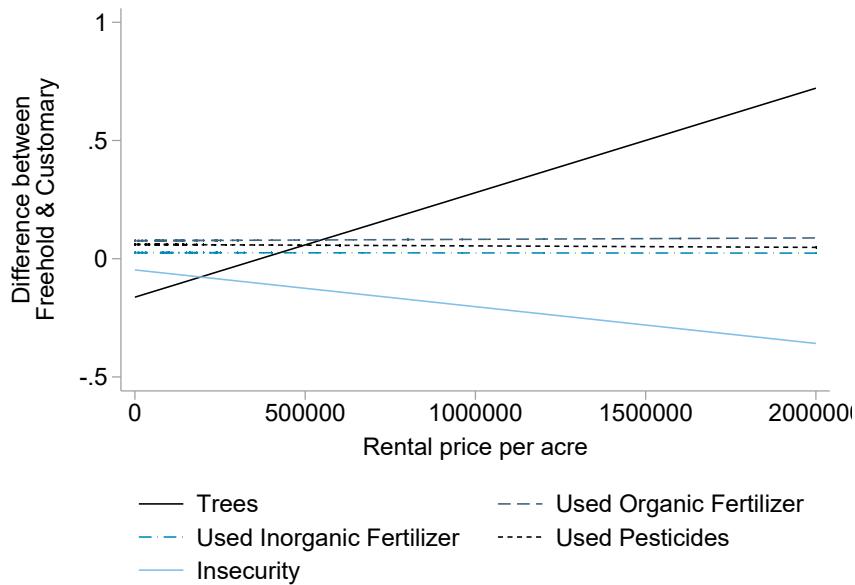


Figure 5: Disparities in tenure types increase with rental values more strongly for long-term than short-term inputs. Customary parcels become relatively more insecure than freehold as rental prices increase.

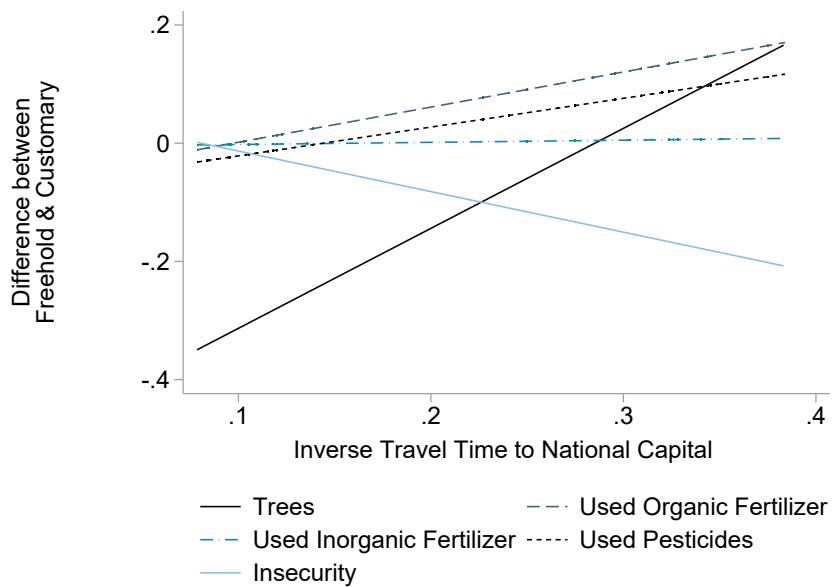


Figure 6: Disparities in tenure types increase with the inverse of travel time to Kampala (and thus demand for land by outsiders who may not understand local customary tenure) more strongly for long-term than short-term inputs.

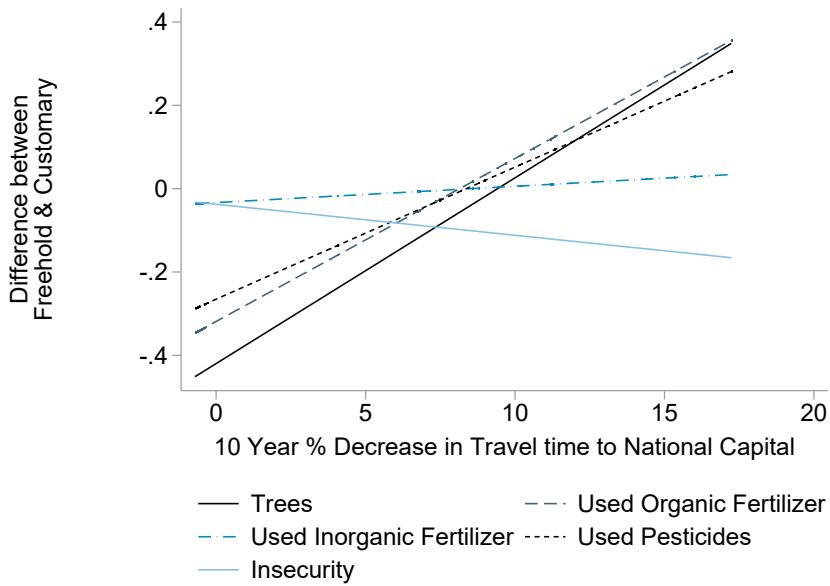


Figure 7: Disparities in tenure types increase with a greater percentage decrease in travel time to Kampala, a measure of increasing demand for land by outsiders, more strongly for longer-term inputs. However, there is a relatively large difference in responses for pesticides.

and freehold tenure are perceived as roughly equivalently secure. As pressures rise, respondents report higher perceived likelihoods of losing their customary parcels without an equivalent rise on freehold parcels.

In each table below, I present several different specifications; additional robustness checks are provided in the appendix. I include three distinct measures of land pressures. First, I use the standardized per-acre rental price in shillings as reported for a given parcel (either actual paid rental price or estimated potential rent if the parcel were rented out, and predicted using similar nearby parcels if the respondent did not report a rental price). As discussed above, this measure is not solely driven by exogenous land market pressures, and it could be capturing unobserved land quality (or even influenced by prior long-term investments in the land).<sup>32</sup> Therefore, I also show results using the inverse travel time to the national capital and 10-year decreases in travel time to Kampala (proportional to 2005 travel time) as proxies for underlying pressures, particularly outsider demand for land. These measures of land values are interacted with a dummy for the tenure status of a parcel, so the coefficient on ‘Freehold\*Land Value’ represents the responsiveness to land values on freehold land, while ‘Customary\*Land Value’ represents the same on customary parcels.<sup>33</sup>

In all regressions shown, I control for household characteristics: the Probability of Poverty Index (PPI)

<sup>32</sup>In the appendix, I show that results are similar when using predicted rental prices for all parcels, predicted using the probability of urbanization, latitude and longitude of the household, tenure status, existence of trees on the parcel, and village fixed effects.

<sup>33</sup>Although conceptually similar to the slopes in figures 5 - 6, they are computed differently, include the addition of controls, and use clustered standard errors.

as well as for a household's total landholdings in acres. The PPI uses low-cost survey indicators to estimate the likelihood that a household has consumption below a given poverty line, and it can be interpreted approximately as a wealth index (with higher values indicating a lower likelihood of poverty) (Schreiner, 2012). Encouragingly, the coefficient on PPI accords with intuition: wealthier farmers are generally more likely to use agricultural inputs, with the exception of trees, which may be more important for their security-enhancing functions for poorer households. I also control for how the parcel was acquired (inherited, purchased, assigned by authorities, loaned, etc), to support the conditional exogeneity of land tenure status. In columns (1), (3), and (4) pooled regressions are run, clustering standard errors at the parish level. In column (2), farmer-group fixed effects are added to the clustered model. This model is the most conservative, but because of relatively low input use and the geographic clustering of farmer groups (restricting the identifying variation somewhat) results are at times insignificant (although patterns are generally consistent with the pooled models).

## 6.1 Tenure Security

Before turning to agricultural inputs used on parcels, recall that exogenous land pressures should influence input decisions through two pathways: increasing inputs by relaxing the liquidity constraint (which should be equally true for all parcels and all inputs), and increased tenure insecurity (attenuating the liquidity effect, but only for long-term inputs under customary tenure). Customary tenure is not necessarily less secure than freehold; rather, it can become less secure if local elites face incentives to expropriate customary land. These incentives, I argue, increase with local land values.

Actual elite expropriation of customary land to sell to outsiders is relatively rare and therefore difficult to detect statistically in random-sample surveys such as this one. However, even if respondents have not personally experienced elite expropriation, they may worry about it, particularly as their community experiences the external pressures that have led to elite expropriation elsewhere. If this pattern holds, I would expect respondents to express greater concern about losing customary parcels as land pressures increase. These land pressures should not affect the perceived security of freehold land to the same extent, as titles provide some legal recourse in case of expropriation.

Table 1 presents regression results using the average perceived insecurity of a parcel as the outcome. That is, for each parcel, respondents were asked first who in the household had rights to that parcel, and what the likelihood was that each rights-holder would involuntarily lose the land (on a scale of 1 to 5, with higher numbers representing a greater chance of losing it). These responses were averaged across all rights-holders to each parcel to measure household-level insecurity about that parcel.

VARIABLES	Average Insecurity			
	(1)	(2)	(3)	(4)
Freehold × Rental Price	0.0290 (0.0255)	0.0348 (0.0227)		
Customary × Rental Price	0.150*** (0.0295)	0.154*** (0.0377)		
Freehold × Inverse Travel Time			-0.777** (0.305)	
Customary × Inverse Travel Time			1.174*** (0.276)	
Freehold × Decrease in Travel Time				-0.958 (0.794)
Customary × Decrease in Travel Time				1.561* (0.777)
Customary	0.0673 (0.0519)	0.0546 (0.0499)	-0.447*** (0.108)	-0.177 (0.121)
Wealth Index	0.000203 (0.00137)	-0.000635 (0.00152)	-0.000578 (0.00167)	-0.000323 (0.00155)
Landholdings	-0.00205** (0.000955)	-0.00196* (0.00110)	-0.00201** (0.000908)	-0.00212** (0.000965)
Observations	5,560	5,560	5,537	5,537
R-squared	0.255	0.325	0.252	0.245
Fixed Effect	None	Group	None	None
Cluster	Parish	Parish	Parish	Parish

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

Table 1: OLS results of average tenure insecurity across all rightsholders (scale of 1-5, with higher values indicating more insecure) on a parcel on measures of land pressures, controlling for the Progress out of Poverty Index wealth index, total landholdings of the household in acres, and dummies for the method of parcel acquisition. Farmer Group fixed effects included in column (2), and standard errors are clustered at the parish level in all specifications (reported in parentheses). Customary is a dummy equal to one for customary parcels and zero otherwise. Difference in number of observations between columns (1) and (2) vs. (3) and (4) is due to missing GPS locations for some households, so they could not be matched to spatial measures of travel time.

In table 1, tenure insecurity responds weakly to higher land pressures on freehold land, but demonstrates a statistically significant positive relationship with land pressures on customary land. This implies that customary land becomes more insecure than freehold as land pressures rise. These results suggest that the hypothesized mechanism for agricultural investment (rising insecurity on customary land) does indeed hold in Uganda. In table A4, I conduct a similar exercise using a larger sample of data collected for monitoring & evaluation purposes of ACDP across an additional 30 districts (this data does not contain consistent measures of input use, so cannot be used for the full analysis). Results are consistent, even stronger, when using this more geographically diverse sample.

## 6.2 Tree Planting

Planting trees in Uganda represents a long-term investment in agricultural productivity. In an inter-cropped system, trees provide structure for climbing crops (increasing the productivity of those crops), prevent soil erosion, and produce fruit or coffee themselves (Deininger and Ali, 2008), though their value takes some time to be realized. Therefore, the expected benefits of tree planting are lessened as the risk of expropriation increases, as modeled above.

Trees have a more nuanced relationship with tenure security on customary land. Because trees are such a visible investment in the land, planting trees on a parcel can actually reduce the risk of expropriation, particularly by neighbors who understand the social context of customary tenure. Therefore, it might be expected that in more isolated (low land-pressure areas) where local social dynamics dominate, tree-planting might actually be more valuable on customary land than on freehold. As external land pressures increase and the primary security concern shifts to elite expropriation to sell to outsiders, this security-enhancing effect may not be as strong. Therefore, the model would predict that as external land pressures increase, tree-planting on customary land may increase; on freehold land, tree-planting would increase substantially.

When looking at table 2, this pattern does largely hold. When land pressures are measured using standardized rental prices, there is a small, marginally significant increase in tree-planting on freehold land; when using the inverse travel time or relative decrease in travel time to Kampala to proxy these pressures, freehold land sees more trees as external pressures mount (without farmer-group fixed effects). With all measures, however, the response is attenuated on customary parcels, as predicted by the model.

As a point of interest, note that in figures 5 - 7, tree planting is actually more common on customary plots than freehold at low land values. This stems from the role of trees in establishing tenure in customary systems: trees demonstrate to neighbors effective control and serve as a visible investment in land stewardship, thereby forestalling ‘horizontal’ encroachment. This is less effective when dealing with outsiders to the social system, so the effect reverses as land pressures increase; in this case, trees serve primarily as a long-term investment in the agricultural productivity of the parcel. PPI, our proxy for wealth, actually has a negative relationship with tree-planting; poorer households are more likely to plant trees, perhaps because they serve as a way to signal ownership if other avenues are unavailable to poor households. In contrast, other inputs (particularly those requiring up-front cash purchases such as commercial fertilizers) are more common among wealthier households, in tables 3 - A3.

VARIABLES	Trees			
	(1)	(2)	(3)	(4)
Freehold × Rental Price	0.0164 (0.0110)	0.0112 (0.0122)		
Customary × Rental Price	-0.0161 (0.0347)	-0.0336*** (0.00672)		
Freehold × Inverse Travel Time			1.368*** (0.399)	
Customary × Inverse Travel Time			0.605 (0.526)	
Freehold × Decrease in Travel Time				2.015* (1.049)
Customary × Decrease in Travel Time				-1.361 (0.945)
Customary	-0.0735 (0.0552)	-0.0102 (0.0367)	0.163 (0.136)	0.264** (0.104)
Wealth Index	-0.00218 (0.00162)	0.000359 (0.000804)	-0.00454*** (0.00116)	-0.00255** (0.00107)
Landholdings	-0.00103 (0.000853)	-0.00119** (0.000567)	-0.000420 (0.000527)	-0.00128 (0.000794)
Observations	5,505	5,505	5,483	5,483
R-squared	0.030	0.236	0.062	0.043
Fixed Effect	None	Group	None	None
Cluster	Parish	Parish	Parish	Parish

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

Table 2: OLS results of a dummy equal to one for parcels with trees planted on them (a long-term investment) on measures of land pressures, controlling for the Progress out of Poverty Index wealth index, total landholdings of the household in acres, and dummies for the method of parcel acquisition. Farmer Group fixed effects included in column (2), and standard errors are clustered at the parish level in all specifications (reported in parentheses). Customary is a dummy equal to one for customary parcels and zero otherwise. Difference in number of observations between columns (1) and (2) vs. (3) and (4) is due to missing GPS locations for some households, so they could not be matched to spatial measures of travel time.

### 6.3 Organic Fertilizer Use

Organic fertilizer use both improves agricultural productivity in the season in which it is applied, and can also have medium-term effects by improving soil organic content (Johansen et al., 2015).<sup>34</sup> Indeed, Deininger et al. (2021) follow a long literature in treating organic fertilizer application as a key long-term investment in land productivity in the Sub-Saharan African smallholder context, which can be affected by tenure security (Jacoby et al., 2002; Jacoby and Mansuri, 2008). The model would predict, then, that organic fertilizer use would increase along with land values on freehold land, but the effect will be attenuated on customary land.

When looking at a binary indicator for the application of organic fertilizer in Table 3, the relationships are somewhat mixed. Organic fertilizer use does seem to respond positively to land pressures on freehold land (especially as measured by travel time; the relationship is less statistically significant for standardized rental prices). On customary land, the relationship with travel-time based measures is qualitatively weaker than for freehold land, although this is not true for rental prices (within-group changes in rental prices in column (2) seem unrelated to organic fertilizer use). Broadly, these results are consistent with the model's predictions for an intermediate-term input that is not immediately visible to potential tenure challengers.

In the appendix, I also use the value of organic fertilizer<sup>35</sup> applied as an outcome, following Fenske (2011)'s suggestion that this is more likely to detect statistically significant relationships with tenure. In these Tobit regressions, results are more sensitive to specification, and the inclusion of farmer group fixed effects makes a large difference.

### 6.4 Inorganic Fertilizer Use

Inorganic fertilizer, by contrast, largely exhibits short-term returns to agricultural land. The model predicts that for short-term inputs, rising land values will relax the liquidity constraint and thus increase short-term input use equivalently on freehold and customary land. In table 4, inorganic fertilizer use is slightly more common on higher-pressure freehold land than customary land, although the differences are small. However, the differences between customary and freehold parcels are much smaller in magnitude for short-term inputs: compare the estimates from table 3 to those in table 4.

The patterns are slightly more mixed when we look in table A2 at the value of inorganic fertilizer applied for those who do use inorganic fertilizer; application on customary parcels seems more responsive to land pressures particularly as proxied by inverse travel time. This is not inconsistent with the theoretical model's predictions: if long-term input use decreases due to new insecurity, the relaxed liquidity constraint can allow

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<sup>34</sup>Improved soil content can also have complementarities with inorganic fertilizer use, although this is not studied in detail in the current analysis.

<sup>35</sup>Standardized from a shilling value; this data is often imputed as many farmers generate and apply their own organic fertilizer including manure outside of the market.

VARIABLES	(1)	(2)	Used Organic Fertilizer (3)	(4)
Freehold × Rental Price	0.00190 (0.00264)	-0.00129 (0.00105)		
Customary × Rental Price	0.0209** (0.00931)	0.00301 (0.00259)		
Freehold × Inverse Travel Time			0.717*** (0.248)	
Customary × Inverse Travel Time			0.304*** (0.0817)	
Freehold × Decrease in Travel Time				4.040*** (0.420)
Customary × Decrease in Travel Time				1.239*** (0.215)
Customary	-0.106*** (0.0288)	-0.0253 (0.0171)	0.0195 (0.0450)	0.210*** (0.0422)
Wealth Index	0.00538*** (0.000958)	0.00125*** (0.000382)	0.00421*** (0.000860)	0.00170*** (0.000590)
Landholdings	0.000543 (0.000414)	0.000341 (0.000395)	0.000936* (0.000543)	0.00104** (0.000426)
Observations	5,503	5,503	5,481	5,481
R-squared	0.100	0.290	0.119	0.185
Fixed Effect	None	Group	None	None
Cluster	Parish	Parish	Parish	Parish

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

Table 3: OLS results of a dummy equal to one for parcels with organic fertilizer applied (a medium-term investment) on measures of land pressures, controlling for the Progress out of Poverty Index wealth index, total landholdings of the household in acres, and dummies for the method of parcel acquisition. Farmer Group fixed effects included in column (2), and standard errors are clustered at the parish level in all specifications (reported in parentheses). Customary is a dummy equal to one for customary parcels and zero otherwise. Difference in number of observations between columns (1) and (2) vs. (3) and (4) is due to missing GPS locations for some households, so they could not be matched to spatial measures of travel time.

VARIABLES	Used Inorganic Fertilizer			
	(1)	(2)	(3)	(4)
Freehold × Rental Price	0.00437*	0.00523**		
	(0.00223)	(0.00198)		
Customary × Rental Price	0.0183	0.00277		
	(0.0169)	(0.00249)		
Freehold × Inverse Travel Time			0.638***	
			(0.0824)	
Customary × Inverse Travel Time			0.534***	
			(0.0833)	
Freehold × Decrease in Travel Time				1.024***
				(0.342)
Customary × Decrease in Travel Time				0.614*
				(0.309)
Customary	-0.0213	0.00190	0.0242	0.0299
	(0.0205)	(0.0238)	(0.0233)	(0.0187)
Wealth Index	0.00357***	0.00172***	0.00221***	0.00248***
	(0.000517)	(0.000584)	(0.000569)	(0.000646)
Landholdings	0.000364	0.000571*	0.000905**	0.000660*
	(0.000367)	(0.000332)	(0.000402)	(0.000376)
Observations	5,501	5,501	5,479	5,479
R-squared	0.027	0.127	0.053	0.036
Fixed Effect	None	Group	None	None
Cluster	Parish	Parish	Parish	Parish

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

Table 4: OLS results of a dummy equal to one for parcels with inorganic fertilizer applied (a short-term investment) on measures of land pressures, controlling for the Progress out of Poverty Index wealth index, total landholdings of the household in acres, and dummies for the method of parcel acquisition. Farmer Group fixed effects included in column (2), and standard errors are clustered at the parish level in all specifications (reported in parentheses). Customary is a dummy equal to one for customary parcels and zero otherwise. Difference in number of observations between columns (1) and (2) vs. (3) and (4) is due to missing GPS locations for some households, so they could not be matched to spatial measures of travel time.

for additional investment in short-term inputs up to their marginal productivity. In figure 3, note that fertilizer investment on freehold land is at  $A'_F$ , while fertilizer applied to customary land is higher at  $F_C^{*'}.$

## 6.5 Pesticide Use

Pesticides, another short-term input, are generally used as-needed in the Ugandan agricultural sector rather than being applied proactively. The model would predict that use of pesticides responds similarly to land pressures on freehold and customary parcels; however, in table 5 there is a slight pattern on more responsiveness on freehold parcels. This could be driven by changing cropping patterns due to output markets. Cash crops such as vegetables sold to urban markets are particularly vulnerable to pests, so farmers generally use more pesticides on these crops, which in turn are more likely to be planted on freehold land facing urban

VARIABLES	Used Pesticides			
	(1)	(2)	(3)	(4)
Freehold × Rental Price	0.00151 (0.00469)	-0.00162 (0.00283)		
Customary × Rental Price	0.0215 (0.0140)	-0.0160*** (0.00403)		
Freehold × Inverse Travel Time			0.969*** (0.130)	
Customary × Inverse Travel Time			0.547*** (0.164)	
Freehold × Decrease in Travel Time				3.215*** (0.371)
Customary × Decrease in Travel Time				0.651* (0.350)
Customary	-0.0768 (0.0506)	-0.0355 (0.0505)	0.0599** (0.0296)	0.206*** (0.0355)
Wealth Index	0.00601*** (0.00104)	0.00247*** (0.000913)	0.00416*** (0.00115)	0.00327*** (0.00104)
Landholdings	0.000644 (0.000566)	0.000552 (0.000380)	0.00110* (0.000593)	0.000858* (0.000438)
Observations	5,499	5,499	5,477	5,477
R-squared	0.063	0.185	0.095	0.105
Fixed Effect	None	Group	None	None
Cluster	Parish	Parish	Parish	Parish

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

Table 5: OLS results of a dummy equal to one for parcels with pesticides applied (a short-term investment) on measures of land pressures, controlling for the Progress out of Poverty Index wealth index, total landholdings of the household in acres, and dummies for the method of parcel acquisition. Farmer Group fixed effects included in column (2), and standard errors are clustered at the parish level in all specifications (reported in parentheses). Customary is a dummy equal to one for customary parcels and zero otherwise. Difference in number of observations between columns (1) and (2) vs. (3) and (4) is due to missing GPS locations for some households, so they could not be matched to spatial measures of travel time.

pressures: many of the primary cash crops grown in Uganda, such as coffee, are perennials which are also subject to long-term expropriation risk. This link between crop choice and land tenure explains the small, significant differences in responses on freehold land apparent in table 5 and the mixed results in table A3 that depend on the particular proxy for land pressures used. These differences are generally smaller than those observed for long-term inputs, as the increasing insecurity on customary land does not impact decisions about pesticide use.

