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The Effects of Land Title Registration on Tenure Security, Investment and the Allocation of Productive Resources

Evidence from Ghana

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Abstract

Smallholder farmers' investment decisions and the efficiency of resource allocation depend on the security of land tenure. This paper develops a simple model that captures essential institutional features of rural land markets in Ghana, including the dependence of future rights over land on current cultivation and land rental decisions. The model predictions guide the evaluation of a pilot land titling intervention that took place in an urbanizing area located in the Central Region of Ghana. The evaluation is based on a regression discontinuity design combined with three rounds of household survey data collected over a period of six years. The analysis finds strong markers for the program's success in registering land in the targeted program area. However, land registration does not translate into agricultural investments or increased credit taking. Instead, treated households decrease their amount of agricultural labor, accompanied by only a small reduction of agricultural production and no changes in productivity. In line with this result, households decrease their landholdings amid a surge in land valuations. The analysis uncovers important within-household differences in how women and men respond differentially to the program. There appears to be a general shift to nonfarm economic activities, and women's business profits increased considerably.

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The Effects of Land Title Registration on Tenure Security, Investment and the Allocation of Productive Resources: Evidence from Ghana*

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1. Introduction

Property rights play a central role in the allocation of resources, investment decisions and economic development more broadly. In economies based on or transitioning from agriculture, economic activity is shaped in particular by the characteristics of property rights over land. Economic theory suggests that there are four main pathways through which secure property rights will improve resource allocation and ultimately welfare (Besley & Ghatak, 2010). First, limiting expropriation risk helps ensure investors that they will be able to reap the dividends of increased investment. Second, expropriation risk might induce property owners to devote productive resources to protecting their property rights. More secure rights could permit agents to reduce such wasteful expenditures. Third, secure property rights may allow or facilitate market transactions by ensuring a smooth transition of ownership or usage rights. This allows for more efficient resource allocations and allows agents to realize gains from trade. Finally, well-defined land property rights can stimulate investment through improved access to credit markets.

A pilot land titling program implemented by the Government of Ghana in a limited and sharply-defined geographic area of Ghana's Central Region provides an opportunity to investigate the link between secure land property rights, resource allocation, access to credit and investment. The primary objective of this program was to comprehensively register informal claims of landholders in the pilot district and formalize these rights by issuing certificates.[1] The program was intended to stimulate agricultural and non-agricultural investment in order to reduce poverty and spur economic growth in the long run. We use the geographic discontinuity at the boundaries of the pilot land titling program to examine the effects over a six year period of increases in the security of land property rights on investment and resource allocation through these four pathways.

We start by describing the formal legal framework of land rights in Ghana, the *de facto* land tenure system as it exists in the area around the pilot titling program, and the features of the program itself, which was initiated in 2009 in the Awutu-Effutu-Senya area of the Central Region with the support of the Millennium Development Authority (MiDA). We then develop a theoretical framework that captures important institutional features of the rural Ghanaian land market. Farmers have secure tenure over land that is currently cultivated and so conditional on the amount of land cultivated, resource allocation within farms and between farm and non-farm enterprises is efficient. However, farmers risk losing control over land that is rented out or otherwise not currently self-cultivated. This uncertainty induces farmers to cultivate more land than would otherwise be optimal, and consequently farmers use more labor and capital in agriculture than is efficient and use less than optimal quantities of labor and capital in nonfarm enterprises. Improved tenure security upon titling permits farmers to

[1] The program required that landholders provide evidence that these claims to a plot (set of rights) exceeded a three-year lease prior to the start of the intervention.

reallocate scarce labor from cultivation to nonfarm enterprises, and reduced frictions in land rental markets drive up the rental price of land.

We then analyze the impacts of the pilot Land Titling Program implemented in Ghana's Central Region. We use a geographic regression discontinuity design (RDD) with three rounds of household survey data collected over a period of six years. We find that there are strong markers that the program was successful in registering land in the treatment group. However, land registration does not appear to translate into agricultural investments or increased borrowing. Instead, households decrease their amount of agricultural labor, accompanied by a small reduction of agricultural production and no changes to productivity, and appear to shift to non-farm economic activities. In particular, women's profits from operating a business increase considerably. In line with this result, we observe that households decrease their land holdings amid a surge in land valuations.

This evaluation contributes to the literature linking property rights more generally and land titles in particular to investment and access to credit as well as household decisions related to production and the allocation of resources. DeSoto (2000) argued that secure land tenure can allow households to collateralize loans and thus obtain financing for investments. Given the regulatory environment in some countries, real estate may in fact be the only largely acceptable form of collateral. The additional capital obtained this way can be used to drive both farm and non-farm investment and has been found to trigger labor productivity and income (Field & Torero, 2005). This link has become a key argument for the role of land security in promoting development (Besley, 1995). However, there is mixed evidence on the impact of land titling programs on access to formal credit (Deininger & Chamorro, 2004; Galiani & Schargrodsky, 2010; Zegarra et al., 2008). In addition, those studies that have found empirical support for this relationship frequently qualify their findings in several ways. In particular, these evaluations of land titling programs highlight impact heterogeneity and the importance of the implementation approach (Mushinski, 1999; Dower & Potamites, 2005). Taken together, the findings of these studies suggest that credit markets thrive within a plethora of enabling factors, of which land titling, and thus the ability to use real estate as collateral, is an important, but not the sole driver to access to credit. The fact that we find no evidence that titling increases borrowing is consistent with the lessons of this literature.

The most basic economic argument linking land tenure security, investment and agricultural productivity is the possibility that the land, and any investments sunk into it, may be expropriated. This possibility acts like a tax on investment and reduces the incentive to invest. Ali, Deininger & Goldstein (2014), for example, find that a pilot regularization land program had large impacts on investment and maintenance of soil conservation measures in Rwanda. Jacoby et al. (2002); Hornbeck (2010) and Galiani and Schargrodsky (2010) provide other important examples of this mechanism. In contrast, we show that there is no evidence that land registration in Ghana and the associated increase in tenure security increases investment in agriculture; instead, we find that *nonfarm* investments increase in households provided with land titles.

Field (2007) documented important labor supply effects of improved land property rights as time otherwise used to "guard" property against expropriation in urban Peru. Goldstein et al. (2018) find that women farmers respond to a land formalization program by moving production away from relatively secure towards less secure land in order to guard those parcels.

Land tenure rights that are based on land use are at the heart of our analysis. Cultivators maintain usufruct rights over land only by continuing to cultivate that land; otherwise land might be expropriated without compensation. This generates an incentive to cultivate more land, with more investment, than a farmer otherwise would. Exogenous improvements in tenure security may reduce the need for the cultivator to make these defensive investments. This argument is parallel to that made by Giles and Mu (2014) and Zhao (2014), who describe periodic land reallocations in Chinese villages based on the recent history of each resident family's land use, and with that of De Janvry et al. (2015), who describe a similar process in Mexican *ejidos*. In both cases, expected future landholdings increase with the amount of land currently self-cultivated, and with the intensity of own-labor used on that land. And in both cases, off-farm labor and migration are discouraged by the insecurity of land tenure. Our findings are consistent with the idea that the security of a farmer's tenure over land are endogenous to her cultivation choices, and thus that she might have an incentive to use extra resources in cultivation to reduce the chance of expropriation.

The context of the title registration pilot is important. While most studies that investigate the effects of land titling concentrate on either rural or urban households, this study builds on data collected in a peri-urban setting. That is, in the study location there is considerable competition among alternative land uses: agricultural, commercial and residential. The increasing rate of urbanization of our study location over the duration of the evaluation period – the study site is located on the outskirts of Accra, Ghana's rapidly growing capital and commercial center – presents its inhabitants with changes to their local economy that challenge existing structures and institutions but also provides new opportunities in terms of income generation. Finally, the data set on which this study builds has gender-disaggregated information on plot ownership and thus identifies which plots are controlled by men or women in the study households. This allows us to examine the gender-disaggregated impacts of land titling on investment and credit.

The remainder of this paper is organized into five sections. Section 2 presents background information on land tenure in the Ghanaian context and on the implementation arrangements of the MiDA Land Titling Project. In Section 3, we present the theoretical framework that guides our empirical analysis. The program, our data and the regression model we use are explained in more detail in Section 4. Section 5 discusses our estimates of the impact of the land titling project on tenure security, investment, economic activity and measures of household welfare. Finally, Section 6 provides the concluding remarks and discusses potential avenues for future work.