## 6.6 Crop Choice

In order to understand these slightly surprising results for pesticides and inorganic fertilizer, I examine the primary crops planted on each parcel to determine whether changing cropping patterns may influence input

use. In table 6, I present regressions where the outcome of interest is an indicator for at least one plot on the parcel being primarily planted to a high-value cash crop (staple crop production is presented in table A39, and shows the inverse). Overall, cropping patterns do not significantly change on customary parcels as land values increase while cash crops are more common on freehold parcels in higher land-pressure environments. This is unsurprising: nearby urban markets increase demand locally for fragile cash crops such as fruits and vegetables. Farmers are more likely to shift their crop production to meet this demand on freehold parcels. This could be due to the perceived insecurity of customary parcels near urban centers discouraging investment in commercial crops, particularly as many cash crops in Uganda are perennials such as fruit trees or coffee bushes. It also could be that households who own freehold land are more able to take advantage of urban output markets (due to more connections with formal markets, for example, or wealth differences), although the observed effect holds even controlling for a rough measure of household wealth in the PPI. Importantly, the effect of changing crop patterns on input use should be no greater for long-term inputs than short-term ones such as pesticides and inorganic fertilizer (which are more commercial). Therefore, the additional responsiveness of long-term inputs to land pressures on freehold land can be attributed directly to insecurity and is not wholly mediated by crop choice. In the appendix, I also show results for inputs controlling for whether or not any plot on the parcel is primarily devoted to a cash crop. These results show that the effects of rising land values and the resulting insecurity remain for long-term inputs, while those for short-term inputs are reduced.

## 6.7 Thresholds

In the sections above, I have modeled the relationship between land pressures and agricultural investment as linear on both customary and freehold land. It could be, however, that there are multiple regimes of land pressures where the relationship differs. To explore this empirically, I use a threshold of 2 hours travel time to Kampala; in interviews, this was identified as the distance within which most urban residents are seeking agricultural land, and therefore there should be higher likelihood of elite expropriation of customary land in these areas. I separately run the regressions on either side of the cutoff, to see whether the responsiveness to changes in land pressures differs (regression results in appendix, as well as simultaneously detected thresholds with estimation on either side; these results are substantially noisier due to the sparse support near the detected thresholds).

It could be that within this 2-hour commute of Kampala, the insecurity stemming from outside pressures has already been ‘priced in’ to farmers’ investment decisions, and therefore investment behavior on customary vs. freehold parcels is relatively unchanging as land pressures increase within this high-pressure environment.

VARIABLES	(1)	(2)	(3)	(4)
Freehold × Rental Price	0.0125* (0.00646)	0.0103** (0.00446)		
Customary × Rental Price	0.0179 (0.0160)	-0.000699 (0.00283)		
Freehold × Inverse Travel Time			0.750* (0.394)	
Customary × Inverse Travel Time			0.327 (0.297)	
Freehold × Decrease in Travel Time				5.452*** (0.741)
Customary × Decrease in Travel Time				2.551*** (0.844)
Customary	-0.129*** (0.0313)	-0.0152 (0.0140)	-0.000478 (0.0531)	0.218*** (0.0623)
Wealth Index	0.00584*** (0.00208)	-0.000504 (0.000634)	0.00452** (0.00173)	9.75e-05 (0.00113)
Landholdings	0.00201* (0.00104)	0.000790 (0.000880)	0.00224* (0.00112)	0.00268** (0.00105)
Observations	5,511	5,511	5,489	5,489
R-squared	0.094	0.389	0.106	0.189
Fixed Effect	None	Group	None	None
Cluster	Parish	Parish	Parish	Parish

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

Table 6: OLS results of a dummy equal to one for parcels with at least one plot primarily devoted to a cash crop on measures of land pressures, controlling for the Progress out of Poverty Index wealth index, total landholdings of the household in acres, and dummies for the method of parcel acquisition. Farmer Group fixed effects included in column (2), and standard errors are clustered at the parish level in all specifications (reported in parentheses). Customary is a dummy equal to one for customary parcels and zero otherwise. Difference in number of observations between columns (1) and (2) vs. (3) and (4) is due to missing GPS locations for some households, so they could not be matched to spatial measures of travel time.

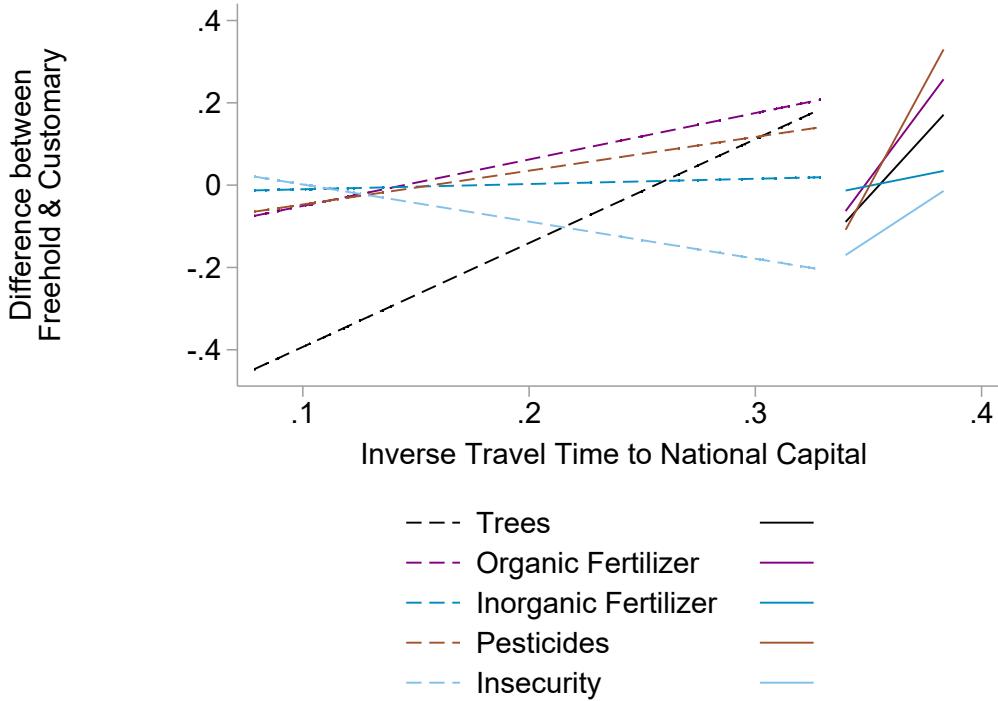


Figure 8: The divergence in input use across customary and freehold parcels is more responsive to land pressures closer to Kampala.

Alternately, in more remote areas, outsider demand for land may not be salient, so customary land is not perceived as any less secure even as land pressures ramp up.

Figure 8 shows, like figures 5 - 7, the difference between freehold and customary parcels as land pressures increase, but models this relationship separately on either side of the two-hour travel time threshold (recall that the inverse travel time measure is  $(1 + time_j)^{-1}$ , so two hours is located at 1/3 on the x-axis). Interestingly, relative tenure insecurity, which in the previous figures was downwards-sloping (customary parcels became relatively more insecure as land pressures increased) is here upwards-sloping although negative close to Kampala (implying that although customary land is less secure than freehold, the difference narrows closer to Kampala), but downwards-sloping further away. This is in contrast to the various investments, which retain their direction on both sides of the threshold. Perhaps perceptions of tenure insecurity have adapted to external threats close to Kampala. In contrast, investments on customary vs. freehold land diverge more sharply as land pressures increase close to Kampala: note the steeper slopes on the right-hand side of Figure 8, within 2 hours of Kampala. In more remote areas, outsider demand shaping insecurity seems to translate less intensely into patterns of agricultural investment.

This result, in conjunction with the prior linear specifications, has interesting policy implications for

where titling may have the greatest benefits. Recall that in general, customary tenure is less secure close to Kampala, where outside demand for land leaves customary parcels vulnerable to elite expropriation. This then leads to an underinvestment in long-term agricultural inputs on customary parcels in these areas. From the threshold analysis, I conclude that investment on customary parcels is more sensitive to land pressures closer to Kampala. Therefore, securing rights to those parcels, such as by titling them and bringing them from the customary realm into freehold, should have larger benefits (such as unlocking agricultural productivity) close to Kampala. This implies that the government should target titling activities in high land pressure environments, such as those easily accessed from Kampala. The net returns to titling are likely even higher here, as the costs of specialized staff such as surveyors are likely lower in more easily accessible areas.

## 7 Conclusion

In this paper, I developed a theoretical model of short- and long-term agricultural investments on customary and freehold land. This model incorporates how expropriation incentives change as land pressures increase. Local elites, observing outsiders' new demand for land and inability to distinguish between overlapping customary rights, may choose to expropriate land used by non-elites in the community to sell. Even if uncommon in practice, the perception and fear of elite expropriation reduces tenure security on customary tenure parcels. This, in turn, reduces the expected returns to long-term inputs.

The model predicts that long-term input use will diverge between customary and freehold parcels as land pressures increase in an area. Indeed, when I test the model's implications using survey data from four regions of Uganda, I find that long-term inputs (such as trees and organic fertilizer) are used more often on freehold land as land pressures increase, while on customary land this relationship is attenuated by tenure insecurity. Changing cropping patterns due to the proximity of urban markets appears to also influence short-term input use, but the effects on long-term inputs are larger, suggesting an independent effect of tenure security on long-term inputs.

The theoretical model and empirical results together suggest the importance of expanding beyond a simplification of customary tenure as less secure to thinking carefully about the social nature of land rights and the interacting incentives of multiple stakeholders. This insight allows researchers to make more detailed predictions about agricultural investment and may help explain the mixed results in much of the empirical literature. Secure customary tenure may become less secure as tenure systems intersect. This also suggests targeted policy to document and clarify rights in areas vulnerable to elite expropriation as land pressures mount to protect the rights of the most vulnerable from elites within their communities and without.

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## A General Analytical Solution

Consider a two-period model. In the first period, the farmer chooses to apply fertilizer,  $F_1$  and trees,  $T$ , to his or her exogenously-given land  $L$  under tenure system  $h$ . The farmer also has some wealth endowment, but can choose to borrow  $B_1$  against the value of the land (and the tenure system). The farmer faces an exogenous interest rate,  $r$ , and has a discount rate of  $\beta$  for second period returns. There is some probability that the farmer's land will be expropriated before the second period, and fixed investments (trees) would be lost then as well. This probability is given by  $(1 - \phi(T, h, vL))$  and could be a function of tree investment, tenure systems, as well as the value of the land. After working through the main features of the model, I will consider what different forms of this  $\phi$  function could imply for the farmer's decisions.

The first period problem faced by the farmer is then to:

$$\max_{F_1, T, B_1} p_a f(F_1, T) - p_F F_1 - p_T T - rB_1 + \beta\phi(T, h, vL)\pi_2^*(F_1, T, B_1) \quad (2)$$

$$\begin{aligned} & \text{subject to:} \\ & p_F F_1 + p_T T \leq w_1 + B_1 \\ & B_1 \leq s(vL, h) \end{aligned} \quad (3)$$

While in the second period, the farmer only chooses fertilizer ( $F_2$ ):

$$\max_{F_2} p_a f(F_2, T) - p_F F_2 \quad (4)$$

$$\begin{aligned} & \text{subject to:} \\ & p_F F_2 \leq w_2 \\ & w_2 = w_1 - rB_1 + p_a f(F_1, T) - p_F F_1 - p_T T \end{aligned} \quad (5)$$

The First Order Conditions of this second stage are:

$$p_a \frac{\partial f}{\partial F_2} - p_F - \lambda_1 p_F = 0 \quad (6)$$

$$\lambda_1 [p_F F_2 - w_1 + rB_1 - p_a f(F_1, T) + p_F F_1 + p_T T] = 0 \quad (7)$$

There are two cases: Either the budget constraint binds in the second stage, or it does not.

### A.1 Case A: Unconstrained Second Stage

First consider the case where the budget constraint does not bind in the second stage,  $\lambda_1 = 0$

Then  $F_2^*$  such that:

$$\frac{\partial f}{\partial F_2} = \frac{p_F}{p_a} \quad (8)$$

Therefore

$$\pi_2^* = p_a f(F_2^*, T) - p_F F_2^* \quad (9)$$

and the derivatives with respect to the first period choice variables are:

$$\frac{\partial \pi_2^*}{\partial F_1} = 0 \quad (10)$$

$$\frac{\partial \pi_2^*}{\partial T} = p_a \frac{\partial f}{\partial T} \Big|_{F_2^*} \quad (11)$$

$$\frac{\partial \pi_2^*}{\partial B_1} = 0 \quad (12)$$

Turning to the first stage, then:

$$\max_{F_1, T, B_1} p_a f(F_1, T) - p_F F_1 - p_T T - r B_1 + \beta \phi(T, h, vL) \pi_2^*(F_1, T, B_1) \quad (13)$$

$$\text{subject to } p_F F_1 + p_T T \leq w_1 + B_1 \quad (14)$$

$$B_1 \leq s(vL, h) \quad (15)$$

FOCs are:

$$p_a \frac{\partial f}{\partial F_1} - p_F + \beta \phi(T, h, vL) \frac{\partial \pi_2^*}{\partial F_1} - \lambda_2 p_F = 0 \quad (16)$$

$$p_a \frac{\partial f}{\partial T} - p_T + \beta \frac{\partial \phi}{\partial T} \pi_2^* + \beta \phi(T, h, vL) \frac{\partial \pi_2^*}{\partial T} - \lambda_2 p_T = 0 \quad (17)$$

$$-r + \beta \phi(T, h, vL) \frac{\partial \pi_2^*}{\partial B_1} + \lambda_2 - \lambda_3 = 0 \quad (18)$$

$$\lambda_2(p_F F_1 + p_T T - w_1 - B_1) = 0 \quad (19)$$

$$\lambda_3(B_1 - s(vL, h)) = 0 \quad (20)$$

Which simplify to:

$$p_a \frac{\partial f}{\partial F_1} - p_F - \lambda_2 p_F = 0 \quad (21)$$

$$p_a \frac{\partial f}{\partial T} - p_T + \beta \frac{\partial \phi}{\partial T} \pi_2^* + \beta \phi(T, h, vL) \frac{\partial \pi_2^*}{\partial T} - \lambda_2 p_T = 0 \quad (22)$$

$$-r + \lambda_2 - \lambda_3 = 0 \quad (23)$$

$$\lambda_2(p_F F_1 + p_T T - w_1 - B_1) = 0 \quad (24)$$

$$\lambda_3(B_1 - s(vL, h)) = 0 \quad (25)$$

### A.1.1 Case 1A: Totally Unconstrained

As a benchmark, consider a farmer who has a sufficient initial endowment of wealth  $w_1$  that neither the borrowing nor the budget constraint bind ( $\lambda_1 = \lambda_2 = \lambda_3 = 0$ )

The FOCs are then:

$$p_a \frac{\partial f}{\partial F_1} - p_F = 0 \quad (26)$$

$$p_a \frac{\partial f}{\partial T} - p_T + \beta \frac{\partial \phi}{\partial T} \pi_2^* + \beta \phi(T, h, vL) p_a \frac{\partial f}{\partial T} \Big|_{F_2^*} = 0 \quad (27)$$

$$(28)$$

This then gives us:

$$\frac{\partial f}{\partial F_1} = \frac{p_F}{p_a} \quad (29)$$

$$(30)$$

Therefore, in the totally unconstrained case,  $F_1^* = F_2^*$ . Furthermore, if I assume that under freehold tenure,  $\phi = 1$  and  $\frac{\partial \phi}{\partial T} = 0$  (tenure is perfectly secure and planting trees has no effect on tenure security), then

$$\frac{\partial f}{\partial T} \Big|_{h=1} = \frac{p_T}{p_a} \frac{1}{(1+\beta)} \quad (31)$$

However, if  $\phi < 1$ , such as is possible under customary tenure, then the marginal productivity of trees in equilibrium would be higher, and therefore investment in trees would be lower. This effect would be

attenuated by  $\frac{\partial\phi}{\partial T} > 0$ , as would be the case if planting trees helped secure tenure.

This is only a benchmark case, as our real interest is in the liquidity-constrained farmer (where the borrowing constraint, and therefore the budget constraint, bind). However, it demonstrates that our model accords with most theoretical models of tenure and long-term investments.

### A.1.2 Case 2A: Binding Budget Constraint

Now consider a world in which the farmer is not constrained in their ability to borrow, but they do exhaust their budget constraint ( $\lambda_1 = \lambda_3 = 0; \lambda_2 \neq 0$ )

The FOCs in this case are:

$$p_a \frac{\partial f}{\partial F_1} - p_F - \lambda_2 p_F = 0 \quad (32)$$

$$p_a \frac{\partial f}{\partial T} - p_T + \beta \frac{\partial \phi}{\partial T} \pi_2^* + \beta \phi(T, h, vL) \frac{\partial \pi_2^*}{\partial T} - \lambda_2 p_T = 0 \quad (33)$$

$$-r + \lambda_2 = 0 \quad (34)$$

$$p_F F_1 + p_T T - w_1 - B_1 = 0 \quad (35)$$

$$(36)$$

I now have fertilizer use in the first stage determined by setting the marginal product not equal to the relative price, as in the totally unconstrained case, but instead to a (higher) shadow price determined by the interest rate, and thus lower than optimal fertilizer usage.

$$\frac{\partial f}{\partial F_1} = \frac{p_F}{p_a} (1 + r) \quad (37)$$

Similarly, in the freehold case, where tree planting has no effect on (full) tenure security,

$$\left. \frac{\partial f}{\partial T} \right|_{h=1} = \frac{p_T}{p_a} \frac{(1+r)}{(1+\beta)} \quad (38)$$

Which mirrors the unconstrained case, but has the marginal product of trees (discounted across both periods) equal to a shadow price which is higher than the true price and thus tree planting will be lower than in 1A. Furthermore, as in 1A, if tenure security was incomplete ( $\phi < 1$ ), but unresponsive to tree planting, the condition would be:

$$\frac{\partial f}{\partial T} \Big|_{h=0} = \frac{p_T}{p_a} \frac{(1+r)}{(1+\beta\phi)} > \frac{p_T}{p_a} \frac{(1+r)}{(1+\beta)} = \frac{\partial f}{\partial T} \Big|_{h=1} \quad (39)$$

Therefore, the marginal productivity of trees is higher under customary tenure and thus under normal assumptions of diminishing marginal returns, the level of investment in trees is lower on customary land than freehold. If  $\frac{\partial\phi}{\partial T} > 0$ , that would attenuate this result somewhat (as the marginal product of trees in equilibrium would be reduced by the (positive) term  $\beta \frac{\partial\phi}{\partial T} \pi_2^*$ ), for reasonable parameter values the net effect would be similar to that found empirically: that investment in trees on customary land is no higher than on freehold.

#### A.1.3 Case 3A: Binding Borrowing Constraint

This case will never occur, as the farmer would not exhaust the (costly) borrowing option if wealth was high enough for the budget constraint not to bind.

#### A.1.4 Case 4A: Both Constraints Binding

Finally, consider a liquidity-constrained farmer who faces both a binding borrowing and budget constraint:

$$\lambda_1 = 0, \lambda_2 \neq 0, \lambda_3 \neq 0$$

This is the case depicted in Figures 1-3, so I will devote particular attention to it.

Working with the constraints, the FOCs are:

$$p_a \frac{\partial f}{\partial F_1} - p_F - \lambda_2 p_F = 0 \quad (40)$$

$$p_a \frac{\partial f}{\partial T} - p_T + \beta \frac{\partial \phi}{\partial T} \pi_2^* + \beta \phi(T, h, vL) \frac{\partial \pi_2^*}{\partial T} - \lambda_2 p_T = 0 \quad (41)$$

$$-r + \lambda_2 - \lambda_3 = 0 \quad (42)$$

$$p_F F_1 + p_T T - w_1 - s(vL, h) = 0 \quad (43)$$

$$B_1 = s(vL, h) \quad (44)$$

First, consider the freehold case ( $\phi = 1$ ). Then the equilibrium condition is:

$$\frac{\partial f}{\partial T} \Big|_{F_1^*} + \beta \frac{\partial f}{\partial T} \Big|_{F_2^*} = \frac{p_T}{p_F} \frac{\partial f}{\partial F_1} \quad (45)$$

Despite not being able to solve this explicitly for  $F_1$  and  $T$ , I can use the implicit function theorem to see how input choices respond to the parameters of interest. The Jacobian for choice variables is the following:

$$D_x = \begin{bmatrix} \frac{\partial^2 f}{\partial T \partial F_1} \Big|_{F_1^*} + \beta \frac{\partial^2 f}{\partial T \partial F_1} \Big|_{F_2^*} - \frac{p_T}{p_F} \frac{\partial^2 f}{\partial F_1^2} & \frac{\partial^2 f}{\partial T^2} \Big|_{F_1^*} + \beta \frac{\partial^2 f}{\partial T^2} \Big|_{F_2^*} - \frac{p_T}{p_F} \frac{\partial^2 f}{\partial F_1 \partial T} \Big|_{F_1^*} \\ p_F & p_T \end{bmatrix} \quad (46)$$

and its inverse is:

$$D_x^{-1} = \frac{1}{|D_x|} \begin{bmatrix} p_T & -\frac{\partial^2 f}{\partial T^2} \Big|_{F_1^*} - \beta \frac{\partial^2 f}{\partial T^2} \Big|_{F_2^*} + \frac{p_T}{p_F} \frac{\partial^2 f}{\partial F_1 \partial T} \Big|_{F_1^*} \\ -p_F & \frac{\partial^2 f}{\partial T \partial F_1} \Big|_{F_1^*} + \beta \frac{\partial^2 f}{\partial T \partial F_1} \Big|_{F_2^*} - \frac{p_T}{p_F} \frac{\partial^2 f}{\partial F_1^2} \end{bmatrix} \quad (47)$$

Where the determinant,  $|D_X|$ , is given by:

$$|D_x| = (\frac{\partial^2 f}{\partial T \partial F_1} \Big|_{F_1^*} + \beta \frac{\partial^2 f}{\partial T \partial F_1} \Big|_{F_2^*} - \frac{p_T}{p_F} \frac{\partial^2 f}{\partial F_1^2}) p_T - (\frac{\partial^2 f}{\partial T^2} \Big|_{F_1^*} + \beta \frac{\partial^2 f}{\partial T^2} \Big|_{F_2^*} - \frac{p_T}{p_F} \frac{\partial^2 f}{\partial F_1 \partial T} \Big|_{F_1^*}) p_F \quad (48)$$

$$= \left( 2p_T \frac{\partial^2 f}{\partial T \partial F_1} \Big|_{F_1^*} + \beta p_T \frac{\partial^2 f}{\partial T \partial F_1} \Big|_{F_2^*} - \frac{p_T^2}{p_F} \frac{\partial^2 f}{\partial F_1^2} - p_F \frac{\partial^2 f}{\partial T^2} \Big|_{F_1^*} - \beta p_F \frac{\partial^2 f}{\partial T^2} \Big|_{F_2^*} \right) \quad (49)$$

or equivalently,

$$D_x^{-1} = \frac{1}{|D_x|} \begin{bmatrix} p_T & -\frac{\partial^2 f}{\partial T^2} \Big|_{F_1^*} - \beta \frac{\partial^2 f}{\partial T^2} \Big|_{F_2^*} + \frac{p_T}{p_F} \frac{\partial^2 f}{\partial F_1 \partial T} \Big|_{F_1^*} \\ -p_F & \frac{\partial^2 f}{\partial T \partial F_1} \Big|_{F_1^*} + \beta \frac{\partial^2 f}{\partial T \partial F_1} \Big|_{F_2^*} - \frac{p_T}{p_F} \frac{\partial^2 f}{\partial F_1^2} \end{bmatrix} \quad (50)$$

And for the parameters ( $v$  is the primary parameter of interest for the empirical hypotheses):

$$D_q = \begin{bmatrix} 0 \\ -\frac{\partial s}{\partial v L} L \end{bmatrix} \quad (51)$$

The product is therefore:

$$\frac{-1}{\left( 2p_T \frac{\partial^2 f}{\partial T \partial F_1} \Big|_{F_1^*} + \beta p_T \frac{\partial^2 f}{\partial T \partial F_1} \Big|_{F_2^*} - \frac{p_T^2}{p_F} \frac{\partial^2 f}{\partial F_1^2} - p_F \frac{\partial^2 f}{\partial T^2} \Big|_{F_1^*} - \beta p_F \frac{\partial^2 f}{\partial T^2} \Big|_{F_2^*} \right)} \begin{bmatrix} \left( -\frac{\partial s}{\partial v L} L \right) \left[ -\frac{\partial^2 f}{\partial T^2} \Big|_{F_1^*} - \beta \frac{\partial^2 f}{\partial T^2} \Big|_{F_2^*} + \frac{p_T}{p_F} \frac{\partial^2 f}{\partial F_1 \partial T} \Big|_{F_1^*} \right] \\ \left( -\frac{\partial s}{\partial v L} L \right) \left[ \frac{\partial^2 f}{\partial T \partial F_1} \Big|_{F_1^*} + \beta \frac{\partial^2 f}{\partial T \partial F_1} \Big|_{F_2^*} - \frac{p_T}{p_F} \frac{\partial^2 f}{\partial F_1^2} \right] \end{bmatrix} \quad (52)$$

In order to sign these, I need to specify reasonable assumptions about signs. First, many inter-cropping systems such as are commonly used in Uganda mean that the cross-partial derivatives are positive:  $\frac{\partial^2 f}{\partial F_1 \partial T} > 0$ . Prices

are all positive, as is  $\beta$ . The borrowing constraint is increasing in the value of land used as collateral, so  $\frac{\partial s}{\partial vL} > 0$ . Finally, diminishing marginal returns implies that  $\frac{\partial^2 f}{\partial i^2} < 0$ , for  $i \in F, T$ .

These assumptions allow me to sign the matrix: the determinant is positive (therefore the fraction is negative), and both terms inside the matrix are negative. Therefore I can say that  $\frac{\partial F_1}{\partial v} > 0$  and  $\frac{\partial T}{\partial v} > 0$ : both optimal fertilizer and tree investment are increasing in the value of land if the freeholder farmer is liquidity constrained. This allows me to make hypotheses (3) and (4).

$$\frac{1}{\left(2p_T \frac{\partial^2 f}{\partial T \partial F_1} \Big|_{F_1^*} + \beta p_T \frac{\partial^2 f}{\partial T \partial F_1} \Big|_{F_2^*} - \frac{p_T^2}{p_F} \frac{\partial^2 f}{\partial F_1^2} - p_F \frac{\partial^2 f}{\partial T^2} \Big|_{F_1^*} - \beta p_F \frac{\partial^2 f}{\partial T^2} \Big|_{F_2^*}\right)} \begin{bmatrix} \left(\frac{\partial s}{\partial vL} L\right) \left[ -\frac{\partial^2 f}{\partial T^2} \Big|_{F_1^*} - \beta \frac{\partial^2 f}{\partial T^2} \Big|_{F_2^*} + \frac{p_T}{p_F} \frac{\partial^2 f}{\partial F_1 \partial T} \Big|_{F_1^*} \right] \\ \left(\frac{\partial s}{\partial vL} L\right) \left[ \frac{\partial^2 f}{\partial T \partial F_1} \Big|_{F_1^*} + \beta \frac{\partial^2 f}{\partial T \partial F_1} \Big|_{F_2^*} - \frac{p_T}{p_F} \frac{\partial^2 f}{\partial F_1^2} \right] \end{bmatrix} \quad (53)$$

If I instead consider customary tenure, the equilibrium condition is:

$$p_a \frac{\partial f}{\partial T} \Big|_{F_1^*} + \beta \frac{\partial \phi}{\partial T} (p_a f(F_2^*, T) - p_F F_2^*) + \beta \phi p_a \frac{\partial f}{\partial T} \Big|_{F_2^*} = \frac{p_T p_a}{p_F} \frac{\partial f}{\partial F_1} \quad (54)$$

Which can also be written as:

$$\frac{\partial f}{\partial T} \Big|_{F_1^*} + \beta \frac{\partial \phi}{\partial T} (f(F_2^*, T) - \frac{p_F}{p_a} F_2^*) + \beta \phi \frac{\partial f}{\partial T} \Big|_{F_2^*} = \frac{p_T}{p_F} \frac{\partial f}{\partial F_1} \quad (55)$$

I can again use the implicit function theorem on this condition, along with the budget constraint. The Jacobian for choice variables is:

$$\begin{bmatrix} \frac{\partial^2 f}{\partial T \partial F_1} \Big|_{F_1^*} + \beta \phi \frac{\partial^2 f}{\partial T \partial F_1} \Big|_{F_2^*} - \frac{p_T}{p_F} \frac{\partial^2 f}{\partial F_1^2} & \frac{\partial^2 f}{\partial T^2} \Big|_{F_1} + \beta \frac{\partial^2 \phi}{\partial T^2} \left[ f(F_2^*, T) - \frac{p_F}{p_a} F_2^* \right] + 2\beta \frac{\partial \phi}{\partial T} \frac{\partial f}{\partial T} \Big|_{F_2} + \beta \phi \frac{\partial^2 f}{\partial T^2} \Big|_{F_2} - \frac{p_T}{p_F} \frac{\partial^2 f}{\partial F_1 \partial T} \Big|_{F_1} \\ p_F & p_T \end{bmatrix} \quad (56)$$

Which I invert:

$$D_x^{-1} = \frac{1}{|D_x|} \begin{bmatrix} p_T & -\left[ \frac{\partial^2 f}{\partial T^2} \Big|_{F_1} + \beta \frac{\partial^2 \phi}{\partial T^2} \left[ f(F_2^*, T) - \frac{p_F}{p_a} F_2^* \right] + 2\beta \frac{\partial \phi}{\partial T} \frac{\partial f}{\partial T} \Big|_{F_2} + \beta \phi \frac{\partial^2 f}{\partial T^2} \Big|_{F_2} - \frac{p_T}{p_F} \frac{\partial^2 f}{\partial F_1 \partial T} \Big|_{F_1} \right] \\ -p_F & \frac{\partial^2 f}{\partial T \partial F_1} \Big|_{F_1^*} + \beta \phi \frac{\partial^2 f}{\partial T \partial F_1} \Big|_{F_2^*} - \frac{p_T}{p_F} \frac{\partial^2 f}{\partial F_1^2} \end{bmatrix} \quad (57)$$

Where  $|D_x|$  is the determinant,

$$|D_x| = \left[ \frac{\partial^2 f}{\partial T \partial F_1} \Big|_{F_1^*} + \beta \phi \frac{\partial^2 f}{\partial T \partial F_1} \Big|_{F_2^*} - \frac{p_T}{p_F} \frac{\partial^2 f}{\partial F_1^2} \right] p_T \quad (58)$$

$$- \left[ \frac{\partial^2 f}{\partial T^2} \Big|_{F_1} + \beta \frac{\partial^2 \phi}{\partial T^2} \left[ f(F_2^*, T) - \frac{p_F}{p_a} F_2^* \right] + 2\beta \frac{\partial \phi}{\partial T} \frac{\partial f}{\partial T} \Big|_{F_2} + \beta \phi \frac{\partial^2 f}{\partial T^2} \Big|_{F_2} - \frac{p_T}{p_F} \frac{\partial^2 f}{\partial F_1 \partial T} \Big|_{F_1} \right] p_F \quad (59)$$

The Jacobian with respect to land values is:

$$D_q = \begin{bmatrix} \beta \frac{\partial^2 \phi}{\partial T \partial v} \left[ f(F_2^*, T) - \frac{p_F}{p_a} F_2^* \right] + \beta \frac{\partial \phi}{\partial v} \frac{\partial f}{\partial T} \Big|_{F_2} \\ -\frac{\partial s}{\partial v L} L \end{bmatrix} \quad (60)$$

The product is therefore:

$$\frac{-1}{|D_x|} \begin{bmatrix} \left( p_T \left[ \beta \frac{\partial^2 \phi}{\partial T \partial v} \left[ f(F_2^*, T) - \frac{p_F}{p_a} F_2^* \right] + \beta \frac{\partial \phi}{\partial v} \frac{\partial f}{\partial T} \Big|_{F_2} \right] \right. \\ \left. + \left[ \frac{\partial^2 f}{\partial T^2} \Big|_{F_1} + \beta \frac{\partial^2 \phi}{\partial T^2} \left[ f(F_2^*, T) - \frac{p_F}{p_a} F_2^* \right] + 2\beta \frac{\partial \phi}{\partial T} \frac{\partial f}{\partial T} \Big|_{F_2} + \beta \phi \frac{\partial^2 f}{\partial T^2} \Big|_{F_2} - \frac{p_T}{p_F} \frac{\partial^2 f}{\partial F_1 \partial T} \Big|_{F_1} \right] \frac{\partial s}{\partial v L} L \right) \\ - p_F \left[ \beta \frac{\partial^2 \phi}{\partial T \partial v} \left[ f(F_2^*, T) - \frac{p_F}{p_a} F_2^* \right] + \beta \frac{\partial \phi}{\partial v} \frac{\partial f}{\partial T} \Big|_{F_2} \right] - \left[ \frac{\partial^2 f}{\partial T \partial F_1} \Big|_{F_1^*} + \beta \phi \frac{\partial^2 f}{\partial T \partial F_1} \Big|_{F_2^*} - \frac{p_T}{p_F} \frac{\partial^2 f}{\partial F_1^2} \right] \frac{\partial s}{\partial v L} L \end{bmatrix} \quad (61)$$

It is convenient to make a few further minor assumptions:

- $\frac{\partial^2 \phi}{\partial T \partial v} = 0$  Without substantial loss of generality, assume the risk of elite expropriation (which responds to land values) is unrelated to the risk of neighbor expropriation (which responds to trees), so the cross-partial of  $\phi$  is zero.
- $\frac{\partial \phi}{\partial v} < 0$ : tenure security is decreasing in land values as risk of elite expropriation increases, the fundamental new insight of this model
- $\frac{\partial^2 \phi}{\partial T^2} = 0$  For the current purposes, assume the risk of expropriation by neighbors is a linear function of tree investment, or a close enough approximation.

This matrix product then simplifies to:

$$\frac{-1}{|D_x|} \begin{bmatrix} \left[ \beta \frac{\partial \phi}{\partial v} \frac{\partial f}{\partial T} \right]_{F_2} + \left[ \frac{\partial^2 f}{\partial T^2} \right]_{F_1} + 2\beta \frac{\partial \phi}{\partial T} \frac{\partial f}{\partial T} \Big|_{F_2} + \beta \phi \frac{\partial^2 f}{\partial T^2} \Big|_{F_2} - \frac{p_T}{p_F} \frac{\partial^2 f}{\partial F_1 \partial T} \Big|_{F_1} \Big] \frac{\partial s}{\partial v L} L \\ -p_F \left[ \beta \frac{\partial \phi}{\partial v} \frac{\partial f}{\partial T} \Big|_{F_2} \right] - \left[ \frac{\partial^2 f}{\partial T \partial F_1} \Big|_{F_1^*} + \beta \phi \frac{\partial^2 f}{\partial T \partial F_1} \Big|_{F_2^*} - \frac{p_T}{p_F} \frac{\partial^2 f}{\partial F_1^2} \right] \frac{\partial s}{\partial v L} L \end{bmatrix} \quad (62)$$

The top component of the matrix is then positive under reasonable parameter values (the determinant is also generally positive). This implies that, as in Hypothesis (5), a liquidity-constrained farmer on customary land will increase fertilizer application as land values increase and the liquidity constraint relaxes.

The sign of the second term, however, depends on the relative magnitudes of the different mechanisms. If tenure insecurity responds drastically enough to rising land values (captured by the term  $\frac{\partial \phi}{\partial v}$ ) to counteract the increasing ability to invest given by the second term, then net investment in trees will actually decrease. This is noted in Hypothesis (6).

Finally, comparing the equilibria conditions for customary and freehold tenure allows me to show that the marginal productivity of tree investment will be higher in the customary case, meaning that liquidity-constrained farmers plant fewer trees on customary land than on freehold. This also means, because the budget constraint binds, that they invest more in fertilizer. This speaks to hypotheses (1) and (2).

## A.2 Case B: Constrained Second Stage

A detailed solution to Case B, where the budget constraint binds in the second period, does not add substantively to the understanding and so is omitted here.

## B Continuous Measures of Input Use

Fenske (2011), in his quantitative review of existing evidence on tenure and agricultural investment in West Africa, finds that using binary measures of investment limits identifying variation and makes it more likely to find insignificant results. Above, I do find statistically significant relationships between tenure and binary investment outcomes, particularly when I explicitly consider the land pressure environment. Nevertheless, the ACDP survey's detailed agricultural production module allows me to construct continuous measures of long- and short-term investment: the value of fertilizer or pesticides applied. Unfortunately, I cannot construct a similar measure for the most long-term of my inputs, tree planting.

Due to the relatively rare use of agricultural inputs, I adapt Fenske (2011)'s suggestion to use the trimmed LAD estimator to my cross-sectional data and use Tobit estimation. These results can be interpreted as in a linear model, although the linear effect represented by the coefficient is the slope on the uncensored (non-zero) outcome. Tables A1 - A3 are generally consistent with the binary outcome results presented in the main text, with a greater divergence between customary and freehold parcels on longer-term inputs (organic fertilizer) than short-term inputs. However, I do not prioritize these results due to the lack of precision in reported valuations of inputs, which in the ACDP survey do not accord with those from other sources in Uganda.

VARIABLES	Value Organic Fertilizer Used			
	(1)	(2)	(3)	(4)
Freehold × Rental Price	0.125 (0.1000)	-0.0311*** (0.00815)		
Customary × Rental Price	0.613* (0.349)	-20.84*** (0.394)		
Freehold × Inverse Travel Time			15.93* (8.619)	
Customary × Inverse Travel Time			7.025 (5.008)	
Freehold × Decrease in Travel Time				64.17** (31.09)
Customary × Decrease in Travel Time				45.26** (20.53)
Customary	-1.889*** (0.706)	-0.418*** (0.0999)	0.941 (1.663)	1.158 (1.750)
Wealth Index	0.194** (0.0856)	0.113*** (0.00291)	0.171** (0.0762)	0.131** (0.0580)
Landholdings	0.0229 (0.0162)	0.0465*** (0.00996)	0.0314* (0.0171)	0.0370** (0.0186)
Observations	5,508	5,508	5,486	5,486
Fixed Effect	None	Group	None	None
Cluster	Parish	Parish	Parish	Parish

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

Table A1: Tobit results with the outcome of the value of organic fertilizer applied to a parcel (a medium-term investment) regressed on measures of land pressures, controlling for the Progress out of Poverty Index wealth index, total landholdings of the household in acres, and dummies for the method of parcel acquisition. Farmer Group fixed effects included in column (2), and standard errors are clustered at the parish level in all specifications (reported in parentheses). Customary is a dummy equal to one for customary parcels and zero otherwise. Difference in number of observations between columns (1) and (2) vs. (3) and (4) is due to missing GPS locations for some households, so they could not be matched to spatial measures of travel time.

VARIABLES	(1)	(2)	(3)	(4)
Freehold × Rental Price	0.0264*** (0.00446)	0.0263*** (0.000239)		
Customary × Rental Price	0.0533 (0.0388)	-0.182*** (0.0333)		
Freehold × Inverse Travel Time			2.429*** (0.921)	
Customary × Inverse Travel Time			2.662*** (0.875)	
Freehold × Decrease in Travel Time				1.766 (1.895)
Customary × Decrease in Travel Time				2.453 (1.642)
Customary	-0.0345 (0.0653)	0.00755 (0.00809)	-0.0654 (0.166)	-0.0829 (0.127)
Wealth Index	0.0127*** (0.00472)	0.00916*** (0.000262)	0.00759** (0.00381)	0.0100** (0.00398)
Landholdings	-0.00436 (0.00463)	-0.00172** (0.000792)	-0.000296 (0.00351)	-0.00258 (0.00455)
Observations	5,508	5,508	5,486	5,486
Fixed Effect	None	Group	None	None
Cluster	Parish	Parish	Parish	Parish

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

Table A2: Tobit results with the outcome of the value of inorganic fertilizer applied to a parcel (a short-term investment) regressed on measures of land pressures, controlling for the Progress out of Poverty Index wealth index, total landholdings of the household in acres, and dummies for the method of parcel acquisition. Farmer Group fixed effects included in column (2), and standard errors are clustered at the parish level in all specifications (reported in parentheses). Customary is a dummy equal to one for customary parcels and zero otherwise. Difference in number of observations between columns (1) and (2) vs. (3) and (4) is due to missing GPS locations for some households, so they could not be matched to spatial measures of travel time.

VARIABLES	(1)	(2)	Value Pesticides Used (3)	(4)
Freehold × Rental Price	0.126 (0.135)	0.0905*** (0.00261)		
Customary × Rental Price	0.352** (0.144)	-0.361*** (0.00879)		
Freehold × Inverse Travel Time			10.72** (5.227)	
Customary × Inverse Travel Time			15.01* (8.201)	
Freehold × Decrease in Travel Time				34.81** (14.41)
Customary × Decrease in Travel Time				16.71 (10.38)
Customary	-1.132** (0.555)	-0.519*** (0.0866)	-2.168 (1.395)	1.257 (1.047)
Wealth Index	0.0843*** (0.0245)	0.0464*** (0.000989)	0.0615*** (0.0155)	0.0491*** (0.0112)
Landholdings	-0.00335 (0.0111)	-0.0161*** (0.00376)	0.00655 (0.00742)	-0.00573 (0.0140)
Observations	5,508	5,508	5,486	5,486
Fixed Effect	None	Group	None	None
Cluster	Parish	Parish	Parish	Parish

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

Table A3: Tobit results with the outcome of the value of pesticides applied to a parcel (a medium-term investment) regressed on measures of land pressures, controlling for the Progress out of Poverty Index wealth index, total landholdings of the household in acres, and dummies for the method of parcel acquisition. Farmer Group fixed effects included in column (2), and standard errors are clustered at the parish level in all specifications (reported in parentheses). Customary is a dummy equal to one for customary parcels and zero otherwise. Difference in number of observations between columns (1) and (2) vs. (3) and (4) is due to missing GPS locations for some households, so they could not be matched to spatial measures of travel time.

## C Robustness Checks

### C.1 Expanded Geographic Sample

The baseline survey for the impact evaluation of ACDP was conducted in four districts in Uganda, with an extensive survey including all agricultural inputs and outputs. However, a more concise survey was additionally conducted for monitoring and evaluation (M&E) purposes in an additional 30 districts located around the country. This M&E survey only asks about agricultural investments on a single target crop in each district (rice, beans, maize, cassava, or coffee), and is therefore not well-suited for the main analysis conducted above. Nevertheless, it does contain parcel-level tenure characteristics, such as perceived insecurity and tenure system, as well as rental prices and GPS locations that allow me to match with travel time data as above. Therefore, I am able to repeat the exercise from table 1 using this larger, more geographically diverse sample in table A4. The results are, if anything, even stronger: tenure insecurity is unrelated to rising land pressures on freehold land, but customary parcels are felt more insecure in higher land pressure environments.