2. Land Tenure in Ghana

In Ghana, land is categorized into four different types: stool, family, state-owned and freehold. Stool and family land constitute about 78 percent of all land while state-owned and freehold land form the remaining 20 percent and 2 percent respectively (Deininger, 2003; Kuntu-Mensah, 2006; Awuah et al., 2013). With regards to stool and family land, the Ghanaian legal framework allows for customary freehold, stranger usufruct rights, sharecropping and leasehold of less than 100 years to be held by individuals. The Ghanaian Land Title Registration Act of 1985 specifically permits these rights to be formally registered so that any interests held by individuals on any parcel of land can be protected (Sittie, 2006).[2] However, poor record keeping emanating from the oral nature of transactions associated with land controlled by stools and families,[3] process complexities as well as other bureaucratic hurdles inhibited title registration in the past. Additionally, the monetary cost of titling land is relatively high and often connected with extensive time lags (Awuah et al., 2013).[4]

Population growth, urbanization and expansion of commercial agriculture over the past decades have increased land scarcity in Ghana. These developments pose challenges to the traditional way in which land ownership and land use rights have been managed even in the face of the regulatory advances discussed above. Traditionally, chiefs oversaw the allocation of land to ensure equity in access to land among members of the group (usually defined by descent) with rights to that land (Udry, 2010; Onoma, 2010). The allocative mechanism is an important resource for traditional leaders, and the allocations can reflect their political interests (Acemoglu, Reed & Robinson 2014). These include a mix of patronage, the imperative to satisfy claims that are seen as legitimate by important

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[2] While intended to ease the land registration process, the Land Title Registration Act from 1985 was not a dramatic deviation from prevailing practices and, instead, was intended to address the weaknesses of land related laws. Prior to the act (and the accompanying law: PNDC Law 152), there already existed legal instruments which supported deeds registration in Ghana (Zevenbergen, 1998). The operation of the deeds registry helped to identify transactions related to land but failed to confer title on the individual who held the deed. Cadastral maps which accompanied such deeds were also frequently inaccurate or, in some instances, not required and thus missing (Kuntu-Mensah, 2006). Therefore, the system failed to address the issues of multiple claims to the same parcel of land.

[3] To improve efficiency of record keeping within the customary system (stool and family lands) the Customary Land Secretariat was established in 2004 with 38 branches throughout the country. Although potentially beneficial the state of operation of the various branches have been mixed – some functioning fully whilst others are yet to take off.

[4] To address these challenges, legislative reforms were initiated in 1987. More specifically, these reforms were meant to introduce a system that allowed the registration of land titles across the country in a stepwise manner. This system was designed to operate side by side with the deeds registration processes that were already in place. Naturally, the main objective of the title registration system was to confer title to the holders of the certificate and assure the holders that in times of any threat to their rights, the government will ensure that they are protected. Any title issued under this law could only be nullified by a court of law (Sittie, 2006).

constituencies, and minimizing the number of idle parcels. But land is "subject to multiple, overlapping claims and ongoing debate over these claims' legitimacy and their implications for land use" (Berry, 2001). Consequently, disputes are common over both who has a right to a particular plot, and even who has the right to allocate that plot. Without a central registry, there are frequent instances, especially in urban and peri-urban areas, where land is rented, sold or allocated land multiple times to different people. Of course, such practices can create an array of conflicts, disputes and ownership insecurity, as for example shown in Kuntu-Mensah (2006), which have resulted in frequent litigation (Aryeetey & Udry, 2010). As noted by Jones-Casey & Knox (2011), the Ghanaian courts were clogged with 35,000 land disputes in 2006.

Given the lack of clear land rights, it is not surprising that investment in housing provision and mortgage markets has been inhibited. In 2010 for example when the housing stock deficit stood at 1,200,000 houses, only 199,000 units of houses were built (Afrane et al., 2016). In the wider international context, tenure insecurity particularly discourages investments by multinational companies in Ghana and thus the national economy forgoes potential positive effects from additional job creation and technology transfer (Barthel et al, 2011).

Amid this complexity, however, a cultivator's rights over her growing crops, on the other hand, are quite secure. Plots are virtually never lost while under cultivation; the 2018 wave of the ISSER-Northwestern-Yale Ghana Panel Survey (GPRL, 2019) reveals only two instances among 5,366 plots in which disputed tenure caused interference with cultivation. Historian Ivor Wilks (1993) summarizes the principle as "the cultivated farm is my property, the land is the stool's". This feature of the property rights system creates an incentive for farmers to use (or appear to be using) their land. Goldstein & Udry (2008) show that individuals, especially women, forsake fallowing on insecure land. Since fallowing is a key input for soil fertility, this has significant costs for productivity. They estimate that for maize and cassava farms alone, this represents a loss equal to around 1 percent of GDP.

3. Model

As described above, Besley & Ghatak (2010) provide a thoughtful overview of the pathways through which insecure land tenure might reduce agricultural productivity, distort household decisions and reduce welfare. The most basic of these is the fact that the expropriation risk generated by insecure tenure reduces incentives to invest. In addition, cultivators may divert resources to protect their property rights ("guard labor"). Insecure rights over land might also reduce its usefulness as collateral and thereby limit access to credit. And insecure property rights may be a source of friction that inhibits the land transactions. The model used by Besley & Ghatak (2010) to clarify their discussion suits that purpose admirably but matches poorly to the institutional setting of this study.

As noted above, in the context of our study area, there is little risk of the expropriation before harvest after inputs have been applied. Tenure insecurity instead appears in a dynamic context: when land is not immediately used for agricultural production such as if the land is fallowed or when it is rented out. The danger a landholder faces is that if she utilizes the land for purposes other than cultivating it herself, the land might be reallocated away from her. This could take the form of expropriation of the whole plot or redrawing of (not well defined) boundaries by a neighbor. This risk, in turn, could have multiple ramifications for the organization of economic activity and for productivity of both agricultural and non-agricultural activities.

We concentrate on the allocation of production between farm and non-farm enterprises, the most dynamic margin of adjustment in this rapidly urbanizing environment. Consider a landowner who allocates her (inelastically supplied) labor to two activities: farm labor (e_f) and non-farm enterprise (e_n).[5] We normalize the labor endowment to 1. Land is allocated to either agricultural production or an alternative, non-farm use. At time t, the farmer controls T_t units of land, which she can choose to allocate to her own farm production or to rental. Imperfect land security in this area manifests as uncertainty over the evolution of T over time, perhaps depending upon this rental decision. Next period's landholding is a random variable

$$T_{t+1} \sim G(T; T_t, L_t, \omega) \tag{1}$$

drawn from the distribution $G(\cdot)$, which depends on tenure security, which we index by ω.

We suppose that utility is linear in consumption, to abstract away from risk aversion and any income effects. We also assume that capital is freely available at interest rate ρ, shutting down possible effects of tenure security on productivity via improved access to capital. The cultivator's problem, therefore, is to maximize the expected present discounted value of farm plus non-farm profits:

$$E_t \sum_{\tau=t}^{\infty} \left(\frac{1}{1+\rho}\right)^{\tau} \Big(A_f(x_{ft}) L_t^{\alpha} (e_{ft})^{\beta} + A_n(x_{nt})(e_{nt})^{\beta} - (1+\rho)(x_{ft} + x_{nt}) + r(T_t - L_t) \Big) \tag{2}$$

[5] This generalizes trivially to a model with leisure as a good. However, perfect markets for labor would generate a "separation" result breaking the interactions between decisions regarding farm and nonfarm activities.

$A_f(x_{ft})$ is the productivity of the cultivator's farm, which is enhanced via purchased farm inputs (which might include hired labor), with $A_f'(x_{ft}) > 0, A_f''(x_{ft}) < 0$. Similarly, $A_n(x_{nt})$ is the productivity of the non-farm enterprise, with $A_n'(x_{nt}) > 0, A_n''(x_{nt}) < 0$.[6]

We are interested in the cultivator's decision to allocate her time across farm and non-farm activities; she may choose to rent out some of her land as part of that allocation decision. Suppose at time t she chooses to cultivate $L \leq T_t$. Conditional on this choice of the proportion of land under cultivation, the cultivator chooses $e_n = (1 - e_f)$ and purchased inputs x_n and x_f to maximize current profits

$$\pi(L) = \max_{e_n, x_f, x_n} A_f(x_f)L^{\alpha}(1-e_n)^{\beta} + A_n(x_n)(e_n)^{\beta} - (1+\rho)(x_f + x_n) \tag{3}$$

Motivated by the observation that cultivated land is secure, the important assumption in (2) is that land tenure insecurity plays no direct role in the static problem. Nevertheless, we show that insecurity endogenously generates inefficient reallocations that are similar to guard labor.

Given a cultivator's choice of $L \leq T_t$ at any period, capital into farm and nonfarm enterprise satisfy

$$\begin{aligned} A_f' &= \frac{(1+\rho)}{L^{\alpha}(1-e_n)^{\beta}} \\ A_n' &= \frac{1+\rho}{(e_n)^{\beta}} \end{aligned} \tag{4}$$

For the cultivator's labor,

$$e_n = \frac{(A_n)^{\frac{1}{1-\beta}}}{(A_f L^{\alpha})^{\frac{1}{1-\beta}} + (A_n)^{\frac{1}{1-\beta}}}. \tag{5}$$

The implicit function theorem implies we can use (4) and (5) to write labor and capital inputs as continuous and differentiable functions of cultivated land, $e_f(L), e_n(L), x_f(L)$ and $x_n(L)$ with

$$\begin{aligned} \frac{de_n}{dL} &\equiv -\frac{de_f}{dL} < 0 \\ \frac{dx_n}{dL} &< 0 \\ \frac{dx_f}{dL} &> 0. \end{aligned} \tag{6}$$

[6] The functions $A_f(.)$ and $A_n(.)$ vary across agents. In addition, the model easily accommodates unanticipated variation in these productivities over time for a given agent. We set the Cobb-Douglas coefficients for farm and nonfarm work to be equal to simplify algebra below, but this is also simple to generalize.