VARIABLES	(1)	(2)	(3)	Average Insecurity (4)
Freehold × Rental Price	-0.00121 (0.00110)	0.000555 (0.00128)		
Customary × Rental Price	5.639*** (0.687)	5.079*** (1.097)		
Freehold × Inverse Travel Time			-0.306 (0.271)	
Customary × Inverse Travel Time			1.113*** (0.237)	
Freehold × Decrease in Travel Time				0.453 (0.308)
Customary × Decrease in Travel Time				0.580** (0.258)
Customary	0.0766** (0.0345)	0.0660* (0.0358)	-0.302*** (0.0734)	0.00312 (0.0388)
Wealth Index	2.44e-05 (0.000973)	-0.000557 (0.000984)	-0.000797 (0.00105)	-0.000688 (0.000987)
Landholdings	2.83e-07 (2.49e-07)	2.54e-06*** (3.07e-07)	4.92e-07** (2.31e-07)	4.32e-07* (2.49e-07)
Observations	10,253	10,229	10,283	10,283
R-squared	0.256	0.331	0.256	0.251
Fixed Effect	None	Group	None	None
Cluster	Parish	Parish	Parish	Parish

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

Table A4: OLS results of average tenure insecurity across all rightsholders (scale of 1-5, with higher values indicating more insecure) on a parcel on measures of land pressures, controlling for the Progress out of Poverty Index wealth index, total landholdings of the household in acres, and dummies for the method of parcel acquisition. Farmer Group fixed effects included in column (2), and standard errors are clustered at the parish level in all specifications (reported in parentheses). Customary is a dummy equal to one for customary parcels and zero otherwise. Difference in number of observations between columns (1) and (2) vs. (3) and (4) is due to missing GPS locations for some households, so they could not be matched to spatial measures of travel time. Data comes not only from the Impact Evaluation sample used throughout the paper, but also from the more condensed ACDP Monitoring and Evaluation survey conducted in an additional 30 districts.

## C.2 Spatial Correlation

In my primary specification above, I cluster standard errors at the parish level to account for any geographic relationships between households in the same parish. Here, I model the spatial dependencies more explicitly, using Conley (1999)'s spatially dependent standard errors. I allow for spatial dependence up to 50km, which would include all households within a district. These regressions, as in the main paper, include controls for how the parcel was acquired, plus the shown wealth index and total household landholdings. These results are the most different of all my robustness checks. In particular, in table A6, the coefficient on Customary  $\times$  Inverse Travel Time becomes negative and statistically significant (at the 10% level), when in most other specifications (such as table 2) it is positive but insignificant. However, this is if anything more consistent with the theoretical model, where long-term input use is attenuated on customary parcels as land pressures rise. Similarly, the coefficient on Customary  $\times$  Decrease in Travel Time switching from positive and significant in table 3 to negative and significant in table A7 is more in line with the model's predictions of attenuation on customary parcels for this medium-term input. On the other hand, the same pattern is observed for pesticides in table A9, which is slightly more difficult to explain but may be due to spatial correlation in pest damage that is accounted for in this estimation.

VARIABLES	Average Insecurity			
	(1)	(2)	(3)	(4)
Freehold × Rental Price	0.0290 (0.0264)	0.0348 (0.0242)		
Customary × Rental Price	0.121*** (0.00302)	0.119*** (0.0201)		
Freehold × Inverse Travel Time			-0.777*** (0.259)	
Customary × Inverse Travel Time			1.951*** (0.423)	
Freehold × Decrease in Travel Time				-0.958 (0.865)
Customary × Decrease in Travel Time				2.519 (1.713)
Customary	0.0673 (0.0717)	0.0546 (0.0572)	-0.447*** (0.0824)	-0.177 (0.123)
Wealth Index	0.000203 (0.00101)	-0.000635 (0.00180)	-0.000578 (0.00133)	-0.000323 (0.00126)
Landholdings	-0.00205 (0.00188)	-0.00196 (0.00173)	-0.00201 (0.00168)	-0.00212 (0.00175)
Observations	5,560	5,560	5,537	5,537
R-squared	0.255	0.325	0.252	0.245
Fixed Effect	None	Group	None	None
SE	Spatial - 50km	Spatial - 50km	Spatial - 50km	Spatial - 50km

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

Table A5: GMM results of average tenure insecurity across all rightsholders (scale of 1-5, with higher values indicating more insecure) on a parcel on measures of land pressures, controlling for the Progress out of Poverty Index wealth index, total landholdings of the household in acres, and dummies for the method of parcel acquisition. Farmer Group fixed effects included in column (2), and standard errors are computed accounting for spatial dependence up to 50 kilometers (the size of a district) in all specifications (reported in parentheses) (Conley, 1999). Customary is a dummy equal to one for customary parcels and zero otherwise. Difference in number of observations between columns (1) and (2) vs. (3) and (4) is due to missing GPS locations for some households, so they could not be matched to spatial measures of travel time.

VARIABLES	Trees			
	(1)	(2)	(3)	(4)
Freehold × Rental Price	0.0164 (0.0133)	0.0112 (0.0119)		
Customary × Rental Price	-0.0325 (0.0395)	-0.0448*** (0.00972)		
Freehold × Inverse Travel Time			1.368** (0.612)	
Customary × Inverse Travel Time			-0.763* (0.436)	
Freehold × Decrease in Travel Time				2.015 (1.686)
Customary × Decrease in Travel Time				-3.376*** (0.639)
Customary	-0.0735 (0.0950)	-0.0102 (0.0577)	0.163 (0.124)	0.264*** (0.0335)
Wealth Index	-0.00218 (0.00245)	0.000359 (0.000849)	-0.00454*** (0.00137)	-0.00255** (0.00112)
Landholdings	-0.00103 (0.00112)	-0.00119* (0.000703)	-0.000420 (0.000589)	-0.00128 (0.00105)
Observations	5,505	5,505	5,483	5,483
R-squared	0.030	0.236	0.062	0.043
Fixed Effect	None	Group	None	None
SE	Spatial - 50km	Spatial - 50km	Spatial - 50km	Spatial - 50km

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

Table A6: GMM results of a dummy equal to one for parcels with trees planted on them (a long term investment) on measures of land pressures, controlling for the Progress out of Poverty Index wealth index, total landholdings of the household in acres, and dummies for the method of parcel acquisition. Farmer Group fixed effects included in column (2), and standard errors are computed accounting for spatial dependence up to 50 kilometers (the size of a district) in all specifications (reported in parentheses) (Conley, 1999). Customary is a dummy equal to one for customary parcels and zero otherwise. Difference in number of observations between columns (1) and (2) vs. (3) and (4) is due to missing GPS locations for some households, so they could not be matched to spatial measures of travel time.

VARIABLES	Used Organic Fertilizer			
	(1)	(2)	(3)	(4)
Freehold × Rental Price	0.00190 (0.00339)	-0.00129 (0.000837)		
Customary × Rental Price	0.0190* (0.0109)	0.00430 (0.00292)		
Freehold × Inverse Travel Time			0.717 (0.485)	
Customary × Inverse Travel Time			-0.413 (0.360)	
Freehold × Decrease in Travel Time				4.040*** (0.731)
Customary × Decrease in Travel Time				-2.800*** (0.523)
Customary	-0.106 (0.0694)	-0.0253 (0.0233)	0.0195 (0.0378)	0.210*** (0.0571)
Wealth Index	0.00538*** (0.00203)	0.00125*** (0.000339)	0.00421*** (0.00157)	0.00170** (0.000762)
Landholdings	0.000543 (0.000687)	0.000341 (0.000461)	0.000936 (0.000882)	0.00104 (0.000694)
Observations	5,503	5,503	5,481	5,481
R-squared	0.100	0.290	0.119	0.185
Fixed Effect	None	Group	None	None
SE	Spatial - 50km	Spatial - 50km	Spatial - 50km	Spatial - 50km

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

Table A7: GMM results of a dummy equal to one for parcels with organic fertilizer applied (a medium-term investment) on measures of land pressures, controlling for the Progress out of Poverty Index wealth index, total landholdings of the household in acres, and dummies for the method of parcel acquisition. Farmer Group fixed effects included in column (2), and standard errors are computed accounting for spatial dependence up to 50 kilometers (the size of a district) in all specifications (reported in parentheses) (Conley, 1999). Customary is a dummy equal to one for customary parcels and zero otherwise. Difference in number of observations between columns (1) and (2) vs. (3) and (4) is due to missing GPS locations for some households, so they could not be matched to spatial measures of travel time.

VARIABLES	Used Inorganic Fertilizer			
	(1)	(2)	(3)	(4)
Freehold × Rental Price	0.00437*** (0.000192)	0.00523*** (0.00105)		
Customary × Rental Price	0.0139 (0.0132)	-0.00246** (0.00111)		
Freehold × Inverse Travel Time			0.638*** (0.101)	
Customary × Inverse Travel Time			-0.104 (0.0742)	
Freehold × Decrease in Travel Time				1.024* (0.549)
Customary × Decrease in Travel Time				-0.410 (0.378)
Customary	-0.0213 (0.0321)	0.00190 (0.0333)	0.0242 (0.0148)	0.0299 (0.0184)
Wealth Index	0.00357*** (0.000638)	0.00172*** (0.000603)	0.00221** (0.000862)	0.00248** (0.00107)
Landholdings	0.000364 (0.000345)	0.000571 (0.000415)	0.000905 (0.000576)	0.000660* (0.000395)
Observations	5,501	5,501	5,479	5,479
R-squared	0.027	0.127	0.053	0.036
Fixed Effect	None	Group	None	None
SE	Spatial - 50km	Spatial - 50km	Spatial - 50km	Spatial - 50km

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

Table A8: GMM results of a dummy equal to one for parcels with inorganic fertilizer applied (a short term investment) on measures of land pressures, controlling for the Progress out of Poverty Index wealth index, total landholdings of the household in acres, and dummies for the method of parcel acquisition. Farmer Group fixed effects included in column (2), and standard errors are computed accounting for spatial dependence up to 50 kilometers (the size of a district) in all specifications (reported in parentheses) (Conley, 1999). Customary is a dummy equal to one for customary parcels and zero otherwise. Difference in number of observations between columns (1) and (2) vs. (3) and (4) is due to missing GPS locations for some households, so they could not be matched to spatial measures of travel time.

VARIABLES	Used Pesticides			
	(1)	(2)	(3)	(4)
Freehold × Rental Price	0.00151 (0.00305)	-0.00162 (0.00119)		
Customary × Rental Price	0.0200 (0.0122)	-0.0144*** (0.00492)		
Freehold × Inverse Travel Time			0.969*** (0.202)	
Customary × Inverse Travel Time			-0.422 (0.355)	
Freehold × Decrease in Travel Time				3.215*** (0.323)
Customary × Decrease in Travel Time				-2.564*** (0.520)
Customary	-0.0768 (0.0963)	-0.0355 (0.0774)	0.0599*** (0.00655)	0.206*** (0.0462)
Wealth Index	0.00601*** (0.00158)	0.00247** (0.00109)	0.00416*** (0.00161)	0.00327** (0.00149)
Landholdings	0.000644 (0.000867)	0.000552 (0.000469)	0.00110 (0.000955)	0.000858 (0.000623)
Observations	5,499	5,499	5,477	5,477
R-squared	0.063	0.185	0.095	0.105
Fixed Effect	None	Group	None	None
SE	Spatial - 50km	Spatial - 50km	Spatial - 50km	Spatial - 50km

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

Table A9: GMM results of a dummy equal to one for parcels with pesticides applied (a short term investment) on measures of land pressures, controlling for the Progress out of Poverty Index wealth index, total landholdings of the household in acres, and dummies for the method of parcel acquisition. Farmer Group fixed effects included in column (2), and standard errors are computed accounting for spatial dependence up to 50 kilometers (the size of a district) in all specifications (reported in parentheses) (Conley, 1999). Customary is a dummy equal to one for customary parcels and zero otherwise. Difference in number of observations between columns (1) and (2) vs. (3) and (4) is due to missing GPS locations for some households, so they could not be matched to spatial measures of travel time.

### C.3 Splitting Sample

The relationship between land pressures and input use on customary vs. freehold land may not be linear, as modeled in my primary specifications. Therefore, I also look at binary splits in the various land pressure measures, and compare outcomes on customary vs. freehold parcels in low vs. high land pressure environments using interactions.

First, in table A10, I create a dummy variable equal to one for all parcels that have an estimated rental price per acre above the median rental price in their district, and consider those parcels to be facing higher land pressures. The results accord with those above: input use is lower on customary parcels, particularly for long-term inputs such as organic fertilizer; higher land pressure parcels are more likely to have inputs applied; but this effect is attenuated on customary parcels. I check, in table A11, that these results are not just driven by the distribution of customary vs freehold parcels across low vs. high land value areas, but the distribution is relatively similar.

Then, in table A12, I compare across districts, considering those close to Kampala (Masaka & Iganga) as facing high land pressures and those further away (Amuru & Ntungamo) having lower land pressures. This distinction is somewhat similar to the prior threshold of two hours travel time that I use in my threshold analysis. Here again, results are consistent with my model: input use is generally less common on customary parcels, more likely in districts near Kampala, but the difference between customary and freehold parcels is significantly different in districts near Kampala. Once again, customary and freehold parcels are distributed across both sets of districts, as seen in table A13.

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Trees		Organic Fertilizer	Inorganic Fertilizer			Pesticides		Insecurity	
Customary	-0.0503 (0.0598)	0.00110 (0.0380)	-0.0712*** (0.0237)	-0.00539 (0.0112)	-0.0154 (0.0246)	0.0122 (0.0258)	-0.0353 (0.0432)	0.000947 (0.0362)	0.118** (0.0518)	0.100* (0.0530)
Higher Price	0.107** (0.0421)	0.0979** (0.0403)	0.106*** (0.0222)	0.0244 (0.0157)	-0.0276* (0.0142)	-0.0220 (0.0144)	0.0514*** (0.0175)	0.00636 (0.0113)	0.0876 (0.0809)	0.0812 (0.0808)
Customary×Higher Price	-0.0428 (0.0377)	-0.0319 (0.0429)	-0.0711*** (0.0136)	-0.0443* (0.0247)	-0.0186 (0.0209)	-0.0225 (0.0220)	-0.0870*** (0.0222)	-0.0779** (0.0311)	-0.104 (0.0795)	-0.1000 (0.0803)
Constant	0.589*** (0.108)	0.0492 (0.0511)	-0.0324 (0.0377)	-0.0204 (0.0257)	-0.0608 (0.0587)	-0.101 (0.0646)	-0.00432 (0.0493)	-0.0253 (0.0456)	1.338*** (0.120)	1.220*** (0.122)
Observations	5,528	5,528	5,526	5,526	5,524	5,524	5,522	5,522	5,583	5,583
R-squared	0.038	0.240	0.116	0.291	0.031	0.128	0.066	0.186	0.245	0.315
Fixed Effect	None	Group	None	Group	None	Group	None	Group	None	Group
Cluster	Parish	Parish	Parish	Parish	Parish	Parish	Parish	Parish	Parish	Parish

Robust standard errors in parentheses

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

69

Table A10: OLS results where the outcome in columns (1) - (8) is a dummy equal to one if the given input was applied to the parcel, and in columns (9) - (10) is the average tenure insecurity across all rightsholders (scale of 1-5, with higher values indicating more insecure). Customary is a dummy equal to one for customary parcels and zero otherwise. Higher price is a dummy equal to one if the parcel has an estimated rental price per acre above the median rental price in the district. Customary × Higher price is the interaction of these two dummies. Controls (not shown) include the Progress out of Poverty wealth index, total household landholdings in acres, and dummies for the method of parcel acquisition. Farmer Group fixed effects included in columns (2), (4), (6), (8), and (10), and standard errors are clustered at the parish level in all specifications (reported in parentheses). Differences in number of observations between outcomes is due to missing data for some outcomes.

Tenure Status	Low Rental Price	High Rental Price	Total
Freehold	2,003	1,905	3,908
Customary	1,203	900	2,103
Total	3,206	2,805	6,011

Table A11: Customary and Freehold parcels are found in relatively similar proportions in low and high rental value environments.

VARIABLES	(1)	(2) Trees	(3)	(4) Organic Fertilizer	(5) Inorganic Fertilizer	(6)	(7)	(8) Pesticides	(9)	(10) Insecurity	
Customary		0.112 (0.101)	-0.0182 (0.0442)	-0.0240 (0.0196)	-0.00802 (0.0152)	0.0237 (0.0158)	0.0119 (0.0190)	0.0165 (0.0220)	-0.00481 (0.0212)	-0.301*** (0.0675)	-0.344*** (0.0621)
Near Kampala		0.357*** (0.0462)	0.151 (0.253)	0.135*** (0.0423)	-0.00863 (0.0450)	0.131*** (0.0120)	0.00609 (0.0175)	0.177*** (0.0326)	0.0331 (0.0382)	-0.218*** (0.0472)	-0.320 (0.449)
Customary×Near Kampala		-0.163 (0.103)	0.00874 (0.0584)	-0.0805** (0.0384)	-0.0222 (0.0217)	-0.0301 (0.0180)	-0.0138 (0.0195)	-0.0832* (0.0452)	-0.0387 (0.0436)	0.457*** (0.0736)	0.505*** (0.0711)
Constant		0.463*** (0.0874)	0.0765 (0.0568)	-0.0554 (0.0347)	-0.0165 (0.0242)	-0.127** (0.0610)	-0.107 (0.0651)	-0.0655 (0.0598)	-0.0264 (0.0495)	1.592*** (0.125)	1.395*** (0.125)
Observations	5,528	5,528	5,526	5,526	5,524	5,524	5,522	5,522	5,583	5,583	
R-squared	0.087	0.234	0.116	0.290	0.052	0.126	0.089	0.183	0.256	0.326	
Fixed Effect	None	Group	None	Group	None	Group	None	Group	None	Group	
Cluster	Parish	Parish	Parish	Parish	Parish	Parish	Parish	Parish	Parish	Parish	

Robust standard errors in parentheses

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

8

Table A12: OLS results where the outcome in columns (1) - (8) is a dummy equal to one if the given input was applied to the parcel, and in columns (9) - (10) is the average tenure insecurity across all rightsholders (scale of 1-5, with higher values indicating more insecure). Customary is a dummy equal to one for customary parcels and zero otherwise. Near Kampala is a dummy equal to one if the parcel is in Masaka or Iganga districts, which are closer to Kampala. Customary × Near Kampala is the interaction of these two dummies. Controls (not shown) include the Progress out of Poverty wealth index, total household landholdings in acres, and dummies for the method of parcel acquisition. Farmer Group fixed effects included in columns (2), (4), (6), (8), and (10), and standard errors are clustered at the parish level in all specifications (reported in parentheses). Differences in number of observations between outcomes is due to missing data for some outcomes.

Tenure Status	Far from Kampala	Near Kampala	Total
Freehold	835	3,948	4,783
Customary	962	1,364	2,326
Total	1,797	5,312	7,109

Table A13: Customary and Freehold parcels are distributed across districts near and far from Kampala, although freehold is relatively more common near Kampala than further away.

#### C.4 Threshold Analysis

In this section, I present the regression results looking separately on either side of a threshold of 2 hours travel time from Kamapala (identified in interviews as being a reasonable radius for external demand for land), as well as detecting thresholds following Hansen (2000) in the lower panel of each table. However, these detected thresholds are not my preferred specification, as both the inverse travel time and the change in travel time lack a continuous support in the geographically concentrated sample of ACDP. Therefore, the simultaneous detection of the existence and location of thresholds is very noisy and prone to overfitting, making them difficult to interpret.

	(1)	(2)	(3)	(4)	(5)	(6)
A; Prior Threshold	Average Insecurity					
Freehold×Rental Price	0.0249 (0.0238)	-0.0692 (0.430)				
Customary×Rental Price	0.137*** (0.0238)	9.863*** (1.463)				
Freehold×Inverse Travel Time			-0.902** (0.358)	-0.126 (2.357)		
Customary×Inverse Travel Time			1.155*** (0.395)	-6.055*** (1.985)		
Freehold×Decrease in Travel Time					-0.321 (0.912)	-1.948* (1.050)
Customary×Decrease in Travel Time					1.197 (0.964)	-1.831 (1.349)
Observations	4,301	1,213	4,321	1,216	4,321	1,216
R-squared	0.309	0.141	0.303	0.133	0.296	0.136
Fixed Effect	None	None	None	None	None	None
Cluster	Parish	Parish	Parish	Parish	Parish	Parish
Sample	> 2 hours	< 2 hours	> 2 hours	< 2 hours	> 2 hours	< 2 hours
	from Kampala					
B: Detected Threshold						
Freehold×Rental Price	-3.318*** (0.842)	0.0270 (0.0184)				
Customary×Rental Price	-2.711** (1.371)	0.104*** (0.00888)				
Freehold×Inverse Travel Time			12.59 (9.252)	-0.435** (0.185)		
Customary×Inverse Travel Time			-1.344 (1.920)	1.337*** (0.149)		
Freehold×Decrease in Travel Time					-6.615*** (1.927)	0.211 (0.693)
Customary×Decrease in Travel Time					1.147* (0.682)	-3.421*** (0.978)
Observations	5,610	5,610	5,537	5,537	5,537	5,537
Fixed Effect	None	None	None	None	None	None
SEs	Robust	Robust	Robust	Robust	Robust	Robust
Sample	< -0.0897 StD	> -0.0897 StD	< 0.120	> 0.120	< 0.0878	> 0.0878
	Price	Price	$(1 + time)^{-1}$	$(1 + time)^{-1}$	$\Delta time$	$\Delta time$
Robust standard errors in parentheses						
*** p<0.01, ** p<0.05, * p<0.1						

Table A14: Regression of average tenure insecurity across all rightholders (scale of 1-5, with higher values indicating more insecure) on a parcel on measures of land pressures. In panel A, OLS regressions were run separately within and outside 2 hours travel time from Kampala, in paired sets of columns, with standard errors clustered at the parish level reported in parentheses. In panel B, threshold regressions were run to simultaneously detect and estimate coefficients on either side of the detected threshold in the land pressure variable, with heteroskedasticity-robust standard errors. All specifications control for a dummy equal to one for customary parcels (and zero otherwise), the Progress out of Poverty wealth index, total landholdings of the household in acres, and dummies for the method of parcel acquisition.