Prediction 1: Quite intuitively, agricultural labor and the use of agricultural inputs increase with the amount of land used for cultivation. Labor not used for agricultural production is allocated to non-farm enterprises. The complementarity between labor and capital use implies that the use of capital in the non-farm enterprise declines as more land is used for cultivation.

Capital and labor are complements in both sectors. For any choice of land cultivated, maximized joint farm and nonfarm profits this period are given by the function

$$\pi(L) = A_f\big(x_f(L)\big)L^{\alpha}(1 - e_n(L))^{\beta} + A_n(x_n(L))(e_n(L))^{\beta} - (1+\rho)\Big(x_f(L) + x_n(L)\Big) \tag{3}$$

The choice of how much land to cultivate is determined by balancing the returns from cultivation described in (3) against the returns generated from alternative, non-farm use such as fallowing or renting out land. Tenure insecurity emerges as a consideration in this decision, because land that is not used by the cultivator for current agricultural production can be contested. And the decision to not cultivate land can lead to its expropriation and reallocation. Let ω in equation (1) be the probability of losing land not cultivated in any period. Therefore, land holdings evolve over time according to

$$T_{t+1} = T_t - \omega(T_t - L_t) \tag{4}$$

The choice to not cultivate a part of the land is dynamic because with probability ω it will be expropriated and reallocated by local land authorities to other community members (or kept by the chief or family head). The choice of how much land to cultivate is determined by the recursive program

$$V(T_t) = \max_{L} \pi(L) + r(T_t - L) + \frac{1}{1+\rho}\ V\big(T_t - \omega(T_t - L)\big). \tag{5}$$

So, the farmer cultivates land up to the point

$$\pi'(L) = r - \frac{1}{1+\rho}\omega V'(T) \tag{6}$$

and using the envelope theorem,

$$\pi'(L) = r\frac{\rho}{\rho + \omega} \tag{7}$$

If tenure is fully secure, the farmer cultivates up to the point at which the marginal value product of land equals the return rate $r > 0$ that is obtained from non-farm use. But insecure tenure induces her to cultivate additional land, driving the marginal value product of land lower. The cultivator with insecure property rights cultivates more land, uses more labor, and applies more capital to her farm than would be efficient in a static equilibrium. These extra resources devoted to cultivation are "guard" labor and capital.

The effect of better land tenure security is straightforward:

$$\frac{dL}{d\omega} = \frac{-r\rho}{\pi''(L)(\rho + \omega)^2} > 0$$

Prediction 2: As expropriation risk decreases, farmers will decrease the amount of land dedicated to cultivation. Consequently, labor and capital used on their farms will decline, and labor and capital used in their non-farm enterprises will increase.

Land tenure security has no direct effect on the static allocation of inputs on a given farm. There is no direct guard labor, for example, protecting a farmer's right to cultivate. However, the dynamic uncertainty that tenure insecurity creates when land is not cultivated induces the farmer to keep more land under cultivation than would be efficient. Given that land allocation, the farmer optimally allocates both labor and capital to the farm. This additional demand for labor for cultivation reduces labor use in the non-farm enterprise, and, simultaneously, the use of capital in the non-farm enterprise. Thus, something akin to "guard labor" and "guard capital" emerge endogenously due to tenure insecurity.

We have focused thus far on those who might consider renting out land in the face of tenure insecurity. The demand for rental farmland is generated by farmers who would like to cultivate more land than they control. The demand for rental land depends on tenure security as well. If there is a dispute over the right of the landlord to provide the land to the tenant, the tenant's upfront payment of rent could be lost without the tenant being able to use the land. The tenant's security is derived (imperfectly) from the landlord, so this loss occurs with no less probability than the chance that the landlord loses control over the land forever.

The geographic location of the titling program ensures that there is an elastic demand for rental land determined by profit maximization. These commercial farmers may use a different set of technologies or farm different crops than the local residents in our sample. Let π_c^* be the per acre profit from cultivation achieved by these farmers. A commercial farmer who pays rL to rent land will with probability $1 - \omega'$ be able to cultivate. However, with probability ω' the rental transaction will be disputed and the farmer will lose the upfront rental payment. Then demand is elastic at

$$r = (1 - \omega')\pi_c^*. \tag{8}$$

(8) sets land rents and makes it clear that land value increases as security improves.

Prediction 3: As tenure security increases, the value of land increases.

In what follows, we show that this model is consistent with the observed effects of the pilot Land Titling Program in Ghana.

4. The Land Titling Program, Data and Evaluation Design

4.1 The Land Titling Program

It is noteworthy that although registration of land titles has been enabled in Ghana for nearly three decades, very few land titles have been issued. As of 2006, only 42,000 registration applications had been submitted and of these a mere 30 percent had been granted (Kuntu-Mensah, 2006). This situation suggests that there are impediments preventing progress in Ghana’s attempt to give titles to land owners and users. In the light of this, the Government of Ghana and its development partners have undertaken several interventions in the last decade to remove some of the barriers which are preventing progress and improve the title registration processes (Jones-Casey, 2011). Despite these reforms being undertaken by the government, the lack of transparency and institutional commitment has remained and the system of land administration and registration is still relatively weak. Other private sector participants, NGOs and bilateral partners have also initiated programs to speed up and improve the titling process on pilot bases. Notable among these efforts is the MiDA program that targeted a comprehensive pilot Land Titling Program in the Central Region of Ghana which is at the center of this evaluation (Jones-Casey & Knox, 2011).

The land tenure facilitation project had the objective of improving the security of tenure of land, with the ultimate goal of improving the commercialization of agriculture, among other outcomes. The activities of the project were designed to provide title registration for parcels of land. To support this, the initial activities included a public outreach campaign and dissemination of information on land registration and land laws. In addition, survey teams surveyed individual parcels and produced parcel plans. At the same time, the project tackled the infrastructure, including refurbishing circuit courts and helping them clear the backlog of land cases, as well as building capacity among the staff at the Lands Commission and the judiciary service.

In the Central region the pilot was in the Awutu-Senya (AS) district. Under this program the pilot communities were divided into 2 groups – AS1 and AS2. Even though the ultimate plan was to work towards the certification of land in both groups, it was anticipated that by the end of the compact the groups would have been at different stages in the certification process. In particular it was expected that 2,500 land title certificates would have been secured for the AS1 - group. For the other group- AS2, it was expected that 1,933 parcels of land would have been surveyed and processed up to the parcel plan level, however these activities did not take place during the timeframe covered by this work. By February 2012, MiDA had concluded the registration process for 2,296 parcels of land for the AS1 group, and had issued title certificates for 1,481 (covering 410 hectares). The remaining 815 unfinished cases were to be completed by the Lands Commission of Ghana. In addition to this, plans for 5,729 land parcels, covering 5,039 hectares had been produced.

The nature of the project and the interventions which accompanied this pilot program were aimed at some of the structural barriers to land registration. The fact that the program created a new registration district and an office with modern equipment for land data collection, processing and storage removes some of the bottlenecks associated with previous attempts. The program also created incentive structures to nudge officials to maintain a constant workflow. Finally, the program facilitated negotiations with chiefs and family heads who hold allodial titles to land in order to ensure consent for the issuance of titles.

4.2 Evaluation Design

We build our analysis on three survey waves conducted in 20 communities that are located around a main road that forms a closed circuit. This main road geographically divides many of the sample communities into two halves. This circuit also corresponds to the boundary of the Land Titling Program. Households within the loop were eligible to participate in the pilot while households outside of the loop were not eligible in the first phase of the program which spans our entire evaluation period. The physical demarcation of the road dividing communities into two forms the basis for our empirical evaluation strategy.[7]

More precisely, households located within the loop of the road and not more than 200 meters away from the road are considered as the treatment group in our study. On the other side of the main road, i.e. outside of the loop and outside of the pilot area, we sampled households such that they form two types of control groups: a short-term control group and a long-term control group. At the time of project initiation, it was anticipated that households just outside the loop would be the most likely future recipients of the land registration assistance (although that never materialized). We refer to households outside of the loop but within 200 meters of the road as the short-term control group.[8] Households outside the loop and located more than 500 meters away from the road constitute the long-term control group. For this evaluation we will exclusively focus on a comparison of the treatment group with the short-term control group. The locations of sample household around the road used to distinguish between treatment and control households are also shown in Appendix Figure A1.