	(1)	(2)	(3)	(4)	(5)	(6)
A: Prior Threshold	Trees					
Freehold×Rental Price	0.0158 (0.0108)	0.0551 (0.162)				
Customary×Rental Price	-0.00979 (0.0334)	1.549* (0.773)				
Freehold×Inverse Travel Time			1.994*** (0.406)	1.164 (3.398)		
Customary×Inverse Travel Time			0.989 (0.617)	-4.189 (3.971)		
Freehold×Decrease in Travel Time					2.498** (1.117)	0.857 (1.119)
Customary×Decrease in Travel Time					-1.487 (1.070)	-0.947 (1.312)
Observations	4,263	1,197	4,283	1,200	4,283	1,200
R-squared	0.036	0.085	0.091	0.089	0.052	0.089
Fixed Effect	None	None	None	None	None	None
Cluster	Parish	Parish	Parish	Parish	Parish	Parish
Sample	> 2 hours	< 2 hours	> 2 hours	< 2 hours	> 2 hours	< 2 hours
	from Kampala					
B: Detected Threshold						
Freehold×Rental Price	-2.016*** (0.430)	0.00778** (0.00360)				
Customary×Rental Price	-12.88*** (1.461)	-0.0470*** (0.00369)				
Freehold×Inverse Travel Time			-8.229*** (2.125)	-0.783*** (0.216)		
Customary×Inverse Travel Time			-15.00*** (1.182)	-1.477*** (0.308)		
Freehold×Decrease in Travel Time					-6.959*** (0.974)	1.399*** (0.330)
Customary×Decrease in Travel Time					-10.66*** (0.674)	-1.224** (0.550)
Observations	5,562	5,562	5,483	5,483	5,483	5,483
Fixed Effect	None	None	None	None	None	None
SEs	Robust	Robust	Robust	Robust	Robust	Robust
Sample	< -0.186 Std Price	> -0.186 Std Price	< 0.139 $(1 + time)^{-1}$	> 0.139 $(1 + time)^{-1}$	< 0.0675 $\Delta time$	> 0.0675 $\Delta time$
	Robust standard errors in parentheses					
	*** p<0.01, ** p<0.05, * p<0.1					

Table A15: Regression of a dummy equal to one for parcels with trees planted on them (a long-term investment) on measures of land pressures. In panel A, OLS regressions were run separately within and outside 2 hours travel time from Kampala, in paired sets of columns, with standard errors clustered at the parish level reported in parentheses. In panel B, threshold regressions were run to simultaneously detect and estimate coefficients on either side of the detected threshold in the land pressure variable, with heteroskedasticity-robust standard errors. All specifications control for a dummy equal to one for customary parcels (and zero otherwise), the Progress out of Poverty wealth index, total landholdings of the household in acres, and dummies for the method of parcel acquisition.

	(1)	(2)	(3)	(4)	(5)	(6)
A: Prior Threshold			Used	Organic Fertilizer		
Freehold×Rental Price	0.00179 (0.00255)	0.0660 (0.119)				
Customary×Rental Price	0.0215** (0.00827)	-0.376 (0.441)				
Freehold×Inverse Travel Time			1.219*** (0.339)	11.03*** (1.304)		
Customary×Inverse Travel Time			0.370*** (0.112)	5.039*** (1.192)		
Freehold×Decrease in Travel Time					4.830*** (0.478)	4.664*** (0.900)
Customary×Decrease in Travel Time					1.291*** (0.245)	1.879** (0.733)
Observations	4,260	1,198	4,280	1,201	4,280	1,201
R-squared	0.120	0.057	0.162	0.150	0.223	0.162
Fixed Effect	None	None	None	None	None	None
Cluster	Parish	Parish	Parish	Parish	Parish	Parish
Sample	> 2 hours	< 2 hours	> 2 hours	< 2 hours	> 2 hours	< 2 hours
	from Kampala	from Kampala	from Kampala	from Kampala	from Kampala	from Kampala
B: Detected Threshold						
Freehold×Rental Price	-1.103*** (0.205)	-0.000876 (0.000641)				
Customary×Rental Price	-0.919** (0.357)	0.0106*** (0.00147)				
Freehold×Inverse Travel Time			1.232*** (0.0769)	9.357*** (1.361)		
Customary×Inverse Travel Time			0.385*** (0.0791)	4.816** (2.093)		
Freehold×Decrease in Travel Time					1.411*** (0.197)	-0.747 (0.964)
Customary×Decrease in Travel Time					0.609*** (0.174)	-2.001 (1.652)
Observations	5,560	5,560	5,481	5,481	5,481	5,481
Fixed Effect	None	None	None	None	None	None
SEs	Robust	Robust	Robust	Robust	Robust	Robust
Sample	< -0.186 Std Price	> -0.186 Price	< 0.328 $(1 + time)^{-1}$	> 0.328 $(1 + time)^{-1}$	< 0.119 $\Delta time$	> 0.119 $\Delta time$
Robust standard errors in parentheses						
*** p<0.01, ** p<0.05, * p<0.1						

Table A16: Regression of a dummy equal to one for parcels with organic fertilizer applied (a medium-term investment) on measures of land pressures. In panel A, OLS regressions were run separately within and outside 2 hours travel time from Kampala, in paired sets of columns, with standard errors clustered at the parish level reported in parentheses. In panel B, threshold regressions were run to simultaneously detect and estimate coefficients on either side of the detected threshold in the land pressure variable, with heteroskedasticity-robust standard errors. All specifications control for a dummy equal to one for customary parcels (and zero otherwise), the Progress out of Poverty wealth index, total landholdings of the household in acres, and dummies for the method of parcel acquisition.

	(1)	(2)	(3)	(4)	(5)	(6)
A; Prior Threshold	Used Inorganic Fertilizer					
Freehold×Rental Price	0.00475*	0.0681 (0.00236)				
Customary×Rental Price	0.0164 (0.0137)	-1.366*** (0.450)				
Freehold×Inverse Travel Time			0.641*** (0.109)	-0.434 (1.561)		
Customary×Inverse Travel Time			0.531*** (0.135)	-2.449 (1.775)		
Freehold×Decrease in Travel Time					1.267*** (0.445)	-0.704** (0.305)
Customary×Decrease in Travel Time					0.563 (0.358)	-1.318** (0.523)
Observations	4,261	1,195	4,281	1,198	4,281	1,198
R-squared	0.028	0.025	0.051	0.024	0.038	0.027
Fixed Effect	None	None	None	None	None	None
Cluster	Parish	Parish	Parish	Parish	Parish	Parish
Sample	> 2 hours	< 2 hours	> 2 hours	< 2 hours	> 2 hours	< 2 hours
	from Kampala					
B: Detected Threshold						
Freehold×Rental Price	-1.382*** (0.330)	0.00322 (0.00615)				
Customary×Rental Price	-0.603* (0.366)	-0.00173 (0.00195)				
Freehold×Inverse Travel Time			0.598*** (0.0535)	-5.389*** (1.811)		
Customary×Inverse Travel Time			0.531*** (0.0694)	-5.338** (2.526)		
Freehold×Inverse Travel Time					0.636*** (0.223)	-0.242 (0.337)
Customary×Inverse Travel Time					0.634** (0.298)	-1.661*** (0.486)
Observations	5,558	5,558	5,479	5,479	5,479	5,479
Fixed Effect	None	None	None	None	None	None
SEs	Robust	Robust	Robust	Robust	Robust	Robust
Sample	< -0.173 Std Price	> -0.173 Std Price	< 0.350 $(1 + time)^{-1}$	> 0.350 $(1 + time)^{-1}$	< 0.0878 $\Delta time$	> 0.0878 $\Delta time$
	Robust standard errors in parentheses					
	*** p<0.01, ** p<0.05, * p<0.1					

Table A17: Regression of a dummy equal to one for parcels with inorganic fertilizer applied (a short-term investment) on measures of land pressures. In panel A, OLS regressions were run separately within and outside 2 hours travel time from Kampala, in paired sets of columns, with standard errors clustered at the parish level reported in parentheses. In panel B, threshold regressions were run to simultaneously detect and estimate coefficients on either side of the detected threshold in the land pressure variable, with heteroskedasticity-robust standard errors. All specifications control for a dummy equal to one for customary parcels (and zero otherwise), the Progress out of Poverty wealth index, total landholdings of the household in acres, and dummies for the method of parcel acquisition.

	(1)	(2)	(3)	(4)	(5)	(6)
A: Prior Threshold			Used Pesticides			
Freehold×Rental Price	0.00199 (0.00479)	0.127 (0.118)				
Customary×Rental Price	0.0154 (0.0103)	-0.0583 (0.966)				
Freehold×Inverse Travel Time			1.156*** (0.188)	8.611*** (1.824)		
Customary×Inverse Travel Time			0.446** (0.174)	-3.242 (3.207)		
Freehold×Decrease in Travel Time					3.464*** (0.527)	3.014*** (0.753)
Customary×Decrease in Travel Time					0.483 (0.322)	-2.443* (1.319)
Observations	4,259	1,195	4,279	1,198	4,279	1,198
R-squared	0.075	0.040	0.113	0.073	0.123	0.071
Fixed Effect	None	None	None	None	None	None
Cluster	Parish	Parish	Parish	Parish	Parish	Parish
Sample	> 2 hours	< 2 hours	> 2 hours	< 2 hours	> 2 hours	< 2 hours
	from Kampala	from Kampala	from Kampala	from Kampala	from Kampala	from Kampala
B: Detected Threshold						
Freehold×Rental Price	0.0562 (0.151)	-0.00633*** (0.00227)				
Customary×Rental Price	-0.884** (0.446)	-0.00145 (0.00239)				
Freehold×Inverse Travel Time			1.169*** (0.0794)	6.991*** (1.424)		
Customary×Inverse Travel Time			0.459*** (0.0892)	-2.249 (1.978)		
Freehold×Decrease in Travel Time					-0.270 (0.262)	2.982*** (0.431)
Customary×Decrease in Travel Time					0.132 (0.309)	-2.175*** (0.577)
Observations	5,556	5,556	5,477	5,477	5,477	5,477
Fixed Effect	None	None	None	None	None	None
SEs	Robust	Robust	Robust	Robust	Robust	Robust
Threshold	< -0.0321	> -0.0321	< 0.328	> 0.328	< 0.0878	> 0.0878
	Price	Price	$(1 + time)^{-1}$	$(1 + time)^{-1}$	$\Delta time$	$\Delta time$
Robust standard errors in parentheses						
*** p<0.01, ** p<0.05, * p<0.1						

Table A18: Regression of a dummy equal to one for parcels with pesticides applied (a short-term investment) on measures of land pressures. In panel A, OLS regressions were run separately within and outside 2 hours travel time from Kampala, in paired sets of columns, with standard errors clustered at the parish level reported in parentheses. In panel B, threshold regressions were run to simultaneously detect and estimate coefficients on either side of the detected threshold in the land pressure variable, with heteroskedasticity-robust standard errors. All specifications control for a dummy equal to one for customary parcels (and zero otherwise), the Progress out of Poverty wealth index, total landholdings of the household in acres, and dummies for the method of parcel acquisition.

## C.5 Parish Fixed Effects

My preferred specification makes use of the farmer group recruitment structure of the ACDP data to account for unobserved heterogeneity in farmer quality, which is likely to be shared among comembers of a self-selected farmer group. However, here I also present regressions using the more traditional administrative unit (parish in this case, given inconsistent identification of villages in the data) fixed effects. Results are consistent with those presented in the body of the paper.

VARIABLES	(1) Trees	(2) Used Organic	(3) Used Inorganic	(4) Used Pesticides	(5) Insecurity
Freehold × Rental Price	0.0134 (0.0121)	0.000162 (0.000780)	0.00345 (0.00240)	-0.000809 (0.00312)	0.0288 (0.0252)
Customary × Rental Price	-0.0396*** (0.00801)	0.00278 (0.00247)	-0.00742*** (0.00243)	-0.0109** (0.00449)	0.144*** (0.0360)
Customary	-0.0149 (0.0388)	-0.0329* (0.0181)	-0.00451 (0.0230)	-0.0321 (0.0500)	0.0656 (0.0530)
Wealth Index	-0.000479 (0.000946)	0.00161*** (0.000399)	0.00247*** (0.000680)	0.00312*** (0.000898)	-5.56e-05 (0.00137)
Landholdings	-0.00109* (0.000577)	0.000417 (0.000386)	0.000693* (0.000356)	0.000803 (0.000497)	-0.00197* (0.00109)
Observations	5,505	5,503	5,501	5,499	5,560
R-squared	0.177	0.263	0.074	0.151	0.278
Fixed Effect	Parish	Parish	Parish	Parish	Parish
Cluster	Parish	Parish	Parish	Parish	Parish

Robust standard errors in parentheses

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

Table A19: OLS results of a dummy for the given input applied to the parcel (in columns (1) - (4) or average tenure security across all rightsholders on the parcel (scale of 1-5, with higher value indicating more insecure, reported in column (5)) on standardized rental prices for freehold and customary parcels, controlling for the Progress out of Poverty wealth index, total landholdings of the household in acres, and dummies for the method of parcel acquisition. Parish fixed effects are included in all specifications, and standard errors are clustered at the parish level for all specifications (reported in parentheses). Customary is a dummy equal to one for customary parcels and zero otherwise.

## C.6 Alternate Measures

### C.6.1 Validating Perceptions of Insecurity

Arnot et al. (2011) discusses how different proxies for tenure security have been used (to varying effect) in the literature. The ACDP survey directly elicits how worried respondents are (on a scale of 1-5) about losing their land in the next 5 years, which I average over all rightsholders on a given parcel as my primary measure of tenure insecurity. However, I also show in table A20 that these perceptions are related to common sources of insecurity. Having a formal document issued by a land board (either a title, lease, or certificate of customary ownership, in most cases) is associated with lower levels of insecurity, as household rights are more easily legally enforceable with such a document. On the other hand, parcels which have in the past been cause for concern over conflict or are currently involved in disputes are (unsurprisingly) held to be more insecure. Although these correlates of perceived insecurity are not the primary focus of this paper, they are consistent with findings in the literature and validate these survey measures.

VARIABLES	Average Insecurity					
	(1)	(2)	(3)	(4)	(5)	(6)
Formal Document	-0.289*** (0.0646)	-0.0281 (0.0459)				
Ever concerned dispute			0.936*** (0.140)	0.755*** (0.0864)		
Active conflicts					1.277*** (0.179)	1.109*** (0.114)
Wealth Index		0.000159 (0.00130)		-0.00103 (0.00118)		-0.000156 (0.00144)
Landholdings		-0.00236** (0.00104)		-0.00289** (0.00130)		-0.00239** (0.00113)
Constant	1.494*** (0.0483)	1.414*** (0.130)	1.255*** (0.0276)	1.344*** (0.115)	1.320*** (0.0292)	1.337*** (0.126)
Observations	5,589	5,574	5,591	5,576	5,596	5,581
R-squared	0.031	0.241	0.129	0.323	0.075	0.299
Controls	None	Parcel Access	None	Parcel Access	None	Parcel Access
Fixed Effect	None	None	None	None	None	None
Cluster	Parish	Parish	Parish	Parish	Parish	Parish

Robust standard errors in parentheses

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

Table A20: OLS results of an average of tenure security across all rightsholders (scale of 1-5, with higher values indicating more insecure) on a parcel of measures of land pressures. Columns (2), (4) and (6) control for the Progress out of Poverty wealth index, total household landholdings, and the method of parcel acquisition. Standard errors are clustered at the parish level in all specifications. Difference in number of observations between columns are due to missing data for some variables.

### C.6.2 Alternate Measures of Land Values

Given that parcel rental prices may be endogenous to soil quality or past agricultural investment, I also explore alternate measures of land values. First, I predict per-acre rental prices using the probability of urbanization, latitude and longitude of the household, a dummy for customary parcels, a dummy for whether or not the parcel has trees, and village dummies. This should strip away noise in the estimated rental prices, and follows the intuition of a hedonic model for land values. Second, I use the median per-acre rental price in a village, to eliminate parcel-level heterogeneity in rental values. Finally, I use a non-standardized version of per-acre rental prices, which exhibits considerable skewness, but can be interpreted as the shilling value. Results with these three alternatives in tables C.6.2 - C.6.2 are by and large consistent with those in the main text, although are generally noisier and therefore less likely to be statistically significant.

VARIABLES	Average Insecurity				
	(1)	(2)	(3)	(4)	(5)
Freehold × Predicted Price	2.07e-07 (1.55e-07)	3.29e-07* (1.77e-07)			
Customary × Predicted Price	4.07e-07 (2.96e-07)	6.11e-07 (3.69e-07)			
Freehold × Village Price			-2.23e-06*** (4.90e-07)		
Customary × Village Price			2.17e-06*** (5.05e-07)		
Freehold × Rental Price (UGX)				5.56e-08 (4.90e-08)	6.68e-08 (4.35e-08)
Customary × Rental Price (UGX)				2.87e-07*** (5.67e-08)	2.96e-07*** (7.23e-08)
Customary	0.0168 (0.102)	-0.0301 (0.0985)	-0.727*** (0.131)	0.0218 (0.0515)	0.00957 (0.0531)
Wealth Index	-0.000425 (0.00149)	-0.000415 (0.00161)	-0.000669 (0.00158)	0.000203 (0.00137)	-0.000635 (0.00152)
Landholdings	-0.00218** (0.000977)	-0.00209* (0.00114)	-0.00218** (0.000933)	-0.00205** (0.000955)	-0.00196* (0.00110)
Observations	5,581	5,581	5,583	5,560	5,560
R-squared	0.247	0.317	0.257	0.255	0.325
Fixed Effect	None	Group	None	None	Group
Cluster	Parish	Parish	Parish	Parish	Parish

Robust standard errors in parentheses

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

Table A21: OLS results of average tenure insecurity across all rightsholders (scale of 1-5, with higher values indicating more insecure) on a parcel on measures of land pressures, controlling for the Progress out of Poverty Index wealth index, total landholdings of the household in acres, and dummies for the method of parcel acquisition. Farmer Group fixed effects included in columns (2) and (5), and standard errors are clustered at the parish level in all specifications (reported in parentheses). Customary is a dummy equal to one for customary parcels and zero otherwise. Predicted price is estimated using the probability of urbanization, latitude and longitude of the household, a dummy for customary parcels, a dummy for whether or not the parcel has trees, and village dummies. Village price is the median per-acre rental price in the village. Rental price (UGX) is the per-acre Ugandan Shilling value of the land.

VARIABLES	(1)	(2)	Trees (3)	(4)	(5)
Freehold × Predicted Price	3.57e-07** (1.75e-07)	4.31e-07** (1.93e-07)			
Customary × Predicted Price	-1.22e-07 (1.92e-07)	4.61e-08 (1.67e-07)			
Freehold × Village Price			3.33e-06*** (5.02e-07)		
Customary × Village Price			1.32e-06 (9.37e-07)		
Freehold × Rental Price (UGX)				3.14e-08 (2.11e-08)	2.16e-08 (2.35e-08)
Customary × Rental Price (UGX)				-3.09e-08 (6.66e-08)	-6.45e-08*** (1.29e-08)
Customary	0.0419 (0.0724)	0.0734* (0.0415)	0.335* (0.179)	-0.0612 (0.0624)	0.00672 (0.0361)
Wealth Index	-0.00242 (0.00147)	0.000373 (0.000831)	-0.00457*** (0.00105)	-0.00218 (0.00162)	0.000359 (0.000804)
Landholdings	-0.000947 (0.000786)	-0.00106* (0.000572)	8.86e-06 (0.000462)	-0.00103 (0.000853)	-0.00119** (0.000567)
Observations	5,526	5,526	5,528	5,505	5,505
R-squared	0.040	0.244	0.078	0.030	0.236
Fixed Effect	None	Group	None	None	Group
Cluster	Parish	Parish	Parish	Parish	Parish

Robust standard errors in parentheses

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

Table A22: OLS results of a dummy equal to one for parcels with trees planted on them (a long-term investment) on measures of land pressures, controlling for the Progress out of Poverty Index wealth index, total landholdings of the household in acres, and dummies for the method of parcel acquisition. Farmer Group fixed effects included in columns (2) and (5), and standard errors are clustered at the parish level in all specifications (reported in parentheses). Customary is a dummy equal to one for customary parcels and zero otherwise. Predicted price is estimated using the probability of urbanization, latitude and longitude of the household, a dummy for customary parcels, a dummy for whether or not the parcel has trees, and village dummies. Village price is the median per-acre rental price in the village. Rental price (UGX) is the per-acre Ugandan Shilling value of the land.

VARIABLES	Used Organic Fertilizer				
	(1)	(2)	(3)	(4)	(5)
Freehold × Predicted Price	1.87e-07 (1.42e-07)	1.48e-10 (7.07e-08)			
Customary × Predicted Price	1.52e-07*** (4.44e-08)	-2.68e-08 (7.06e-08)			
Freehold × Village Price			1.29e-06*** (4.15e-07)		
Customary × Village Price			4.68e-07*** (1.58e-07)		
Freehold × Rental Price (UGX)				3.65e-09 (5.07e-09)	-2.48e-09 (2.02e-09)
Customary × Rental Price (UGX)				4.00e-08** (1.79e-08)	5.78e-09 (4.97e-09)
Customary	-0.1000** (0.0393)	-0.0186 (0.0265)	0.0583 (0.0513)	-0.113*** (0.0304)	-0.0269 (0.0173)
Wealth Index	0.00513*** (0.000949)	0.00124*** (0.000364)	0.00458*** (0.000867)	0.00538*** (0.000958)	0.00125*** (0.000382)
Landholdings	0.000778 (0.000509)	0.000408 (0.000382)	0.00102* (0.000584)	0.000543 (0.000414)	0.000341 (0.000395)
Observations	5,524	5,524	5,526	5,503	5,503
R-squared	0.107	0.290	0.115	0.100	0.290
Fixed Effect	None	Group	None	None	Group
Cluster	Parish	Parish	Parish	Parish	Parish

Robust standard errors in parentheses

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

Table A23: OLS results of a dummy equal to one for parcels with organic fertilizer applied (a medium-term investment) on measures of land pressures, controlling for the Progress out of Poverty Index wealth index, total landholdings of the household in acres, and dummies for the method of parcel acquisition. Farmer Group fixed effects included in columns (2) and (5), and standard errors are clustered at the parish level in all specifications (reported in parentheses). Customary is a dummy equal to one for customary parcels and zero otherwise. Predicted price is estimated using the probability of urbanization, latitude and longitude of the household, a dummy for customary parcels, a dummy for whether or not the parcel has trees, and village dummies. Village price is the median per-acre rental price in the village. Rental price (UGX) is the per-acre Ugandan Shilling value of the land.