[7] Investigations at the start of our evaluation indicated that this division of communities was unintentional, the road was chosen since it gave a clear boundary.

[8] The sample was designed to include every household within 200 meters of the boundary on either side. The 200 meter range was chosen to give us our desired sample size based on the number of households estimated from satellite photographs.

4.3 Data

The household-level panel data for the empirical analysis were collected over a period of five years from households that were targeted by the MiDA land titling pilot intervention as well as those households located just outside the intervention area, i.e. the short-term control group and the long-term control group.

The first of the three surveys waves was collected in 2010; the second in 2011; and the third in 2014.[9,10] Therefore, all three survey waves were collected after the land titling intervention was initiated in 2009. The first two survey waves allow us to understand the short-term effects of the land titling program immediately after program initiation and the third survey wave gives us some insight into medium-term program impacts. Each of the three survey waves comprised of seven survey modules each covering a different dimension of the socio-economic characteristics including: demographic characteristics of sampled households; paid employment engaged in by household members; individual and household assets; agricultural production and land titling; non-farm enterprises; marital history of household heads and spouse(s); and financial literacy training.[11] The survey team also collected data on household and plot locations using GPS.

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[9] During the first round of field survey in 2010, a total of 65 enumerators were trained over a period of six days. Out of this number, 54 enumerators were selected for field work. The selection was based on the outcome of a test conducted to examine enumerator competence with regards to the questionnaire administration. In addition, a language fluency examination was also undertaken to ensure that enumerators had command over the Twi language which was going to be the main medium of communication with respondents. From the set of 54 enumerators, three working teams of 18 members were created. Each team consisted of a supervisor, a field editor, 2 plot mapping experts and 14 enumerators. The supervisor was the team leader and was responsible for overseeing, monitoring and, where necessary, correcting the work of the interviewers and the field editor. The enumerators conduct daily interviews with the head and spouse of sampled households. The plot mapping experts were responsible for demarcating boundaries within which enumeration should be conducted based on the three terms and also to map or take waypoints of plot location (treatment, short term and long Term). A similar strategy was adopted in the second and third rounds of survey.

[10] Although the entire survey in the third round were stipulated to be undertaken in the year 2014, not all the targeted households could be contacted for interviews in 2014. Thus, in the first half of 2015, a tracking exercise was undertaken to mop-up as many households as possible which were missed in the 2014 episode of data collection.

[11] The survey instruments consisted of seven modules that covered (1) seek the household's consent to participate in the data collection exercise and also captures information on the household roster and members; (2) administered to individuals and is designed to gather basic demographic information on household members, on employment and the different sources of income for the male spouse only; (3) designed to collect data on assets owned by the household and individuals within the household - the main sub-sections include tools, durable goods, farm assets, as well as financial assets; (4) collect data on the household's agricultural activities covering agricultural assets such as land, livestock and equipment as well as providing data on agricultural production technology and processing, marketing, input use, output and incomes; (5) designed to gather information on employment, time use and different sources of income for the household head and spouse either as individual owners or jointly owned businesses which are not farm based; (6) the level of financial knowledge among respondents; (7) understand the relations between husband and wife/wives and to study how households in Ghana function.

During the first survey round in 2010 (R1), a sample of 2,450 households was interviewed which represents households from the treatment (790), short-term control (862) and long-term control (798) groups. The second survey round in 2011 (R2) reached a total of 2,099 households in the treatment (693), short-term control (724) and long-term control (682) groups. Finally, the third and last survey round was collected in 2014 (R3) and a total of 1,714 households were traced in the treatment (553), short term control (619) and long-term control (542) groups.

Panel A of Table 1 presents these sample frequencies of households by treatment status and survey round. The treatment and short-term panel households shown in the lower part of the panel form the core part of data during the impact analysis. Panel B shows the corresponding figures for the plots.

Between round 1 and round 2, 351 households representing about 14 percent of the original sample could not be reached. Furthermore, between round 1 and round 3, a total of 736 households which represented about 30 percent of the initial sample could not be tracked. This resulted in a one-year and four-year tracking rate of above 85 percent and 70 percent respectively.

Next, we examine whether specific household characteristics as well as the treatment status are important determinants of attrition. To do this we create a dummy variable for attrition which equals 1 if the household drops out from the panel (does attrit between Round 1 and Round 2/3) and 0 otherwise. We regress this dummy variable on combinations of the household characteristics and the treatment status. In Table 2, we present estimates from OLS regressions in Columns 1 and 2 as well as 4 and 5 and estimates of the marginal effect from a Probit regression in Columns 3 and 6.

Based on the estimates in Table 2, we see that between survey round 1 and round 2, treatment households have a 1 to 2 percentage point (pp) lower probability to drop out of the panel between survey rounds 1 and 2. Contrary to this, treatment households are about 3pp more likely to attrit between rounds 1 and 3.

4.4 Empirical Approach

Our empirical strategy is based on the natural experiment generated by the allocation of households into treatment and control by their location on one side or the other of the main road that divides the communities in our sample into two halves. We use this physical boundary as the assignment rule that separates the treatment (those who were eligible for the pilot land titling intervention) from our control group (those who were not eligible) and forms the basis for our RDD estimation approach. The key identifying assumption that we maintain to justify our estimation strategy is that, conditional on chiefdom fixed effects, unobserved determinants of the outcomes are on average the same for households on either side of the road. It is worth noting that the road was used as a convenient but otherwise arbitrary boundary to delineate an area in which to pilot this systematic land title registration intervention. Indeed, as program implementation started, it was discovered that the dwellings of a significant number of chiefs of the study villages were located in the control group area. In addition, we concentrate on the sample of households located closest to the road, i.e. households located within a 200 meter bandwidth on either side of the road.

Table 3 compares basic demographic characteristics measured in round 1 between households in the treatment group and households in the control group. As a reminder, round 1 was collected just after program implementation had commenced. Hence, we focus on variables that are very unlikely to be immediately impacted by the program. These variables will also form part of the set of controls we use during the main analysis. As Table 3 indicates, all variables except the number of female household members are well balanced between the groups. This finding provides us with confidence that the boundary choice that separates treatment from control does not capture any systematic differences between the two groups other than their eligibility status to participate in the land titling pilot.

We also include chiefdom fixed effects in all specifications, thus limiting comparisons of outcomes to households on either side of the road within a community that shares the same institutional characteristics on the local level. Appendix Figure A1 makes the identification assumption clear. The household clusters that can be seen in the figure generally correspond to communities which are scattered around the main road that serves as the project boundary. We compare outcomes of households within one of the chiefdoms, which comprise of several communities, and inside the boundary with those of other households in the same chiefdom but located outside the boundary. These OLS fixed-effects estimates present the most robust impact estimates in our view.

The measurement of fields and demarcation was intended to be comprehensive. However, households could elect not to collect their certificate. In addition, not all households or individuals who possessed land in the treatment area were able to negotiate approval for the titling process with local authorities such as chiefs. There were others whose claim to the land did not exceed the minimum of three years required before certificates could be issued. It also seems unlikely that all the households in the treatment group with eligible claims and willing to participate in the pilot were able to finalize the titling process by the time of the last survey round. Given that these issues are likely to involve significant degrees of endogeneity, we will focus on estimating intention-to-treat (ITT) impacts.

Ordinary Least Squares (OLS)

Our basic OLS specification to examine the impact of the land titling pilot on the outcome variable y_{ijt} for household or individual i in chiefdom j at time t is:

$$y_{ijt} = \beta X_{ij0} + \sum_{t=1}^{3}(\tau_t treat_i * time_t + \mu_t time_t) + \theta V_j + \varepsilon_{ijt}$$

Where X_{ij0} denotes our basic set of control variables consisting of socio-economic characteristics of the household measured in round 1.[12] $treat_i$ is an indicator variable that equals one if the household is located in the treatment area demarcated by the main road dividing each community. $time_t$ represents a dummy variable indicating the survey round in which the observation is measured. Finally, V_j is a vector of chiefdom dummy variables that will control for local, time-invariant effects. At the center of our interest, of course, is τ_t which denotes the coefficient that measures the ITT impacts of the MiDA Land Titling Pilot for each survey round separately. The standard errors are clustered by village. We also estimate pooled impacts which capture the averaged impacts over the three time periods marked by our surveys.

Spatial Autoregressive Regression (SAR)

It is possible, however, that even within a single community, households which are closer to one another in geographical terms face similar geographically determined conditions and shocks. Thus, clusters of households are potentially affected by the same (unobservable) influence factors. Hence, for robustness, and in order to address these potential local correlations, and improve estimation efficiency we use a spatial autoregressive (SAR) estimation specification as a robustness check for our main impact estimates for variables measured at the household level and where the GPS data are available. Moreover, there may be omitted variables which are correlated within neighborhoods.