VARIABLES	Used Inorganic Fertilizer				
	(1)	(2)	(3)	(4)	(5)
Freehold × Predicted Price	-1.05e-08 (6.68e-08)	-1.77e-08 (8.05e-08)			
Customary × Predicted Price	2.71e-08 (5.55e-08)	-4.38e-08 (5.99e-08)			
Freehold × Village Price			1.28e-06*** (1.24e-07)		
Customary × Village Price			9.09e-07*** (1.65e-07)		
Freehold × Rental Price (UGX)				8.39e-09* (4.28e-09)	1.00e-08** (3.79e-09)
Customary × Rental Price (UGX)				3.51e-08 (3.25e-08)	5.31e-09 (4.79e-09)
Customary	-0.0323* (0.0163)	0.00843 (0.0189)	0.0661*** (0.0222)	-0.0265 (0.0242)	0.00283 (0.0241)
Wealth Index	0.00359*** (0.000525)	0.00167*** (0.000594)	0.00239*** (0.000560)	0.00357*** (0.000517)	0.00172*** (0.000584)
Landholdings	0.000476 (0.000416)	0.000671 (0.000404)	0.000995** (0.000422)	0.000364 (0.000367)	0.000571* (0.000332)
Observations	5,522	5,522	5,524	5,501	5,501
R-squared	0.028	0.126	0.052	0.027	0.127
Fixed Effect	None	Group	None	None	Group
Cluster	Parish	Parish	Parish	Parish	Parish

Robust standard errors in parentheses

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

Table A24: OLS results of a dummy equal to one for parcels with inorganic fertilizer applied (a short-term investment) on measures of land pressures, controlling for the Progress out of Poverty Index wealth index, total landholdings of the household in acres, and dummies for the method of parcel acquisition. Farmer Group fixed effects included in columns (2) and (5), and standard errors are clustered at the parish level in all specifications (reported in parentheses). Customary is a dummy equal to one for customary parcels and zero otherwise. Predicted price is estimated using the probability of urbanization, latitude and longitude of the household, a dummy for customary parcels, a dummy for whether or not the parcel has trees, and village dummies. Village price is the median per-acre rental price in the village. Rental price (UGX) is the per-acre Ugandan Shilling value of the land.

VARIABLES	Used Pesticides				
	(1)	(2)	(3)	(4)	(5)
Freehold × Predicted Price	2.08e-07*** (7.14e-08)	4.12e-08 (6.21e-08)			
Customary × Predicted Price	8.68e-08 (8.25e-08)	-1.02e-07 (1.11e-07)			
Freehold × Village Price			1.74e-06*** (3.21e-07)		
Customary × Village Price			8.30e-07*** (2.85e-07)		
Freehold × Rental Price (UGX)				2.89e-09 (9.00e-09)	-3.10e-09 (5.43e-09)
Customary × Rental Price (UGX)				4.13e-08 (2.69e-08)	-3.07e-08*** (7.73e-09)
Customary	-0.0486 (0.0484)	0.000293 (0.0384)	0.113*** (0.0356)	-0.0843 (0.0526)	-0.0301 (0.0502)
Wealth Index	0.00573*** (0.00113)	0.00253*** (0.000910)	0.00466*** (0.00112)	0.00601*** (0.00104)	0.00247*** (0.000913)
Landholdings	0.000734 (0.000556)	0.000508 (0.000358)	0.00120* (0.000644)	0.000644 (0.000566)	0.000552 (0.000380)
Observations	5,520	5,520	5,522	5,499	5,499
R-squared	0.069	0.184	0.089	0.063	0.185
Fixed Effect	None	Group	None	None	Group
Cluster	Parish	Parish	Parish	Parish	Parish

Robust standard errors in parentheses

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

Table A25: OLS results of a dummy equal to one for parcels with pesticides applied (a short-term investment) on measures of land pressures, controlling for the Progress out of Poverty Index wealth index, total landholdings of the household in acres, and dummies for the method of parcel acquisition. Farmer Group fixed effects included in columns (2) and (5), and standard errors are clustered at the parish level in all specifications (reported in parentheses). Customary is a dummy equal to one for customary parcels and zero otherwise. Predicted price is estimated using the probability of urbanization, latitude and longitude of the household, a dummy for customary parcels, a dummy for whether or not the parcel has trees, and village dummies. Village price is the median per-acre rental price in the village. Rental price (UGX) is the per-acre Ugandan Shilling value of the land.

### C.6.3 Alternate Measures of Market Access

The external land pressures modeled above are not exclusively coming from the national capital, Kampala. In fact, rapidly-growing regional capitals can create the sort of outsider demand for land that causes such insecurity over customary parcels. Therefore, in tables A26 - A30, I use four more regional measures of land pressures, all from Muller-Crepon (2021). First, I construct analogues to the inverse travel time and 10-year decrease in travel time, but to the regional capital rather than Kampala, the national capital and largest city in the country. However, these regional capitals have changed somewhat dramatically in the last 15 years; Uganda has experienced administrative unit proliferation (Grossman and Lewis, 2014). These newly-named regional capitals, which could drastically improve connections to a ‘regional capital’ in the data, may not reflect the demand for rural land by outsiders that I am modeling. Instead of capturing growing markets and real demand, this may be an artefact of politically-driven fragmentation.

I then also use a measure of market access that Muller-Crepon (2021) provides, stemming from Donaldson (2018). This ‘market access’ measure is a “reduced form expression derived from general equilibrium trade theory” (Donaldson and Hornbeck, 2016), which uses the within-country expansion of transport networks. I use this measure as provided in 2015, as well as the 10-year change in market access. This transport-focused market access, however, is more likely to affect agricultural total factor productivity and is less closely linked to the population-based drivers of external demand for land that I model.

However, in tables A26 - A30, results with these alternate measures of land pressures are broadly consistent with those in the main text.

VARIABLES	(1)	(2)	(3)	Average Insecurity (4)
Freehold × Inverse Travel Time to Regional Capital				
	(0.160)			
Customary × Inverse Travel Time to Regional Capital	0.464*** (0.149)			
Freehold × Decrease in Travel Time to Regional Capital		-0.148 (0.325)		
Customary × Decrease in Travel Time to Regional Capital		-0.0990 (0.131)		
Freehold × 2015 Market Access			-3.81e-07** (1.74e-07)	
Customary × 2015 Market Access			6.82e-07*** (2.53e-07)	
Freehold Change in Market Access				0.0853* (0.0498)
Customary × Change in Market Access				-0.171 (0.148)
Customary	-0.277** (0.119)	0.0702 (0.0542)	-0.0850 (0.0649)	0.0906* (0.0522)
Wealth Index	0.000156 (0.00157)	0.000800 (0.00140)	0.000108 (0.00154)	9.88e-05 (0.00142)
Landholdings	-0.00214** (0.00100)	-0.00229** (0.00102)	-0.00221** (0.000996)	-0.00249** (0.00111)
Observations	5,537	5,450	5,537	5,537
R-squared	0.247	0.249	0.248	0.243
Fixed Effect	None	None	None	None
Cluster	Parish	Parish	Parish	Parish

Robust standard errors in parentheses

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

Table A26: OLS results of average tenure security across all rightholders (scale of 1-5, with higher values indicating more insecure) on measures of regional land pressures, controlling for the Progress out of Poverty Index wealth index, total landholdings of the household in acres, and dummies for the method of parcel acquisition. Standard errors are clustered at the parish level in all specifications (reported in parentheses). Customary is a dummy equal to one for customary parcels and zero otherwise. Inverse travel time to regional capital is measured in 2015, and decrease in travel time to regional capital is the 10-year decrease; both are constructed analogue to the national measures in the main text but with the subnational capital. Market access and the change in market access are constructed from Donaldson (2018)'s measure.

VARIABLES		Trees		
	(1)	(2)	(3)	(4)
Freehold × Inverse Travel Time to Regional Capital	0.413*			
	(0.221)			
Customary × Inverse Travel Time to Regional Capital	0.385			
	(0.270)			
Freehold × Decrease in Travel Time to Regional Capital		0.750**		
		(0.286)		
Customary × Decrease in Travel Time to Regional Capital		0.551***		
		(0.141)		
Freehold × 2015 Market Access			1.86e-07	
			(2.29e-07)	
Customary × 2015 Market Access			2.32e-07	
			(3.62e-07)	
Freehold × Change in Market Access				0.107
				(0.0842)
Customary × Change in Market Access				-0.250*
				(0.132)
Customary	-0.0413	-0.0685	-0.0753	-0.0441
	(0.116)	(0.0479)	(0.0725)	(0.0469)
Wealth Index	-0.00392***	-0.000574	-0.00288**	-0.00227
	(0.00125)	(0.00141)	(0.00124)	(0.00146)
Landholdings	-0.000671	-0.00132	-0.000934	-0.00110
	(0.000695)	(0.000948)	(0.000778)	(0.000900)
Observations	5,483	5,396	5,483	5,483
R-squared	0.047	0.070	0.032	0.036
Fixed Effect	None	None	None	None
Cluster	Parish	Parish	Parish	Parish

Robust standard errors in parentheses

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

Table A27: OLS results of a dummy equal to one for parcels with trees planted on them (a long-term investment) on measures of regional land pressures, controlling for the Progress out of Poverty Index wealth index, total landholdings of the household in acres, and dummies for the method of parcel acquisition. Standard errors are clustered at the parish level in all specifications (reported in parentheses). Customary is a dummy equal to one for customary parcels and zero otherwise. Inverse travel time to regional capital is measured in 2015, and decrease in travel time to regional capital is the 10-year decrease; both are constructed analogue to the national measures in the main text but with the subnational capital. Market access and the change in market access are constructed from Donaldson (2018)'s measure.

VARIABLES	(1)	(2)	(3)	(4)
Freehold × Inverse Travel Time to Regional Capital	0.226*			
	(0.118)			
Customary × Inverse Travel Time to Regional Capital	0.142***			
	(0.0444)			
Freehold × Decrease in Travel Time to Regional Capital		0.532***		
		(0.187)		
Customary × Decrease in Travel Time to Regional Capital		0.0389		
		(0.0400)		
Freehold × 2015 Market Access			3.57e-08	
			(1.26e-07)	
Customary × 2015 Market Access			1.02e-07	
			(7.88e-08)	
Freehold × Change in Market Access				0.391***
				(0.0525)
Customary × Change in Market Access				0.192***
				(0.0484)
Customary	-0.0589	-0.112***	-0.116***	-0.0618***
	(0.0434)	(0.0248)	(0.0304)	(0.0161)
Wealth Index	0.00459***	0.00559***	0.00521***	0.00370***
	(0.000969)	(0.000952)	(0.00111)	(0.000598)
Landholdings	0.000769	0.000598	0.000660	0.000417
	(0.000467)	(0.000472)	(0.000462)	(0.000349)
Observations	5,481	5,394	5,481	5,481
R-squared	0.109	0.123	0.099	0.168
Fixed Effect	None	None	None	None
Cluster	Parish	Parish	Parish	Parish

Robust standard errors in parentheses

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

Table A28: OLS results of a dummy equal to one for parcels with organic fertilizer applied (a medium-term investment) on measures of regional land pressures, controlling for the Progress out of Poverty Index wealth index, total landholdings of the household in acres, and dummies for the method of parcel acquisition. Standard errors are clustered at the parish level in all specifications (reported in parentheses). Customary is a dummy equal to one for customary parcels and zero otherwise. Inverse travel time to regional capital is measured in 2015, and decrease in travel time to regional capital is the 10-year decrease; both are constructed analogue to the national measures in the main text but with the subnational capital. Market access and the change in market access are constructed from Donaldson (2018)'s measure.

VARIABLES		Used Inorganic Fertilizer		
	(1)	(2)	(3)	(4)
Freehold × Inverse Travel Time to Regional Capital	0.235*** (0.0635)			
Customary × Inverse Travel Time to Regional Capital	0.237*** (0.0552)			
Freehold × Decrease in Travel Time to Regional Capital		0.0404 (0.126)		
Customary × Decrease in Travel Time to Regional Capital		-0.0328 (0.0376)		
Freehold × 2015 Market Access			1.66e-07* (8.93e-08)	
Customary × 2015 Market Access			3.70e-07*** (9.86e-08)	
Freehold × Change in Market Access				0.00427 (0.0378)
Customary × Change in Market Access				-0.107** (0.0405)
Customary	-0.0126 (0.0321)	-0.0232 (0.0214)	-0.0454* (0.0237)	-0.0166 (0.0155)
Wealth Index	0.00264*** (0.000584)	0.00364*** (0.000528)	0.00283*** (0.000586)	0.00377*** (0.000556)
Landholdings	0.000710* (0.000416)	0.000491 (0.000433)	0.000646 (0.000418)	0.000480 (0.000429)
Observations	5,479	5,392	5,479	5,479
R-squared	0.045	0.030	0.039	0.030
Fixed Effect	None	None	None	None
Cluster	Parish	Parish	Parish	Parish

Robust standard errors in parentheses

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

Table A29: OLS results of a dummy equal to one for parcels with inorganic fertilizer applied (a short-term investment) on measures of regional land pressures, controlling for the Progress out of Poverty Index wealth index, total landholdings of the household in acres, and dummies for the method of parcel acquisition. Standard errors are clustered at the parish level in all specifications (reported in parentheses). Customary is a dummy equal to one for customary parcels and zero otherwise. Inverse travel time to regional capital is measured in 2015, and decrease in travel time to regional capital is the 10-year decrease; both are constructed analogue to the national measures in the main text but with the subnational capital. Market access and the change in market access are constructed from Donaldson (2018)'s measure.

VARIABLES	(1)	(2)	(3)	Used Pesticides (4)
Freehold × Inverse Travel Time to Regional Capital	0.362*** (0.0864)			
Customary × Inverse Travel Time to Regional Capital	0.288*** (0.0917)			
Freehold × Decrease in Travel Time to Regional Capital		0.374** (0.182)		
Customary × Decrease in Travel Time to Regional Capital		-0.0223 (0.0528)		
Freehold × 2015 Market Access			1.87e-07 (1.30e-07)	
Customary × 2015 Market Access			4.51e-07*** (1.56e-07)	
Freehold × Change in Market Access				0.288*** (0.0648)
Customary × Change in Market Access				-0.123* (0.0672)
Customary	-0.0269 (0.0518)	-0.0828* (0.0483)	-0.108* (0.0553)	-0.0284 (0.0245)
Wealth Index	0.00456*** (0.00123)	0.00596*** (0.00102)	0.00503*** (0.00134)	0.00506*** (0.000775)
Landholdings	0.000886* (0.000502)	0.000565 (0.000552)	0.000793 (0.000567)	0.000448 (0.000466)
Observations	5,477	5,392	5,477	5,477
R-squared	0.086	0.072	0.073	0.093
Fixed Effect	None	None	None	None
Cluster	Parish	Parish	Parish	Parish

Robust standard errors in parentheses

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

Table A30: OLS results of a dummy equal to one for parcels with pesticides applied (a short-term investment) on measures of regional land pressures, controlling for the Progress out of Poverty Index wealth index, total landholdings of the household in acres, and dummies for the method of parcel acquisition. Standard errors are clustered at the parish level in all specifications (reported in parentheses). Customary is a dummy equal to one for customary parcels and zero otherwise. Inverse travel time to regional capital is measured in 2015, and decrease in travel time to regional capital is the 10-year decrease; both are constructed analogue to the national measures in the main text but with the subnational capital. Market access and the change in market access are constructed from Donaldson (2018)'s measure.

#### C.6.4 Probability of Urbanization

As an alternate proxy for the external pressures on land that I model, I considered using data from the Global Grid of Probabilities of Urban Expansion to 2030 (Seto et al., 2012, 2016). For each 2.5 arc-minute<sup>36</sup> grid cell that was non-urban in 2000, the data include an estimated probability of becoming urban by the year 2030, forecast using a population density driver map. This map is primarily driven by patterns of urbanization, and thus is reasonably exogenous to local agricultural patterns of land values; instead, it isolates the dimension of land values that will also create pressure on local elites to expropriate and sell customary land to outsiders.

However, this data is remarkably bimodal in Uganda, with sparse support of values of the probability of urbanization in the four districts where the baseline study occurred. Thirty-eight percent of parcels fall in a grid cell with a 100% probability of urbanization; another 19% have a 99% probability. There is another grouping at very low levels of predicted urbanization, including the entire northern district of Amuru which has a probability of zero, and then only a few parcels are assigned a probability between .5 and .8. This makes the probability of urbanization not my preferred proxy, but I present regression results with this measure in tables A31 and A32.

I match households to a grid cell using GPS locations collected during the survey (taken at the household residence, not at agricultural fields which could be at some remove). This measure is correlated with the per-acre rental values households reported for their land; the correlation is low across the whole sample (.0450), but when I winsorize several outliers in estimated rental price (among those who own their land and are estimating how much they could rent it out for), this correlation increases to .1492. When I look instead at the median rental price in a given district, the correlation with the probability of urbanization jumps to .6556,<sup>37</sup> implying (as expected) that this measure is more closely related to broader trends than individual parcel values which may be influenced by soil quality or other agricultural value considerations. Results in table A31 for binary outcomes and A32 for continuous Tobit estimation are relatively consistent with those obtained using either normalized rental values, inverse travel time to Kampala, or the 10-year reduction in travel times, as shown above.

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<sup>36</sup>2.5 arc-minutes contain approximately 5km at the equator, which Uganda spans

<sup>37</sup>Similarly, the correlation with median village rental prices is .6697.

VARIABLES	(1) Trees	(2) Used Organic	(3) Used Inorganic	(4) Used Pesticides	(5) Insecurity
Freehold × Urbanization	0.200*** (0.0672)	0.0962** (0.0449)	0.0488 (0.0296)	0.112*** (0.0361)	-0.0261 (0.0513)
Customary × Urbanization	0.0444 (0.0903)	0.0148 (0.0156)	0.0345 (0.0270)	0.0323 (0.0221)	0.0974* (0.0562)
Customary	0.0660 (0.0827)	-0.0360 (0.0242)	-0.00581 (0.0256)	-0.00454 (0.0363)	-0.0239 (0.0929)
Wealth Index	-0.00292** (0.00138)	0.00514*** (0.000916)	0.00330*** (0.000622)	0.00556*** (0.00105)	-0.000298 (0.00140)
Landholdings	-0.000705 (0.000701)	0.000770 (0.000490)	0.000596 (0.000396)	0.000805 (0.000549)	-0.00228** (0.00107)
Observations	5,523	5,521	5,519	5,517	5,578
R-squared	0.044	0.106	0.030	0.071	0.244
Fixed Effect	None	None	None	None	None
Cluster	Parish	Parish	Parish	Parish	Parish

Robust standard errors in parentheses

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

Table A31: OLS results where the outcome in columns (1) - (4) is a dummy equal to one if the given input was applied to the parcel, and in column (5) is the average tenure insecurity across all rightsholders. Customary is a dummy equal to one for customary parcels and zero otherwise. The probability of urbanization is a proxy for land pressures, and the regression controls for the Progress out of Poverty wealth index, total household landholdings in acres, and dummies for the method of parcel acquisition. Standard errors are clustered at the parish level in all specifications (reported in parentheses).

VARIABLES	(1) Value Organic	(2) Value Inorganic	(3) Value Pesticides
Freehold × Urbanization	2.885 (2.028)	0.123 (0.153)	0.904* (0.485)
Customary × Urbanization	0.760 (1.037)	0.393** (0.177)	-0.193 (0.687)
Customary	0.104 (1.211)	-0.251 (0.157)	-0.203 (0.722)
Wealth Index	0.185** (0.0806)	0.0109** (0.00447)	0.0827*** (0.0256)
Landholdings	0.0296 (0.0181)	-0.00186 (0.00405)	-0.00396 (0.0120)
Observations	5,526	5,526	5,526
Fixed Effect	None	None	None
Cluster	Parish	Parish	Parish

Robust standard errors in parentheses

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

Table A32: Tobit results where the outcome is the value of the given input applied to the parcel. Customary is a dummy equal to one for customary parcels and zero otherwise. The probability of urbanization is a proxy for land pressures, and the regression controls for the Progress out of Poverty wealth index, total household landholdings in acres, and dummies for the method of parcel acquisition. Standard errors are clustered at the parish level in all specifications (reported in parentheses).

## C.7 Additional Controls

### C.7.1 Parcel Characteristics

As can be seen in table A33, customary and freehold parcels are not observably identical. In particular, freehold parcels are more likely to have been purchased, more likely to be documented, and less likely to be primarily residential (none of which are surprising). Additionally, we can see different patterns of land use and tenure security: freehold parcels were acquired slightly more recently, are more likely to have formal documents, and are more likely to be irrigated – but are also more likely to have active conflicts and worries about ownership disputes, and less likely to be fallowed in the past two years or practice crop rotation.

Several of these characteristics may be responses to the insecurity incentives modeled in the paper, but I also run regressions controlling for residential land use, a dummy for whether the parcel was purchased, and the first year the parcel was farmed. Although these characteristics are correlated with input use, the primary results of the paper (diverging responses to land pressures for long-term inputs) remain.

### C.7.2 Crop Change

One notable divergence between the model and empirical results is the patterns of short-term input use increasing somewhat as land pressures increase, which I argued is likely due to changing in cropping patterns. In particular, many cash crops in Uganda are perennials, meaning that the likelihood of expropriation also affects the returns from these crops; at the same time, many cash crops require higher input use (pesticides in particular) in order to receive a market premium. However, I argue that the divergence in long-term input use between customary and freehold parcels as land pressures increase is not due entirely to changing cropping patterns; there is an additional tenure security effect. Therefore, I ran additional regressions (below), controlling for a dummy for if there is a cash crop as the primary crop on any of the plots on a given parcel.

Unsurprisingly, more inputs (except for inorganic fertilizer) are used on parcels that contain cash crops. Interestingly, cash crops are not correlated significantly with average insecurity on the parcel, however, and the general patterns of input responsiveness to land pressures remain.

Variable	(1)		(2)		(1)-(2)	
	N	Freehold Mean/(SE)	N	Customeary Mean/(SE)	N	Pairwise t-test Difference
Residential Land Use	3854	0.080 (0.004)	2326	0.104 (0.006)	6180	-0.024***
Agricultural Land Use	3854	0.912 (0.005)	2326	0.891 (0.006)	6180	0.021***
Forest Land Use	3854	0.006 (0.001)	2326	0.003 (0.001)	6180	0.003*
Parcel was purchased or rented in	3863	0.739 (0.007)	2326	0.107 (0.006)	6189	0.632***
First Year Farmed, cleaned	2594	2007.114 (0.248)	1023	2001.629 (0.479)	3617	5.486***
Document issued by land board	4023	0.534 (0.008)	2109	0.359 (0.010)	6132	0.175***
Active conflicts	4029	0.040 (0.003)	2106	0.027 (0.004)	6135	0.014***
Ever concerned dispute ownership	4026	0.138 (0.005)	2105	0.066 (0.005)	6131	0.073***
Seasons parcel fallowed in last 2 years	3500	0.195 (0.009)	1947	0.388 (0.017)	5447	-0.193***
Crop rotation practiced on parcel	3540	0.567 (0.008)	2092	0.625 (0.011)	5632	-0.058***
Irrigation on parcel (binary)	3542	0.022 (0.002)	2093	0.013 (0.003)	5635	0.008**

Significance: \*\*\*=.01, \*\*=.05, \*=.1.

Table A33: Balance table of plot characteristics between freehold and customary parcels. Note that some of these, such as fallowing and crop rotation, are other kinds of investment in the land and therefore may be responding to the incentives described throughout. Residential, agricultural, and forest land use are dummies for the primary use of the parcel. Parcel was purchased or rented in is a dummy equal to one if the respondent reported accessing the parcel through purchase or a formal rental arrangement. Document issued by land board is a dummy equal to one if the parcel has a document (including a title deed, certificate of ownership, certificate of hereditary acquisition, lease or rental contract). Active conflicts is a dummy equal to one if the parcel has an active conflict or dispute ongoing. Ever concerned dispute ownership is a dummy equal to one if the respondent has ever been concerned that someone would dispute their ownership of the parcel. Seasons parcel fallowed in last 2 years is a count of the number of seasons the parcel has been left fallow, out of four potential seasons. Crop rotation and irrigation are dummies equal to one if the respondent reports rotating crops or irrigation on any plot within the parcel.

VARIABLES	(1)	(2)	(3)	(4)
	Average Insecurity			
Freehold × Rental Price	0.0220 (0.0222)	0.0245 (0.0158)		
Customary × Rental Price	0.109*** (0.0137)	0.122*** (0.0193)		
Freehold × Inverse Travel Time			-1.348*** (0.442)	
Customary × Inverse Travel Time			0.782 (0.493)	
Freehold × Decrease in Travel Time				-2.230* (1.145)
Customary × Decrease in Travel Time				0.0693 (1.152)
Customary	0.0952 (0.0781)	0.0749 (0.0758)	-0.499** (0.219)	-0.142 (0.195)
Wealth Index	-0.00161 (0.00228)	-0.00134 (0.00268)	-0.000833 (0.00251)	-6.51e-05 (0.00237)
Landholdings	-0.00425 (0.00279)	-0.00579 (0.00376)	-0.00516** (0.00249)	-0.00545** (0.00268)
Residential	0.0674 (0.0928)	0.00934 (0.0760)	0.0774 (0.0954)	0.0864 (0.0931)
Purchased	0.373 (0.465)	0.400 (0.474)	0.334 (0.477)	0.397 (0.488)
First Year Farming	0.00134** (0.000649)	0.000957 (0.000791)	0.00117 (0.000729)	0.00109 (0.000691)
Observations	3,284	3,284	3,265	3,265
R-squared	0.261	0.380	0.258	0.252
Fixed Effect	None	Group	None	None
Cluster	Parish	Parish	Parish	Parish

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

Table A34: OLS results of average tenure insecurity across all rightsholders on a parcel on measures of land pressures, controlling for the Progress out of Poverty Index wealth index, total landholdings of the household in acres, dummies for the method of parcel acquisition, a dummy for if the parcel is primarily residential, a dummy for if the parcel was purchased or formally rented in, and the year the parcel was first farmed. Farmer Group fixed effects included in column (2), and standard errors are clustered at the parish level in all specifications (reported in parentheses). Customary is a dummy equal to one for customary parcels and zero otherwise. Difference in number of observations between columns (1) and (2) vs. (3) and (4) is due to missing GPS locations for some households, so they could not be matched to spatial measures of travel time.

VARIABLES	(1)	(2)	(3) Trees	(4)
Freehold × Rental Price	0.0145 (0.00900)	0.0100 (0.0100)		
Customary × Rental Price	-0.0422*** (0.0118)	-0.0379*** (0.00857)		
Freehold × Inverse Travel Time			0.935** (0.430)	
Customary × Inverse Travel Time			-0.00877 (0.439)	
Freehold × Decrease in Travel Time				1.542* (0.889)
Customary × Decrease in Travel Time				-1.385* (0.739)
Customary	0.0162 (0.0435)	0.0239 (0.0485)	0.281** (0.111)	0.313*** (0.0915)
Wealth Index	-0.000757 (0.00159)	0.00173** (0.000780)	-0.00192 (0.00140)	-0.00122 (0.00127)
Landholdings	0.00109 (0.00145)	0.00182 (0.00126)	0.00143 (0.00139)	0.000908 (0.00152)
Residential	0.171*** (0.0539)	0.149** (0.0571)	0.160*** (0.0560)	0.158** (0.0587)
Purchased	-0.0240 (0.185)	-0.0730 (0.191)	-0.0152 (0.186)	-0.0397 (0.186)
First Year Farming	-0.00295*** (0.000842)	-0.00318*** (0.00108)	-0.00294*** (0.000856)	-0.00294*** (0.000822)
Observations	3,250	3,250	3,232	3,232
R-squared	0.053	0.239	0.065	0.060
Fixed Effect	None	Group	None	None
Cluster	Parish	Parish	Parish	Parish

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

Table A35: OLS results of a dummy equal to one for parcels with trees planted on them (a long-term investment) on measures of land pressures, controlling for the Progress out of Poverty Index wealth index, total landholdings of the household in acres, dummies for the method of parcel acquisition, a dummy for if the parcel is primarily residential, a dummy for if the parcel was purchased or formally rented in, and the year the parcel was first farmed. Farmer Group fixed effects included in column (2), and standard errors are clustered at the parish level in all specifications (reported in parentheses). Customary is a dummy equal to one for customary parcels and zero otherwise. Difference in number of observations between columns (1) and (2) vs. (3) and (4) is due to missing GPS locations for some households, so they could not be matched to spatial measures of travel time.

VARIABLES	(1)	(2)	(3)	(4)
	Used Organic Fertilizer			
Freehold × Rental Price	0.00145 (0.00197)	-0.000688 (0.00112)		
Customary × Rental Price	0.0158** (0.00588)	0.00304 (0.00200)		
Freehold × Inverse Travel Time			0.629** (0.258)	
Customary × Inverse Travel Time			0.302** (0.138)	
Freehold × Decrease in Travel Time				3.985*** (0.482)
Customary × Decrease in Travel Time				1.508*** (0.346)
Customary	-0.0862*** (0.0228)	-0.0172 (0.0185)	0.00487 (0.0457)	0.186*** (0.0515)
Wealth Index	0.00525*** (0.00101)	0.000950 (0.000607)	0.00421*** (0.000961)	0.00117 (0.000755)
Landholdings	0.00204 (0.00150)	0.00139 (0.00103)	0.00269* (0.00157)	0.00323*** (0.00112)
Residential	0.128*** (0.0404)	0.0820 (0.0495)	0.117*** (0.0400)	0.0933** (0.0377)
Purchased	0.145 (0.0966)	-0.0500 (0.0682)	0.177 (0.118)	0.0972 (0.124)
First Year Farming	-0.000267 (0.000575)	-5.39e-05 (0.000441)	-0.000363 (0.000564)	-0.000172 (0.000479)
Observations	3,248	3,248	3,230	3,230
R-squared	0.113	0.324	0.127	0.203
Fixed Effect	None	Group	None	None
Cluster	Parish	Parish	Parish	Parish

Robust standard errors in parentheses

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

Table A36: OLS results of a dummy equal to one for parcels with organic fertilizer applied (a medium-term investment) on measures of land pressures, controlling for the Progress out of Poverty Index wealth index, total landholdings of the household in acres, dummies for the method of parcel acquisition, a dummy for if the parcel is primarily residential, a dummy for if the parcel was purchased or formally rented in, and the year the parcel was first farmed. Farmer Group fixed effects included in column (2), and standard errors are clustered at the parish level in all specifications (reported in parentheses). Customary is a dummy equal to one for customary parcels and zero otherwise. Difference in number of observations between columns (1) and (2) vs. (3) and (4) is due to missing GPS locations for some households, so they could not be matched to spatial measures of travel time.

VARIABLES	(1)	(2)	(3)	(4)
	Used Inorganic Fertilizer			
Freehold × Rental Price	0.00347 (0.00261)	0.00501*** (0.00183)		
Customary × Rental Price	0.00921 (0.00883)	0.00414 (0.00261)		
Freehold × Inverse Travel Time			0.760*** (0.0808)	
Customary × Inverse Travel Time			0.599*** (0.111)	
Freehold × Decrease in Travel Time				1.376*** (0.392)
Customary × Decrease in Travel Time				0.630* (0.321)
Customary	0.00525 (0.0379)	0.00268 (0.0421)	0.0504 (0.0487)	0.0870** (0.0328)
Wealth Index	0.00467*** (0.000698)	0.00199** (0.000862)	0.00324*** (0.000739)	0.00328*** (0.000864)
Landholdings	0.00172** (0.000780)	0.00147* (0.000859)	0.00277*** (0.000910)	0.00259*** (0.000927)
Residential	-0.0485 (0.0333)	-0.0684** (0.0338)	-0.0606* (0.0311)	-0.0593* (0.0347)
Purchased	0.0960 (0.183)	0.0280 (0.185)	0.0612 (0.180)	0.0287 (0.181)
First Year Farming	0.00122*** (0.000445)	0.000815 (0.000497)	0.00116** (0.000436)	0.00130*** (0.000439)
Observations	3,245	3,245	3,227	3,227
R-squared	0.030	0.151	0.059	0.042
Fixed Effect	None	Group	None	None
Cluster	Parish	Parish	Parish	Parish

Robust standard errors in parentheses

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

Table A37: OLS results of a dummy equal to one for parcels with inorganic fertilizer applied (a short-term investment) on measures of land pressures, controlling for the Progress out of Poverty Index wealth index, total landholdings of the household in acres, dummies for the method of parcel acquisition, a dummy for if the parcel is primarily residential, a dummy for if the parcel was purchased or formally rented in, and the year the parcel was first farmed. Farmer Group fixed effects included in column (2), and standard errors are clustered at the parish level in all specifications (reported in parentheses). Customary is a dummy equal to one for customary parcels and zero otherwise. Difference in number of observations between columns (1) and (2) vs. (3) and (4) is due to missing GPS locations for some households, so they could not be matched to spatial measures of travel time.

VARIABLES	(1)	(2)	(3)	(4)
	Used Pesticides			
Freehold × Rental Price	0.000271 (0.00382)	-0.00103 (0.00263)		
Cutomary × Rental Price	0.0131 (0.00858)	-0.0125*** (0.00341)		
Freehold Inverse Travel Time			0.913*** (0.144)	
Customary × Inverse Travel Time			0.586*** (0.206)	
Freehold × Decrease in Travel Time				2.589*** (0.558)
Customary × Decrease in Travel Time				0.251 (0.445)
Customary	-0.0456 (0.0641)	-0.0446 (0.0647)	0.0482 (0.0535)	0.204*** (0.0459)
Wealth Index	0.00679*** (0.00102)	0.00340*** (0.00104)	0.00495*** (0.00109)	0.00438*** (0.00107)
Landholdings	0.00223 (0.00168)	0.000873 (0.00104)	0.00268* (0.00148)	0.00247** (0.00118)
Residential	0.105*** (0.0277)	0.0708* (0.0372)	0.0898*** (0.0270)	0.0828*** (0.0295)
Purchased	0.130 (0.115)	0.0619 (0.124)	0.168 (0.127)	0.118 (0.136)
First Year Farming	0.000458 (0.000498)	0.000549 (0.000549)	0.000374 (0.000479)	0.000514 (0.000500)
Observations	3,244	3,244	3,226	3,226
R-squared	0.060	0.199	0.088	0.087
Fixed Effect	None	Group	None	None
Cluster	Parish	Parish	Parish	Parish

Robust standard errors in parentheses

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

Table A38: OLS results of a dummy equal to one for parcels with pesticides applied (a short-term investment) on measures of land pressures, controlling for the Progress out of Poverty Index wealth index, total landholdings of the household in acres, dummies for the method of parcel acquisition, a dummy for if the parcel is primarily residential, a dummy for if the parcel was purchased or formally rented in, and the year the parcel was first farmed. Farmer Group fixed effects included in column (2), and standard errors are clustered at the parish level in all specifications (reported in parentheses). Customary is a dummy equal to one for customary parcels and zero otherwise. Difference in number of observations between columns (1) and (2) vs. (3) and (4) is due to missing GPS locations for some households, so they could not be matched to spatial measures of travel time.

VARIABLES	(1)	(2)	(3)	(4)
Freehold × Rental Price	-0.0126** (0.00582)	-0.0118** (0.00446)		
Customary × Rental Price	0.000813 (0.00888)	0.00390 (0.00377)		
Freehold × Inverse Travel Time			-0.521* (0.306)	
Customary × Inverse Travel Time			0.0136 (0.225)	
Freehold × Decrease in Travel Time				-3.830*** (0.616)
Customary × Decrease in Travel Time				-1.161 (0.719)
Customary	0.0629*** (0.0209)	-0.00288 (0.0132)	-0.0868* (0.0465)	-0.239*** (0.0501)
Wealth Index	-0.00322** (0.00149)	0.000490 (0.000449)	-0.00262** (0.00120)	0.000348 (0.000756)
Landholdings	-0.000727 (0.000481)	0.000440 (0.000469)	-0.000784 (0.000486)	-0.00107** (0.000440)
Observations	5,511	5,511	5,489	5,489
R-squared	0.047	0.252	0.053	0.103
Fixed Effect	None	Group	None	None
Cluster	Parish	Parish	Parish	Parish

Robust standard errors in parentheses

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

Table A39: OLS results of a dummy equal to one for parcels with at least one plot primarily devoted to a staple crop on measures of land pressures, controlling for the Progress out of Poverty Index wealth index, total landholdings of the household in acres, and dummies for the method of parcel acquisition. Farmer Group fixed effects included in column (2), and standard errors are clustered at the parish level in all specifications (reported in parentheses). Customary is a dummy equal to one for customary parcels and zero otherwise. Difference in number of observations between columns (1) and (2) vs. (3) and (4) is due to missing GPS locations for some households, so they could not be matched to spatial measures of travel time.

VARIABLES	Average Insecurity			
	(1)	(2)	(3)	(4)
Freehold × Rental Price	0.0284 (0.0250)	0.0348 (0.0223)		
Customary × Rental Price	0.149*** (0.0290)	0.154*** (0.0382)		
Freehold × Inverse Travel Time		-0.835** (0.327)		
Customary × Inverse Travel Time		1.185*** (0.285)		
Freehold × Decrease in Travel Time			-1.271 (0.923)	
Customary × Decrease in Travel Time			1.486* (0.784)	
Customary	0.0729 (0.0507)	0.0544 (0.0497)	-0.460*** (0.110)	-0.196 (0.126)
Wealth Index	-7.75e-05 (0.00145)	-0.000793 (0.00152)	-0.000873 (0.00168)	-0.000427 (0.00154)
Landholdings	-0.00208** (0.000958)	-0.00189* (0.00105)	-0.00208** (0.000927)	-0.00222** (0.000985)
Cash Crops	0.0293 (0.0431)	-0.0110 (0.0509)	0.0414 (0.0486)	0.0464 (0.0532)
Observations	5,490	5,490	5,468	5,468
R-squared	0.256	0.327	0.253	0.246
Fixed Effect	None	Group	None	None
Cluster	Parish	Parish	Parish	Parish

Robust standard errors in parentheses

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

Table A40: OLS results of average tenure insecurity across all rightsholders on a parcel on measures of land pressures, controlling for a dummy equal to one if the primary crop on any plot on the parcel is a cash crop, the Progress out of Poverty Index wealth index, total landholdings of the household in acres, and dummies for the method of parcel acquisition. Farmer Group fixed effects included in column (2), and standard errors are clustered at the parish level in all specifications (reported in parentheses). Customary is a dummy equal to one for customary parcels and zero otherwise. Difference in number of observations between columns (1) and (2) vs. (3) and (4) is due to missing GPS locations for some households, so they could not be matched to spatial measures of travel time.

VARIABLES	Trees			
	(1)	(2)	(3)	(4)
Freehold × Rental Price	0.0150 (0.0103)	0.0102 (0.0118)		
Customary × Rental Price	-0.0180 (0.0339)	-0.0335*** (0.00663)		
Freehold × Inverse Travel Time			1.304*** (0.389)	
Customary × Inverse Travel Time			0.577 (0.527)	
Freehold × Decrease in Travel Time				1.502 (1.129)
Customary × Decrease in Travel Time				-1.599 (0.975)
Customary	-0.0594 (0.0519)	-0.00871 (0.0368)	0.163 (0.135)	0.244** (0.101)
Wealth Index	-0.00283* (0.00153)	0.000408 (0.000799)	-0.00492*** (0.00105)	-0.00256** (0.00100)
Landholdings	-0.00126 (0.000909)	-0.00127** (0.000587)	-0.000613 (0.000535)	-0.00154* (0.000820)
Cash Crops	0.110*** (0.0320)	0.102*** (0.0330)	0.0853*** (0.0271)	0.0934** (0.0368)
Observations	5,505	5,505	5,483	5,483
R-squared	0.039	0.241	0.067	0.049
Fixed Effect	None	Group	None	None
Cluster	Parish	Parish	Parish	Parish

Robust standard errors in parentheses

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

Table A41: OLS results of a dummy equal to one for parcels with trees planted on them (a long-term investment) on measures of land pressures, controlling for the a dummy equal to one if the primary crop on any plot on the parcel is a cash crop, the Progress out of Poverty Index wealth index, total landholdings of the household in acres, and dummies for the method of parcel acquisition. Farmer Group fixed effects included in column (2), and standard errors are clustered at the parish level in all specifications (reported in parentheses). Customary is a dummy equal to one for customary parcels and zero otherwise. Difference in number of observations between columns (1) and (2) vs. (3) and (4) is due to missing GPS locations for some households, so they could not be matched to spatial measures of travel time.

VARIABLES	Used Organic Fertilizer			
	(1)	(2)	(3)	(4)
Freehold × Rental Price	-0.000420 (0.00171)	-0.00170* (0.000949)		
Customary × Rental Price	0.0176** (0.00693)	0.00304 (0.00262)		
Freehold × Inverse Travel Time			0.587*** (0.186)	
Customary × Inverse Travel Time			0.248*** (0.0674)	
Freehold × Decrease in Travel Time				3.376*** (0.349)
Customary × Decrease in Travel Time				0.932*** (0.222)
Customary	-0.0826*** (0.0237)	-0.0247 (0.0175)	0.0190 (0.0419)	0.183*** (0.0373)
Wealth Index	0.00430*** (0.000606)	0.00127*** (0.000372)	0.00343*** (0.000585)	0.00169*** (0.000492)
Landholdings	0.000167 (0.000239)	0.000310 (0.000370)	0.000547 (0.000357)	0.000716** (0.000313)
Cash Crops	0.185*** (0.0219)	0.0403** (0.0169)	0.172*** (0.0217)	0.121*** (0.0187)
Observations	5,503	5,503	5,481	5,481
R-squared	0.156	0.291	0.166	0.207
Fixed Effect	None	Group	None	None
Cluster	Parish	Parish	Parish	Parish

Robust standard errors in parentheses

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

Table A42: OLS results of a dummy equal to one for parcels with organic fertilizer applied (a medium-term investment) on measures of land pressures, controlling for the a dummy equal to one if the primary crop on any plot on the parcel is a cash crop, the Progress out of Poverty Index wealth index, total landholdings of the household in acres, and dummies for the method of parcel acquisition. Farmer Group fixed effects included in column (2), and standard errors are clustered at the parish level in all specifications (reported in parentheses). Customary is a dummy equal to one for customary parcels and zero otherwise. Difference in number of observations between columns (1) and (2) vs. (3) and (4) is due to missing GPS locations for some households, so they could not be matched to spatial measures of travel time.

VARIABLES	Used Inorganic Fertilizer			
	(1)	(2)	(3)	(4)
Freehold × Rental Price	0.00418*	0.00511**		
	(0.00225)	(0.00199)		
Customary × Rental Price	0.0180	0.00278		
	(0.0167)	(0.00250)		
Freehold × Inverse Travel Time			0.636***	
			(0.0841)	
Customary × Inverse Travel Time			0.533***	
			(0.0831)	
Freehold × Decrease in Travel Time				1.057***
				(0.363)
Customary × Decrease in Travel Time				0.629**
				(0.310)
Customary	-0.0193	0.00207	0.0242	0.0312
	(0.0203)	(0.0239)	(0.0233)	(0.0196)
Wealth Index	0.00348***	0.00172***	0.00220***	0.00248***
	(0.000549)	(0.000589)	(0.000571)	(0.000650)
Landholdings	0.000333	0.000562*	0.000900**	0.000676*
	(0.000375)	(0.000332)	(0.000405)	(0.000382)
Cash Crops	0.0152	0.0110	0.00234	-0.00591
	(0.0113)	(0.0113)	(0.00927)	(0.0114)
Observations	5,501	5,501	5,479	5,479
R-squared	0.028	0.127	0.053	0.036
Fixed Effect	None	Group	None	None
Cluster	Parish	Parish	Parish	Parish

Robust standard errors in parentheses

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

Table A43: OLS results of a dummy equal to one for parcels with inorganic fertilizer applied (a short-term investment) on measures of land pressures, controlling for the a dummy equal to one if the primary crop on any plot on the parcel is a cash crop, the Progress out of Poverty Index wealth index, total landholdings of the household in acres, and dummies for the method of parcel acquisition. Farmer Group fixed effects included in column (2), and standard errors are clustered at the parish level in all specifications (reported in parentheses). Customary is a dummy equal to one for customary parcels and zero otherwise. Difference in number of observations between columns (1) and (2) vs. (3) and (4) is due to missing GPS locations for some households, so they could not be matched to spatial measures of travel time.