The first step of our second approach is to define the nature of expected spatial interdependencies among households. There can be three different interaction effects: (i) endogenous - where the dependent variable of one household depends on the dependent variable of another and vice versa; (ii) exogenous - where the dependent variable of a unit depends on the independent variable of other units; and (iii) interactions are among the error terms of nearby units. In our present analyses we concentrate on the first type of interactions that takes into account potential spill overs or correlated shocks in outcome variables as a result of proximity between households.

The SAR is based on the OLS specification in equation (1) and introduces an additional term which accounts for endogeneity among outcomes of spatially distributed households based on their proximities with the use of a spatial weights matrix. Equation (1) becomes:

[12] More specifically, the baseline control variables include household size, number of female household members, number of householder member aged 5 or younger, an indicator for male household head, the age of the household head and whether the household has ever attended any school.

$$y_{ijt} = \sum_{s=1}^{N} \rho w_{is} y_{sjt} + \beta X_{ij_0} + \sum_{t=1}^{3} (\tau_t treat_i * time_t + \mu_t time_t) + \theta V_j + \varepsilon_{ist}$$

Where all variables are defined as before except w_{ij} which are elements of a spatial weight matrix W, which forms together with the y_{sjt} the endogenous interaction effects. W is an N by N inverse distance matrix or an inverse distance matrix with a certain cut-off point.[13] ρ is referred to as the spatial autoregressive coefficient and, essentially, our model would reduce to an OLS if ρ were to equal zero.

When estimating equations (1) and (2) we limit the sample to households to those located in a 200 meter band to the main road. This sub-sample is further refined by exclusively focusing on panel households. Panel households are those households which we observe in all three survey rounds.

5. Results

In this section we present our main results. Many outcome variables are measured at the household level. However, several of these outcomes are also reported separately by different individuals within households which allows us to explore gender-differentiated impacts. In Tables 4 to 13 we present the main impact estimates for the Land Titling Program. All tables follow a similar format. Column 1 provides the sample size for the pooled regression and Column 2 the mean of the dependent or outcome variable of interest in the control group for the third survey round. Columns 3 to 5 report the estimates for each survey round separately which correspond to the coefficients on the interaction terms in Equation 1. Column 6 reports the estimates from the pooled regression and Columns 9 to 11 show the results from estimating the SAR regression model on those respondents for whom household-level GPS data were available.[14]

We start our examination of impacts with the most proximate indicator that the program might be working: individuals reporting that the land was registered and their perceptions of security. Table 4 shows these variables. Land in the treatment area is significantly more likely to be reported as registered by the respondents, and this coefficient increases across our three rounds for women. Although it is hard to capture in quantitative data, there is some suggestion that perceptions of security have also improved. A significant fraction of both men and women are worried that they will lose their plot if they leave it fallow (about a third in the control group in round 3). For men we see significant reductions of this for the pooled estimate, although this effect may have tapered off by the

[13] The distance decay can also be formulated as a power function and the elements of W matrix can be inverse distances with a distance decay factor, γ, $\emptyset = \frac{1}{d_{ij}}$, where d_{ij} denotes the distance between units i and j.

[14] The GPS measurements of plots in our data are incomplete and, as mentioned above, we rely on a repeated cross section of plot-level data. Therefore, we only present SAR estimates for household- or individual-level regressions where we are using the location of the dwelling as the geographic coordinates. We do not estimate SAR regressions for plot-level outcome variables.

third round. For women we only see real movement on this variable in the third round (and then only significant at the 10 percent level) where there is 7.4 percentage point decline.

Before turning to the predictions of our model, we examine what is commonly cited as the main justification for improving tenure security: that it will lead to increased investment. In Table 5 we look at investments in soil fertility and planting of trees. Based on the mean values in the control group the two most common investments are fallowing and planting trees. Overall, we find very little indication of increased land fallowing for both men and women (men show a *decrease* in fallowing in round 2, but this does not persist). In terms of investment in trees, women show positive and fairly consistent effects in all three rounds, and the pooled estimates indicates a 4.4 percentage point increase (significant at 10 percent). However, this result is not robust to our SAR specification.

Two significantly less common forms of investment (less than 1 percent in the control group) are soil and irrigation improvements. We find some very small effects here. Women show higher soil investment in round 2, but this does not persist in round three. Men show a significant increase in irrigation investment in round 3, but it is very small.

We next turn to some of the predictions of our model. We start with the overall scope of agricultural activities by looking at land holdings in tables 6, 7 and 8. Table 6 looks at all land and the manner of acquisition. Since we do not have a panel of plots, we use a repeated cross-section of fields reported by our panel households in each of the survey rounds. This data provides insight into potential changes through which market or non-market transactions land was acquired. For women, we see a sharp increase in the probability that a parcel was purchased: this increases by 7.5pp in our pooled estimates, roughly a 35 percent increase relative to the round 3 control mean. This seems to be replacing sharecropping as a mode of acquisition, which drops by 3.6pp in our pooled estimates (significant at 10 percent), with a particularly sharp drop in round 3. For men, we also see a significant increase in purchases of 7.1pp, with declines not only in sharecropping, but renting as well (the latter significant at 10 percent). Taken together, these results suggest that both men and women are taking advantage of the clarification of property rights that certification provides to move from rental contracts of various forms to land purchases. It is also worth noting that there is a significant increase of 10 percentage points, in round 3, in the acquisition of land through inheritance for men.

In Table 7, Panel A we examine how improved security translates into changes in overall landholdings controlled by women and men. Since we do not have a plot panel, we cannot accurately measure sales, but the overall level of holdings reveal a significant amount of land being released. Women reduce their number of plots in the pooled estimates by 0.068, with the largest reduction happening in round 3. They also end up having significantly smaller plots, a reduction of about 0.14 hectares using the round 3 estimates. Putting these two measures together at the owner level, we can see a reduction in aggregate individual land holdings of about a quarter of a hectare in round 3.

Against this, treated female respondents report significantly higher land values (another prediction of our model), which could be due to the increased purchase activity in the treatment area or just the increased value that comes with certification. From Table 7, we can see that these values increase by 11,065 cedis in our pooled estimates or 26 percent of the round 3 mean.[15]

On average, men have close to double the number of parcels that women have. The treatment effects, however, play out in a similar fashion. We see a significant decline in the number of parcels by 0.103 when we combine all three rounds. The size of the average plot held by men drops by 0.097 hectares in our pooled estimate, and the aggregate land holdings (at the individual levels) drops by 0.192 hectares. In terms of value, men also report an increase in value per hectare, although the results are statistically weaker than for women. In table 7 we can see that for round three, men report an increase of 19,385 hectares, but this is significant only at the ten percent level. The pooled estimate is similar to the female coefficient, but not statistically significant at conventional levels.

Table 8 gives us further insight into the changes in land holding portfolios. Recall from Table 6 that there was a reduction in land acquired through sharecropping and renting (for men) with an increase in purchases. Table 8 focuses solely on land owned, which we define here as inherited or purchased. In the pooled estimates, we do not see a significant change in the number of parcels individuals own. This is the same for men and women, but the time path for women is worth noting. After an initial increase (significant at 10 percent) in round 1, there is a decline (again only significant at 10 percent) in round 3. This could be consistent with women selling some of their accumulated land as they move more into business. It is to these production choices that we now turn.

Recall that our model predicts not only a decline in the land being used by individuals, but also a decline in labor and purchased inputs as well. We start with an examination of overall production in Table 9. In panel A we can see a significant decline in the total value of harvest on land controlled by women in all three rounds, with a magnitude of around 75 percent of the control group mean in round 3. The model implies that per hectare output and inputs change less than total output or inputs, because the area cultivated falls. The point estimate of the effect of the program on output per hectare on women's plots is large and negative but not significantly different from zero in any of the rounds or in our pooled estimate. The point estimate of the effect of the treatment on output on the plots of men is negative, and similar in magnitude to the effect on women's plots, but not significantly different from zero, nor is there any significant change in the per acre value of harvest.

Table 10 looks at the labor use on male and female plots. We asked the respondents to report the hours by main activities during the last season and so we report here for four main activities. These activities follow each other sequentially: land preparation, field management, harvesting and post-

[15] In mid-2010, US$1 was worth about 1.4 Ghanaian cedis, in mid-2011 about 1.5 cedis and in mid-2014 about 3.3 cedis.

harvest activities. For women, we see a significant decline in labor devoted to land preparation, with a pooled estimate of a 23.2 hour decline (or 54 percent in round 3). We also see a decline of 28.9 hours in field management (or a 23 percent decline in round 3). The other activities show no significant decline in the pooled estimates but do (at the 10 percent level) in round 3. This pattern is of decline in labor use at all stages is consistent with the model's implication that labor is being withdrawn from cultivation as tenure security improves.

For men as well, we see sizable and significant declines in labor for all four major activities in the pooled estimates. It is apparent that labor is being withdrawn from cultivation activities by men who are in the treatment group. There is a particularly large decline in land preparation activities during the early period of the season when current cultivation is being established, often from fallow land. This is the period of the agricultural cycle in which tenure rights are least secure and boundaries are least well-established, as without crops boundaries (and land use overall) are not as clear. There may be an element of direct guard labor associated with this early season activity that becomes less imperative as tenure security increases.