VARIABLES	Used Pesticides			
	(1)	(2)	(3)	(4)
Freehold × Rental Price	-0.000439 (0.00403)	-0.00241 (0.00270)		
Customary × Rental Price	0.0188 (0.0124)	-0.0159*** (0.00401)		
Freehold × Inverse Travel Time			0.865*** (0.0881)	
Customary × Inverse Travel Time			0.503*** (0.186)	
Freehold × Decrease in Travel Time				2.622*** (0.328)
Customary × Decrease in Travel Time				0.375 (0.436)
Customary	-0.0566 (0.0471)	-0.0343 (0.0509)	0.0599** (0.0253)	0.182*** (0.0316)
Wealth Index	0.00509*** (0.000717)	0.00251*** (0.000899)	0.00353*** (0.000908)	0.00326*** (0.000960)
Landholdings	0.000330 (0.000468)	0.000490 (0.000345)	0.000789 (0.000474)	0.000567 (0.000370)
Cash Crops	0.156*** (0.0200)	0.0775*** (0.0180)	0.138*** (0.0193)	0.108*** (0.0203)
Observations	5,499	5,499	5,477	5,477
R-squared	0.094	0.190	0.119	0.119
Fixed Effect	None	Group	None	None
Cluster	Parish	Parish	Parish	Parish

Robust standard errors in parentheses

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

Table A44: OLS results of a dummy equal to one for parcels with pesticides applied (a short-term investment) on measures of land pressures, controlling for the a dummy equal to one if the primary crop on any plot on the parcel is a cash crop, the Progress out of Poverty Index wealth index, total landholdings of the household in acres, and dummies for the method of parcel acquisition. Farmer Group fixed effects included in column (2), and standard errors are clustered at the parish level in all specifications (reported in parentheses). Customary is a dummy equal to one for customary parcels and zero otherwise. Difference in number of observations between columns (1) and (2) vs. (3) and (4) is due to missing GPS locations for some households, so they could not be matched to spatial measures of travel time.

### C.7.3 Distance to Output Markets

Changing patterns of input use could be responding not to rising land values, but increasing access to agricultural markets, either for inputs (agroinput dealers) or outputs. However, this should not impact customary parcels differently than freehold, so it seems unlikely to be driving our primary results. However, for a subset of respondents we collected data on the distance to input and output markets, so in this appendix I control for those distances. In tables A45 - A49, I control for the one-way travel cost to the nearest agroinput dealer, to control for access to input markets. In tables A50 - A54, I control for the one-way travel cost to the nearest village in which crops can be sold, focusing on output markets. In results not reported, I also control for the average distance in kilometers at which crops were actually sold in the past season, but when crops were sold at the farm gate this was reported as a zero, making it a difficult to interpret measure (as more remote farms may be more likely to sell at the farm gate). These controls do not change the substance of my results in the main text, indicating access to markets is not driving them; however, I do not use this as a primary control given the 40% reduction in sample size when including these controls.<sup>38</sup>

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<sup>38</sup>These questions were asked towards the end of the survey, and there was increasing nonresponse towards the end of the multi-hour survey.

VARIABLES	Average Insecurity			
	(1)	(2)	(3)	(4)
Freehold × Rental Price	0.0319 (0.0221)	0.0374* (0.0197)		
Customary × Rental Price	0.150*** (0.0314)	0.165*** (0.0442)		
Freehold × Inverse Travel Time			-0.800*** (0.290)	
Customary × Inverse Travel Time			1.127*** (0.273)	
Freehold × Decrease in Travel Time				-1.242 (0.917)
Customary × Decrease in Travel Time				1.399* (0.796)
Customary	0.0690 (0.0555)	0.0498 (0.0529)	-0.440*** (0.105)	-0.193 (0.125)
Wealth Index	-0.000285 (0.00153)	-7.44e-05 (0.00131)	-0.000910 (0.00163)	-0.000469 (0.00154)
Landholdings	-0.00174* (0.000915)	-0.00226* (0.00122)	-0.00187** (0.000900)	-0.00195** (0.000939)
Travel Cost to Agroinput Dealer	-9.23e-06* (5.09e-06)	-7.13e-06 (5.84e-06)	-4.59e-06 (4.64e-06)	-6.53e-06 (4.96e-06)
Observations	2,971	2,971	2,962	2,962
R-squared	0.262	0.333	0.258	0.252
Fixed Effect	None	Group	None	None
Cluster	Parish	Parish	Parish	Parish

Robust standard errors in parentheses

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

Table A45: OLS results of average tenure insecurity across all rightsholders on a parcel on measures of land pressures, controlling for the one-way travel cost to the nearest agroinput dealer, the Progress out of Poverty Index wealth index, total landholdings of the household in acres, and dummies for the method of parcel acquisition. Farmer Group fixed effects included in column (2), and standard errors are clustered at the parish level in all specifications (reported in parentheses). Customary is a dummy equal to one for customary parcels and zero otherwise. Difference in number of observations between columns (1) and (2) vs. (3) and (4) is due to missing GPS locations for some households, so they could not be matched to spatial measures of travel time.

VARIABLES	Trees			
	(1)	(2)	(3)	(4)
Freehold × Rental Price	0.0141 (0.0119)	0.00864 (0.0128)		
Customary × Rental Price	-0.00945 (0.0409)	-0.0331*** (0.00734)		
Freehold × Inverse Travel Time			1.396*** (0.398)	
Customary × Inverse Travel Time			0.749 (0.560)	
Freehold × Decrease in Travel Time				2.331** (1.132)
Customary × Decrease in Travel Time				-0.932 (1.112)
Customary	-0.0738 (0.0575)	-0.00827 (0.0330)	0.137 (0.150)	0.260** (0.121)
Wealth Index	-0.00210 (0.00166)	0.000323 (0.000816)	-0.00468*** (0.00115)	-0.00311*** (0.00114)
Landholdings	-0.00104 (0.000856)	-0.000916 (0.000602)	-0.000362 (0.000568)	-0.00108 (0.000786)
Travel Cost to Agroinput Dealer	2.69e-06 (3.61e-06)	-3.11e-06 (3.98e-06)	3.73e-06 (3.62e-06)	3.67e-07 (3.57e-06)
Observations	2,943	2,943	2,934	2,934
R-squared	0.033	0.255	0.070	0.047
Fixed Effect	None	Group	None	None
Cluster	Parish	Parish	Parish	Parish

Robust standard errors in parentheses

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

Table A46: OLS results of a dummy equal to one for parcels with trees planted on them (a long-term investment) on measures of land pressures, controlling for the one-way travel cost to the nearest agroinput dealer, the Progress out of Poverty Index wealth index, total landholdings of the household in acres, and dummies for the method of parcel acquisition. Farmer Group fixed effects included in column (2), and standard errors are clustered at the parish level in all specifications (reported in parentheses). Customary is a dummy equal to one for customary parcels and zero otherwise. Difference in number of observations between columns (1) and (2) vs. (3) and (4) is due to missing GPS locations for some households, so they could not be matched to spatial measures of travel time.

VARIABLES	(1)	(2)	Used Organic Fertilizer (3)	(4)
Freehold × Rental Price	0.00205 (0.00308)	-0.00284*** (0.000882)		
Customary × Rental Price	0.0265** (0.0125)	0.00564 (0.00366)		
Freehold × Inverse Travel Time			0.801*** (0.278)	
Customary × Inverse Travel Time			0.418*** (0.107)	
Freehold × Decrease in Travel Time				4.411*** (0.439)
Customary × Decrease in Travel Time				1.692*** (0.306)
Customary	-0.126*** (0.0317)	-0.0322 (0.0203)	-0.00577 (0.0522)	0.188*** (0.0442)
Wealth Index	0.00669*** (0.00118)	0.00188*** (0.000434)	0.00531*** (0.00102)	0.00242*** (0.000677)
Landholdings	0.000676 (0.000529)	0.000560 (0.000518)	0.00114 (0.000716)	0.00129** (0.000617)
Travel Cost to Agroinput Dealer	3.59e-06 (3.00e-06)	1.22e-06 (2.24e-06)	3.97e-06 (2.96e-06)	3.04e-06 (2.18e-06)
Observations	2,941	2,941	2,932	2,932
R-squared	0.123	0.344	0.146	0.218
Fixed Effect	None	Group	None	None
Cluster	Parish	Parish	Parish	Parish

Robust standard errors in parentheses

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

Table A47: OLS results of a dummy equal to one for parcels with organic fertilizer applied (a medium-term investment) on measures of land pressures, controlling for the one-way travel cost to the nearest agroinput dealer, the Progress out of Poverty Index wealth index, total landholdings of the household in acres, and dummies for the method of parcel acquisition. Farmer Group fixed effects included in column (2), and standard errors are clustered at the parish level in all specifications (reported in parentheses). Customary is a dummy equal to one for customary parcels and zero otherwise. Difference in number of observations between columns (1) and (2) vs. (3) and (4) is due to missing GPS locations for some households, so they could not be matched to spatial measures of travel time.

VARIABLES	Used Inorganic Fertilizer			
	(1)	(2)	(3)	(4)
Freehold × Rental Price	-0.00338** (0.00130)	-0.00254*** (0.000882)		
Customary × Rental Price	0.0239 (0.0191)	0.00293 (0.00265)		
Freehold × Inverse Travel Time			0.716*** (0.0833)	
Customary × Inverse Travel Time			0.635*** (0.112)	
Freehold × Decrease in Travel Time				1.245*** (0.374)
Customary × Decrease in Travel Time				0.951*** (0.337)
Customary	-0.0324 (0.0250)	-0.00201 (0.0278)	0.00994 (0.0363)	0.0112 (0.0355)
Wealth Index	0.00452*** (0.000600)	0.00173*** (0.000578)	0.00293*** (0.000623)	0.00299*** (0.000712)
Landholdings	0.000270 (0.000461)	0.000584 (0.000452)	0.000833 (0.000579)	0.000622 (0.000520)
Travel Cost to Agroinput Dealer	4.26e-06 (3.07e-06)	7.88e-06** (3.73e-06)	5.20e-06* (2.87e-06)	4.44e-06 (2.96e-06)
Observations	2,941	2,941	2,932	2,932
R-squared	0.038	0.162	0.071	0.051
Fixed Effect	None	Group	None	None
Cluster	Parish	Parish	Parish	Parish

Robust standard errors in parentheses

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

Table A48: OLS results of a dummy equal to one for parcels with inorganic fertilizer applied (a short-term investment) on measures of land pressures, controlling for the one-way travel cost to the nearest agroinput dealer, the Progress out of Poverty Index wealth index, total landholdings of the household in acres, and dummies for the method of parcel acquisition. Farmer Group fixed effects included in column (2), and standard errors are clustered at the parish level in all specifications (reported in parentheses). Customary is a dummy equal to one for customary parcels and zero otherwise. Difference in number of observations between columns (1) and (2) vs. (3) and (4) is due to missing GPS locations for some households, so they could not be matched to spatial measures of travel time.

VARIABLES	Used Pesticides			
	(1)	(2)	(3)	(4)
Freehold × Rental Price	-0.000879 (0.00376)	-0.00584*** (0.00164)		
Customary × Rental Price	0.0317* (0.0189)	-0.0124** (0.00539)		
Freehold × Inverse Travel Time			1.100*** (0.191)	
Customary × Inverse Travel Time			0.747*** (0.194)	
freehold × Decrease in Travel Time				3.705*** (0.494)
Customary × Decrease in Travel Time				1.141*** (0.391)
Customary	-0.0886 (0.0594)	-0.0352 (0.0601)	0.0361 (0.0492)	0.202*** (0.0372)
Wealth Index	0.00741*** (0.00121)	0.00279*** (0.000832)	0.00518*** (0.00121)	0.00394*** (0.00107)
Landholdings	0.000631 (0.000667)	0.000726 (0.000453)	0.00114 (0.000694)	0.000948* (0.000561)
Travel Cost to Agroinput Dealer	8.45e-06* (4.43e-06)	9.93e-06** (4.56e-06)	9.37e-06** (4.41e-06)	7.45e-06* (4.07e-06)
Observations	2,940	2,940	2,931	2,931
R-squared	0.082	0.242	0.124	0.136
Fixed Effect	None	Group	None	None
Cluster	Parish	Parish	Parish	Parish

Robust standard errors in parentheses

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

Table A49: OLS results of a dummy equal to one for parcels with pesticides applied (a short-term investment) on measures of land pressures, controlling for the one-way travel cost to the nearest agroinput dealer, the Progress out of Poverty Index wealth index, total landholdings of the household in acres, and dummies for the method of parcel acquisition. Farmer Group fixed effects included in column (2), and standard errors are clustered at the parish level in all specifications (reported in parentheses). Customary is a dummy equal to one for customary parcels and zero otherwise. Difference in number of observations between columns (1) and (2) vs. (3) and (4) is due to missing GPS locations for some households, so they could not be matched to spatial measures of travel time.

VARIABLES	(1)	(2)	Average Insecurity (3)	(4)
Freehold × Rental Price	0.0314 (0.0222)	0.0370* (0.0198)		
Customary × Rental Price	0.153*** (0.0347)	0.166*** (0.0450)		
Freehold × Inverse Travel Time			-0.799** (0.305)	
Customary × Inverse Travel Time			1.161*** (0.280)	
Freehold × Decrease in Travel Time				-1.260 (0.916)
Customary × Decrease in Travel Time				1.497* (0.827)
Customary	0.0686 (0.0555)	0.0496 (0.0530)	-0.448*** (0.107)	-0.204 (0.128)
Wealth Index	-0.000125 (0.00152)	-0.000101 (0.00132)	-0.000873 (0.00166)	-0.000415 (0.00157)
Landholdings	-0.00199** (0.000935)	-0.00229* (0.00127)	-0.00199** (0.000906)	-0.00211** (0.000947)
Travel Cost to Output Market	5.66e-07 (6.43e-06)	1.66e-06 (4.88e-06)	1.15e-06 (6.60e-06)	9.95e-07 (6.42e-06)
Observations	2,968	2,968	2,959	2,959
R-squared	0.261	0.333	0.258	0.251
Fixed Effect	None	Group	None	None
Cluster	Parish	Parish	Parish	Parish

Robust standard errors in parentheses

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

Table A50: OLS results of average tenure insecurity across all rightsholders on a parcel on measures of land pressures, controlling for the one-way travel cost to the nearest village in which crops can be sold, the Progress out of Poverty Index wealth index, total landholdings of the household in acres, and dummies for the method of parcel acquisition. Farmer Group fixed effects included in column (2), and standard errors are clustered at the parish level in all specifications (reported in parentheses). Customary is a dummy equal to one for customary parcels and zero otherwise. Difference in number of observations between columns (1) and (2) vs. (3) and (4) is due to missing GPS locations for some households, so they could not be matched to spatial measures of travel time.

VARIABLES	Trees			
	(1)	(2)	(3)	(4)
Freehold × Rental Price	0.0143 (0.0120)	0.00850 (0.0129)		
Customary × Rental Price	-0.0117 (0.0392)	-0.0325*** (0.00721)		
Freehold × Inverse Travel Time			1.395*** (0.404)	
Customary × Inverse Travel Time			0.732 (0.557)	
Freehold × Decrease in Travel Time				2.279** (1.121)
Customary × Decrease in Travel Time				-0.993 (1.084)
Customary	-0.0736 (0.0572)	-0.00840 (0.0327)	0.141 (0.149)	0.260** (0.121)
Wealth Index	-0.00219 (0.00164)	0.000294 (0.000822)	-0.00472*** (0.00115)	-0.00307*** (0.00114)
Landholdings	-0.000937 (0.000807)	-0.000921 (0.000591)	-0.000279 (0.000536)	-0.00104 (0.000761)
Travel Cost to Output Market	-3.63e-06 (4.31e-06)	2.99e-06 (2.29e-06)	3.20e-07 (2.23e-06)	-3.76e-06 (3.70e-06)
Observations	2,940	2,940	2,931	2,931
R-squared	0.033	0.255	0.069	0.047
Fixed Effect	None	Group	None	None
Cluster	Parish	Parish	Parish	Parish

Robust standard errors in parentheses

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

Table A51: OLS results of a dummy equal to one for parcels with trees planted on them (a long-term investment) on measures of land pressures, controlling for the one-way travel cost to the nearest village in which crops can be sold, the Progress out of Poverty Index wealth index, total landholdings of the household in acres, and dummies for the method of parcel acquisition. Farmer Group fixed effects included in column (2), and standard errors are clustered at the parish level in all specifications (reported in parentheses). Customary is a dummy equal to one for customary parcels and zero otherwise. Difference in number of observations between columns (1) and (2) vs. (3) and (4) is due to missing GPS locations for some households, so they could not be matched to spatial measures of travel time.

VARIABLES	(1)	(2)	Used Organic Fertilizer (3)	(4)
Freehold × Rental Price	0.00221 (0.00295)	-0.00274*** (0.000848)		
Customary × Rental Price	0.0274** (0.0129)	0.00567 (0.00370)		
Freehold × Inverse Travel Time			0.823*** (0.274)	
Customary × Inverse Travel Time			0.451*** (0.0985)	
Freehold × Decrease in Travel Time				4.414*** (0.443)
Customary × Decrease in Travel Time				1.762*** (0.302)
Customary	-0.125*** (0.0312)	-0.0321 (0.0197)	-0.00692 (0.0518)	0.182*** (0.0445)
Wealth Index	0.00664*** (0.00115)	0.00184*** (0.000430)	0.00520*** (0.000993)	0.00235*** (0.000678)
Landholdings	0.000707 (0.000544)	0.000579 (0.000512)	0.00118 (0.000737)	0.00130** (0.000627)
Travel Cost to Output Market	5.14e-06*** (1.62e-06)	4.59e-06*** (1.65e-06)	7.38e-06*** (1.86e-06)	7.34e-06*** (1.89e-06)
Observations	2,938	2,938	2,929	2,929
R-squared	0.124	0.342	0.148	0.219
Fixed Effect	None	Group	None	None
Cluster	Parish	Parish	Parish	Parish

Robust standard errors in parentheses

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

Table A52: OLS results of a dummy equal to one for parcels with organic fertilizer applied (a medium-term investment) on measures of land pressures, controlling for the one-way travel cost to the nearest village in which crops can be sold, the Progress out of Poverty Index wealth index, total landholdings of the household in acres, and dummies for the method of parcel acquisition. Farmer Group fixed effects included in column (2), and standard errors are clustered at the parish level in all specifications (reported in parentheses). Customary is a dummy equal to one for customary parcels and zero otherwise. Difference in number of observations between columns (1) and (2) vs. (3) and (4) is due to missing GPS locations for some households, so they could not be matched to spatial measures of travel time.

VARIABLES	Used Inorganic Fertilizer			
	(1)	(2)	(3)	(4)
Freehold × Rental Price	-0.00317** (0.00127)	-0.00217** (0.000930)		
Customary × Rental Price	0.0218 (0.0178)	0.00206 (0.00240)		
Freehold × Inverse Travel Time			0.709*** (0.0875)	
Customary × Inverse Travel Time			0.610*** (0.118)	
Freehold × Decrease in Travel Time				1.197*** (0.376)
Customary × Decrease in Travel Time				0.877** (0.339)
Customary	-0.0321 (0.0252)	-0.00262 (0.0277)	0.0146 (0.0358)	0.0132 (0.0377)
Wealth Index	0.00441*** (0.000582)	0.00178*** (0.000574)	0.00287*** (0.000607)	0.00298*** (0.000706)
Landholdings	0.000397 (0.000490)	0.000606 (0.000484)	0.000948 (0.000617)	0.000730 (0.000549)
Travel Cost to Output Market	-1.99e-06 (1.44e-06)	-9.42e-08 (1.77e-06)	2.53e-07 (1.65e-06)	-1.34e-06 (1.14e-06)
Observations	2,938	2,938	2,929	2,929
R-squared	0.038	0.159	0.069	0.050
Fixed Effect	None	Group	None	None
Cluster	Parish	Parish	Parish	Parish

Robust standard errors in parentheses

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

Table A53: OLS results of a dummy equal to one for parcels with inorganic fertilizer applied (a short-term investment) on measures of land pressures, controlling for the one-way travel cost to the nearest village in which crops can be sold, the Progress out of Poverty Index wealth index, total landholdings of the household in acres, and dummies for the method of parcel acquisition. Farmer Group fixed effects included in column (2), and standard errors are clustered at the parish level in all specifications (reported in parentheses). Customary is a dummy equal to one for customary parcels and zero otherwise. Difference in number of observations between columns (1) and (2) vs. (3) and (4) is due to missing GPS locations for some households, so they could not be matched to spatial measures of travel time.

VARIABLES	Used Pesticides			
	(1)	(2)	(3)	(4)
Freehold × Rental Price	-0.000422 (0.00344)	-0.00523*** (0.00145)		
Customary × Rental Price	0.0313 (0.0188)	-0.0136** (0.00557)		
Freehold × Inverse Travel Time			1.158*** (0.181)	
Customary × Inverse Travel Time			0.765*** (0.204)	
Freehold × Decrease in Travel Time				3.804*** (0.486)
Customary × Decrease in Travel Time				1.164*** (0.425)
Customary	-0.0883 (0.0588)	-0.0340 (0.0600)	0.0486 (0.0482)	0.210*** (0.0386)
Wealth Index	0.00731*** (0.00118)	0.00266*** (0.000847)	0.00501*** (0.00120)	0.00379*** (0.00107)
Landholdings	0.000788 (0.000740)	0.000808 (0.000487)	0.00131* (0.000777)	0.00107* (0.000618)
Travel Cost to Output Market	5.81e-06*** (1.90e-06)	7.93e-06*** (1.89e-06)	9.33e-06** (4.22e-06)	7.50e-06** (3.37e-06)
Observations	2,937	2,937	2,928	2,928
R-squared	0.082	0.244	0.127	0.138
Fixed Effect	None	Group	None	None
Cluster	Parish	Parish	Parish	Parish

Robust standard errors in parentheses

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

Table A54: OLS results of a dummy equal to one for parcels with pesticides applied (a short-term investment) on measures of land pressures, controlling for the one-way travel cost to the nearest village in which crops can be sold, the Progress out of Poverty Index wealth index, total landholdings of the household in acres, and dummies for the method of parcel acquisition. Farmer Group fixed effects included in column (2), and standard errors are clustered at the parish level in all specifications (reported in parentheses). Customary is a dummy equal to one for customary parcels and zero otherwise. Difference in number of observations between columns (1) and (2) vs. (3) and (4) is due to missing GPS locations for some households, so they could not be matched to spatial measures of travel time.