The second parts of panels A and B of table 10 look at male and female labor per hectare. Consistent with the model, there is relatively little change in labor per hectare on the plots of men or women at any stage of production.

Since both men and women are reducing their labor inputs in agriculture by fairly significant amounts, the question is whether they re-allocate their time to other income generating activities. Table 11 provides some indication. While we do not have hours worked in enterprises, we can see an increase in enterprise activity as measured by the engagement in off-farm businesses and profits. For women, we can see that they are significantly more likely to be engaged in off-farm work by 10.4pp in our pooled estimates. Conditional on being involved in enterprises, they also experience higher profits, with the increase starting in round 2. The pooled impact estimate is fairly large and significant. The treatment group reports a 98 cedis increase in monthly profits against a round 3 control mean of 75 cedis (conditional on operating a business). For men, there is no effect at the extensive margin and the effect in profits is significant and large in round three only – our pooled impacts are not significant. Putting the agriculture and the enterprise results together suggests that as land tenure security improves, labor is being reallocated from agriculture to nonfarm activities with relatively high returns, particularly for women.

One of the channels through which secure property rights can affect owners' behavior laid out in Besley & Ghatak (2010) is related to access to credit. The supposition here is that registered land can be used to collateralize loans. While Ghana has a growing mortgage market, this is largely confined to urban areas and high value rural parcels. Hence, it is not surprising that we see none of our respondents taking a mortgage. Table 12 presents results for borrowing.[16] For both men and women there is no significant change in the likelihood that that they had a complete loan in the last 12 months. However, there are some changes in the amount of borrowing they have outstanding. For women, there is a decline in round 2 (significant at 10 percent) and an increase in round 3 (also significant at 10 percent). This is consistent with the growth in business profits we see over these two rounds. For men, the increase in borrowing is only present in round 3, where we see an increase that is about one-third of the mean in the control group. As for women, this is consistent with the increase in business activity for men during that time. Thus, while we see some credit effect here, it is likely a by-product of the increase in enterprise activity, rather than a direct effect of the ability to use land as collateral.

Given the increase in income, we now turn to a measure of household welfare. We do not have consumption data, so we rely instead on individual assets. Table 13 shows the asset positions. For women, we can see a significant decrease of 27.2 cedis in their livestock holdings in the pooled estimates or a 30 percent decline using the round 3 estimates. This is more than offset by a (pooled) 78 cedis increase in their individually owned durable goods, which is driven almost entirely by a large 219 cedis increase in round 3. Men, on the other hand, have a significant increase of 220 cedis in the value of their livestock holdings in round 3, but the pooled estimates are not significant (likely due to a decline in livestock in round 1). For individually owned durable goods, men have a significant increase of 227 cedis in our pooled estimates, or a 48 percent increase using the round 3 estimates (which are driving this result). Thus, by the end of round 3, both men and women are experiencing a large and meaningful increase in their non-land wealth.

6. Conclusion

Secure land tenure is often considered a key to smallholder farmers' willingness to invest and their ability to allocate resources more efficiently. In this paper, we use a simple model that captures essential institutional features of rural land markets in Ghana, which is applicable to contexts elsewhere. In particular, our theoretic framework model introduces tenure insecurity in a dynamic context. More precisely, when land is not immediately used for agricultural production such as if the land is fallowed or when it is rented out, tenure insecurity is the highest, which may ultimately result in the land being reallocated away from the farmer. We used this model to derive predictions to guide our evaluation of a pilot land titling intervention that took place in an urbanizing area located in the Central Region of Ghana.

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[16] Results (not shown here) on lending are, for the most part, not significant.

Using a regression discontinuity design combined with three rounds of household survey data collected over a period of six years, we find strong markers for the program's success in registering land in the targeted program area. Land registration, however, does not translate into agricultural investments or increased credit taking. Instead, treated households decrease their amount of agricultural labor, accompanied by only a small reduction of agricultural production and no changes to productivity. In line with this result, we observe that households decrease their sharecropped land holdings amid a surge in land valuations. The analysis also uncovers important within-household differences in how women and men respond differentially to the program. There appears to be a general shift to non-farm economic activities, and in particular women's business profits increase considerably.

Our results show that one key channel through which secure land rights can improve smallholders' welfare is through gains in allocative efficiency of productive resources. Resources, in the form of land and labor, spent on agricultural production are reduced and switched (especially for women) into non-farm enterprises. Combined with the increase in household wealth, this evidence provides a suggestion that improvements in land security through land registration may contribute to structural transformation.

Table 1: Unbalanced and Balanced Household/Plot Samples by Treatment and Survey Wave

Round	Treatment	Short-Term Control	Long-Term Control	Total
Panel A: Households				
		All		
Round 1 (2010)	790	862	798	2,450
Round 2 (2011)	693	724	682	2,099
Round 3 (2014/15)	553	619	542	1,714
Total observations	2,036	2,205	2,022	6,263
		Panel		
Over all three rounds	549	615	542	1,706
Total observations	1,647	1,845	1,626	5,118
Panel B: Plots				
		All		
Round 1 (2010)	1,130	1,299	1,149	3,578
Round 2 (2011)	1,185	1,314	1,247	3,746
Round 3 (2014/15)	984	1,150	990	3,124
Total observations	3,299	3,763	3,386	10,448

Table 2: Determinants of Attrition between R1 and R2/R3
Coefficients (marginal effects), standard errors in parentheses

	Respondent attrited between 2010 and 2011 [yes=1]			Respondent attrited between 2010 and 2014 [yes=1]		
	OLS		Probit	OLS		Probit
	(1)	(2)	(3)	(4)	(5)	(6)
Treatment	-.01**	-.02**	-.02**	.030**	.030***	.030**
	(.007)	(.007)	(.007)	(.010)	(.010)	(.010)
Number of household members		-.005	-.005		-.020***	-.020***
		(.003)	(.004)		(.006)	(.006)
Number of female household members		.0008	.0008		.009	.009
		(.005)	(.005)		(.008)	(.008)
Number of household members (below 5years)		.0004	.0001		.007	.008
		(.006)	(.006)		(.009)	(.009)
Male household head [yes=1]		.004	.003		-.001	-.001
		(.009)	(.009)		(.010)	(.010)
Age of household head		.0006**	.0006**		-.002***	-.002***
		(.0003)	(.0002)		(.0004)	(.0004)
Household head attended any school [yes=1]		.010	.010		-.040***	-.040***
		(.008)	(.008)		(.010)	(.01)
Constant	.06***	.04***		.200***	.300***	
	(.005)	(.02)		(.008)	(0.03)	
Observations	4,240	4,234	4,234	4,240	4,234	4,234
Sample	T, ST	T, ST	T, ST	T, ST	T, ST	T, ST
R-squared	.006	0.004		.001	.015	

Notes: *** denotes significance at 1% level; ** at 5%; and * at 10%. The dependent variable is a dummy that is equal to 1 if a household attrit between the baseline and follow-up surveys and 0 otherwise. We report marginal effects for the Probit model. The standard errors in parenthesis are clustered by community.

Table 3: Mean Comparisons of Control Variables measure in R1, Panel Households
Means, coefficients standard errors in parentheses

Variable	N	Treatment mean	Control	Difference
Number of household members	1,057	3.42	3.15	.274
				(.158)
Number of female household members	1,057	1.81	1.66	.152*
				(.080)
Number of household members (below 5 years of age)	1,057	.505	.435	.070
				(.041)
Male household head [yes=1]	1,057	.571	.567	.004
				(.031)
Age of household head	1,057	45.7	45.3	.492
				(.892)
Household head attended any school [yes=1]	1,057	.673	.632	.041
				(.029)

Notes: *** denotes significance at 1% level; ** at 5%; and * at 10%. The standard errors on the differences are estimated from running the corresponding least squares regression and allowing for the errors to be clustered by community. Sample restricted to households within a 200m bandwidth.

Table 4: Title Registration and Tenure Security
Coefficients, standard errors in parentheses

	Pooled N	Mean R3	Impact by Round (OLS) R1	R2	R3	Pooled Impact
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Plots Controlled by Women						
Land registered [yes=1]	1,569	.073	.127***	.136***	.199***	.155***
			(.031)	(.033)	(.034)	(.021)
Worried to lose plot if left empty [yes=1]	1,734	.349	.031	.005	-.074*	-.013
			(.042)	(.034)	(.042)	(.026)
Any disagreement ever over this plot [yes=1]	1,724	.065	.012	.003	.036	.016
			(.018)	(.017)	(.026)	(.013)
Panel B: Plots Controlled by Men						
Land registered [yes=1]	2,362	.081	.158**	.104*	.134***	.131***
			(.056)	(.050)	(.036)	(.020)
Worried to lose plot if left empty [yes=1]	2,512	.312	-.106**	-.080*	-.029	-.070***
			(.037)	(.044)	(.039)	(.025)
Any disagreement ever over this plot [yes=1]	2,518	.066	.011	-.005	.004	.003
			(.010)	(.014)	(.022)	(.010)

Notes: Standard errors are reported in parenthesis and are clustered at the individual level. *** denotes significance at 1%, ** at 5% and * at 10%. Standard errors are clustered by respondent and are shown in brackets. All outcome variables in Panel A (B) are measured conditional on the existence of a female (male) plot. Control variables include household structure, household size, number of females in the household, number of household members under five years of age, dummy variable for household head being male, age of household head, dummy for whether household head has ever been to school, three dummies for the predominant chieftaincy institution in the community, number of sampled households situated around respondents' house within a 200m radius (household density), distance between the house of the respondent and the main road demarcation.

Table 5: Soil Improvement and Tree Planting
Coefficients, standard errors in parentheses

	Pooled N (1)	Mean R3 (2)	Impact by Round (OLS) R1 (3)	R2 (4)	R3 (5)	Pooled Impact (6)	Impact by Round (SAR) R1 (7)	R2 (8)	R3 (9)
Panel A: Plots Controlled by Women									
Any part of plot fallowed [yes=1]	1,715	.133	-.044	.026	-.020	-.012	.013	.062*	-.047
			(.032)	(.026)	(.030)	(.017)	(.036)	(.036)	(.048)
Any irrigation investment [yes=1]	1,702	.003	-.002	.002	.002	.002	-.009	.041	.021
			(.002)	(.006)	(.007)	(.003)	(.041)	(.042)	(.044)
Any soil investment [yes=1]	1,699	.005	.006	.040**	-.004	.016**	-.029	.073	.043
			(.004)	(.017)	(.006)	(.007)	(.052)	(.049)	(.053)
Trees planted in past year [yes=1]	1,452	.202	.052	.039	.031	.044*	-.059	-.001	-.032
			(.040)	(.028)	(.051)	(.023)	(.039)	(.031)	(.034)
Panel B: Plots Controlled by Men									
Any part of plot fallowed [yes=1]	2,503	.113	-.026	-.046**	.031	-.013	-.0047	-.040	.015
			(.028)	(.022)	(.044)	(.014)	(.032)	(.032)	(.033)
Any irrigation investment [yes=1]	2,463	.005	-.005	-.0003	.009**	.002	-.000	.001	.007
			(.005)	(.006)	(.004)	(.004)	(.009)	(.009)	(.010)
Any soil investment [yes=1]	2,479	.005	.002	.004	.013	.006	.002	.006	_
			(.007)	(.007)	(.014)	(.005)	(.009)	(.010)	_
Trees planted in past year [yes=1]	2,116	.267	.012	.061	-.002	.029	.009	.082**	.001
			(.042)	(.040)	(.041)	(.020)	(.036)	(.036)	(.044)

Notes: Standard errors are reported in parenthesis and are clustered at the individual level. *** denotes significance at 1%, ** at 5% and * at 10%. Standard errors are clustered by respondent and are shown in brackets. All outcome variables in Panel A (B) are measured conditional on the existence of a female (male) plot. Control variables include household structure, household size, number of females in the household, number of household members under five years of age, dummy variable for household head being male, age of household head, dummy for whether household head has ever been to school, three dummies for the predominant chieftaincy institution in the community, number of sampled households situated around respondents' house within a 200m radius (household density), distance between the house of the respondent and the main road demarcation.

Table 6: Land Acquisition
Coefficients, standard errors in parentheses

		Pooled N	Mean R3	Impact by Round (OLS) R1	R2	R3	Pooled Impact
		(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Plots Controlled by Women							
Mode through which plot was obtained, conditional on female plot existing [yes=1]	Purchase	1,738	.212	.103***	.025	.107***	.075***
				(.039)	(.037)	(.039)	(.028)
	Inheritance	1,738	.246	-.011	.018	.013	.006
				(.045)	(.041)	(.042)	(.030)
	Renting	1,738	.123	-.028	-.016	-.031	-.024
				(.028)	(.028)	(.032)	(.019)
	Sharecropping	1,738	.084	-.027	-.023	-.061**	-.036*
				(.025)	(.025)	(.025)	(.019)
	Free allocation	1,738	.260	-.044	-.005	-.026	-.023
				(.036)	(.037)	(.044)	(.025)
Panel B: Plots Controlled by Men							
Mode through which plot was obtained, conditional on male plot existing [yes=1]	Purchase	2,523	.339	.097**	.095**	.023	.071**
				(.037)	(.039)	(.060)	(.030)
	Inheritance	2,523	.112	.031	-.040	.100***	.030
				(.029)	(.042)	(.030)	(.027)
	Renting	2,523	.133	-.035	-.048	-.023	-.036*
				(.025)	(.027)	(.025)	(.020)
	Sharecropping	2,523	.085	-.032	-.029	-.051**	-.037**
				(.025)	(.027)	(.023)	(.014)
	Free allocation	2,523	.306	-.060	.020	-.038	-.025
				(.041)	(.031)	(.059)	(.025)

Notes: Standard errors are reported in parenthesis and are clustered at the individual level. *** denotes significance at 1%, ** at 5% and * at 10%. Standard errors are clustered by respondent and are shown in brackets. All outcome variables in Panel A (B) are measured conditional on the existence of a female (male) plot. Control variables include household structure, household size, number of females in the household, number of household members under five years of age, dummy variable for household head being male, age of household head, dummy for whether household head has ever been to school, three different dummies for the predominant chieftaincy institution in the community, number of sampled households situated around respondents' house within a 200m radius (household density), distance between the house of the respondent and the main road demarcation.

Table 7: Plot Size and Value (all plots controlled by the respondent)
Coefficients, standard errors in parentheses

	Pooled N (1)	Mean R3 (2)	Impact by Round (OLS) R1 (3)	R2 (4)	R3 (5)	Pooled Impact (6)	Impact by Round (SAR) R1 (7)	R2 (8)	R3 (9)
Panel A: Plots Controlled by Women									
Number of plots, by owner	2,401	.893	.041	-.066	-.169***	-.068**	.069	-.022	-.110**
			(.057)	(.057)	(.054)	(.033)	(.055)	(.055)	(.053)
Average plot size, by plot [in ha]	1,572	.490	.013	-.044	-.135**	-.057			
			(.057)	(.052)	(.053)	(.038)			
Total average plot size, by owner [in ha]	1,289	.962	-.113	-.217**	-.267***	-.073*	-.007	-.061	-.081
			(.096)	(.102)	(.100)	(.043)	(.048)	(.053)	(.057)
Value of land per ha, by plot [in Cedis]	1,070	43,107	-2,709	5,916	25,293**	11,065**			
			(4,083)	(5,990)	(10,226)	(4,550)			
Panel B: Plots Controlled by Men									
Number of plots, by owner	1,847	1.70	-.100	-.093	-.117	-.103**	-.048	-.003	-.042
			(.089)	(.089)	(.088)	(.052)	(.087)	(.087)	(.086)
Average plot size, by plot [in ha]	2,346	.616	-.134**	-.052	-.108**	-.097**			
			(.066)	(.061)	(.054)	(.048)			
Total average plot size, by owner [in ha]	1,612	1.39	-.481***	-.357***	-.398***	-.192***	-.160***	-.11*	-.100*
			(.130)	(.136)	(.138)	(.039)	(.054)	(.058)	(.057)
Value of land per ha, by plot [in Cedis]	1,795	54,046	5,043	-5,862	19,385*	6,999			
			(8,964)	(9,506)	(9,919)	(6,285)			

Notes: Standard errors are reported in parenthesis and are clustered at the individual level. *** denotes significance at 1%, ** at 5% and * at 10%. Standard errors are clustered by respondent and are shown in brackets. All outcome variables in Panel A (B) are measured conditional on the existence of a female (male) plot. Control variables include household structure, household size, number of females in the household, number of household members under five years of age, dummy variable for household head being male, age of household head, dummy for whether household head has ever been to school, three dummies for the predominant chieftaincy institution in the community, number of sampled households situated around respondents' house within a 200m radius (household density), distance between the house of the respondent and the main road demarcation.

Table 8: Plots owned by the respondent
Coefficients, standard errors in parentheses

	Pooled N	Mean R3	Impact by Round (OLS) R1	R2	R3	Pooled Impact
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Plots Owned by Women						
Number of inherited or purchased plots	2,401	.524	.102*	.030	-.099*	.007
			(.054)	(.053)	(.051)	(.031)
Panel B: Plots Owned by Men						
Number of male plots	1,847	1.01	.172*	-.020	-.010	.047
			(.102)	(.102)	(.101)	(.060)

Notes: Standard errors are reported in parenthesis and are clustered at the individual level. *** denotes significance at 1%, ** at 5% and * at 10%. Standard errors are clustered by respondent and are shown in brackets. All outcome variables in Panel A (B) are measured conditional on the existence of a female (male) plot. Control variables include household structure, household size, number of females in the household, number of household members under five years of age, dummy variable for household head being male, age of household head, dummy for whether household head has ever been to school, three dummies for the predominant chieftaincy institution in the community, number of sampled households situated around respondents' house within a 200m radius (household density), distance between the house of the respondent and the main road demarcation.

Table 9: Agricultural Production
Coefficients, standard errors in parentheses

	Pooled N	Mean R3	Impact by Round (OLS) R1	R2	R3	Pooled Impact	Impact by Round (SAR) R1	R2	R3
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A: Plots Controlled by Women									
Total value of harvest in the last major season [in Cedis]	1,400	93.2	-48.8*	-54.2*	-70.4**	-57.1***	-28.6	-24.4	-42.6
			(28.3)	(29.1)	(31.0)	(17.3)	(27.0)	(27.8)	(29.5)
Total value of harvest per ha in the last major season [in Cedis]	1,276	217	-102	12.3	-63.2	-53.1	-6.56	8.20	-15.0
			(63.2)	(66.8)	(65.9)	(38.3)	(9.69)	(9.96)	(11.6)
Panel B: Plots Controlled by Men									
Total value of harvest in the last major season [in Cedis]	1,672	466	-69.2	-71.4	-44.1	-62.1	-55.2	-60.5	-28.3
			(74.2)	(75.5)	(78.3)	(44.5)	(73.0)	(74.3)	(77.0)
Total value of harvest per ha in the last major season [in Cedis]	1,599	1,239	22.3	-103	12.8	-22.0	89.8	-87.8	267
			(70.7)	(73.2)	(74.7)	(42.8)	(170)	(173.1)	(228)

Notes: Standard errors are reported in parenthesis and are clustered at the individual level. *** denotes significance at 1%, ** at 5% and * at 10%. Standard errors are clustered by respondent and are shown in brackets. All outcome variables in Panel A (B) are measured conditional on the existence of a female (male) plot. Control variables include household structure, household size, number of females in the household, number of household members under five years of age, dummy variable for household head being male, age of household head, dummy for whether household head has ever been to school, three dummies for the predominant chieftaincy institution in the community, number of sampled households situated around respondents' house within a 200m radius (household density), distance between the house of the respondent and the main road demarcation.

Table 10: Agricultural Labor Use
Coefficients, standard errors in parentheses

		Pooled N (1)	Mean R3 (2)	Impact by Round (OLS) R1 (3)	R2 (4)	R3 (5)	Pooled Impact (6)	Impact by Round (SAR) R1 (7)	R2 (8)	R3 (9)
Panel A: Plots Controlled by Women										
Agricultural labor use by task [in hours]	Land preparation	1,411	73.8	-28.7*	-2.77	-39.7**	-23.2**	-16.8	4.70	-26.6
				(17.3)	(17.9)	(19.0)	(10.6)	(16.9)	(17.4)	(18.5)
	Field management	1,411	128	-42.9**	22.0	-69.6***	-28.9**	-38.5*	34.2	-44.1*
				(21.3)	(22.0)	(23.3)	(13.0)	(20.7)	(21.3)	(22.7)
	Harvesting	1,411	69.5	-4.27	3.50	-22.8*	-7.20	3.80	12.8	-10.3
				(12.5)	(12.9)	(13.7)	(7.62)	(12.1)	(12.5)	(13.3)
	Post-harvest	1,411	37.8	-9.41	6.54	-16.1*	-6.02	-4.51	12.2	-9.84
				(8.87)	(9.16)	(9.73)	(5.42)	(8.65)	(8.91)	(9.46)
Agricultural labor use by hectare and by task [in hours]	Land preparation	1,285	126	-41.9	-.271	28.1	27.9	-4.11	-10.5	-0.30
				(55.1)	(58.6)	(57.9)	(19.3)	(50.7)	(52.7)	(51.0)
	Field management	1,285	208	-124	77.0	-57.8	7.95	-18.2	39.5	-20.8
				(75.9)	(80.8)	(79.8)	(12.6)	(67.2)	(69.9)	(67.5)
	Harvesting	1,285	128	-39.2	23.1	-20.8	10.1	12.6	-6.99	-11.5
				(43.8)	(46.6)	(46.0)	(11.5)	(15.5)	(16.2)	(15.6)
	Post-harvest	1,285	49.4	-27.0	44.2*	5.91	9.61	-0.048	-5.99	-7.73
				(23.7)	(25.3)	(24.9)	(6.29)	(13.9)	(14.5)	(13.9)
Panel B: Plots Controlled by Men										
Agricultural labor use by task [in hours]	Land preparation	1,689	110	-78.5***	-31.5	-49.6**	-53.7***	-66.0***	-21.7	-31.1
				(21.0)	(21.5)	(22.1)	(12.6)	(20.5)	(21.0)	(21.7)
	Field management	1,689	99.2	-52.1**	-22.7	-40.9*	-38.7***	-40.4*	-20.1	-28.7
				(23.5)	(24.0)	(24.7)	(14.1)	(23.0)	(23.5)	(24.2)
	Harvesting	1,689	80.6	-28.1**	-15.5	-31.0**	-24.8***	-25.1**	-12.0	-21.0
				(13.2)	(13.5)	(13.9)	(7.95)	(12.8)	(13.1)	(13.5)
	Post-harvest	1,689	40.6	-11.2	-8.70	-12.8	-10.9**	-8.08	-10.3	-8.01
				(8.71)	(8.91)	(9.17)	(5.24)	(8.45)	(8.66)	(8.90)
Agricultural labor use by hectare and by task [in hours]	Land preparation	1,612	101	43.3	-47.8	-27.2	-2.29	-17.0	90.5***	19.9
				(60.9)	(63.4)	(64.4)	(30.8)	(32.6)	(32.2)	(32.6)
	Field management	1,612	84.2	3.32	-6.38	-30.8	-.0009	-27.5	56.9***	-2.87
				(41.8)	(43.5)	(44.2)	(40.8)	(21.3)	(21.1)	(21.4)
	Harvesting	1,612	69.4	53.3	3.59	-18.6	-1.54	-16.9	52.4***	-1.50
				(39.3)	(40.9)	(41.5)	(9.46)	(19.5)	(19.2)	(19.5)
	Post-harvest	1,612	38.6	8.05	-4.00	-22.4	-3.83	-4.73	38.1***	-3.12
				(26.7)	(27.8)	(28.2)	(8.38)	(10.6)	(10.5)	(10.6)

Notes: Standard errors are reported in parenthesis and are clustered at the individual level. *** denotes significance at 1%, ** at 5% and * at 10%. Standard errors are clustered by respondent and are shown in brackets. All outcome variables in Panel A (B) are measured conditional on the existence of a female (male) plot. Control variables include household structure, household size, number of females in the household, number of household members under five years of age, dummy variable for household head being male, age of household head, dummy for whether household head has ever been to school, three different dummies for the predominant chieftaincy institution in the community, number of sampled households situated around respondents' house within a 200m radius (household density), distance between the house of the respondent and the main road demarcation.

Table 11: Household Enterprise

Coefficients, standard errors in parentheses

	Pooled N	Mean R3	Impact by Round (OLS) R1	R2	R3	Pooled Impact	Impact by Round (SAR) R1	R2	R3
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A: Reported by Women									
Involved in any self-employed, non-farm IGA in the past year [yes=1]	2,313	.561	.106***	.122***	.084**	.104***	.083**	.097***	.059*
			(.035)	(.035)	(.034)	(.020)	(.035)	(.034)	(.034)
Total average monthly profit for female controlled non-farm enterprises [in Cedis]	1,210	75.2	-52.7	97.8	203***	98.3**	-58.9	82.7	191***
			(74.0)	(66.0)	(61.4)	(39.1)	(73.4)	(65.3)	(60.6)
Panel B: Reported by Men									
Involved in any self-employed, non-farm IGA in the past year [yes=1]	1,779	.303	.039	.041	-.008	.024	.025	0.016	-0.027
			(.036)	(.035)	(.035)	(.021)	(.035)	(.035)	(.034)
Total average monthly profit for male controlled non-farm enterprises [in Cedis]	433	555	-498	123	564**	145	-484	81.7	544**
			(315)	(258)	(247)	(159)	(310)	(252)	(244)

Notes: Standard errors are reported in parenthesis and are clustered at the individual level. *** denotes significance at 1%, ** at 5% and * at 10%. Standard errors are clustered by respondent and are shown in brackets. All outcome variables in Panel A (B) are measured conditional on a female (male) respondent interviewed. Control variables include household structure, household size, number of females in the household, number of household members under five years of age, dummy variable for household head being male, age of household head, dummy for whether household head has ever been to school, three dummies for the predominant chieftaincy institution in the community, number of sampled households situated around respondents' house within a 200m radius (household density), distance between the house of the respondent and the main road demarcation.

Table 12: Borrowing

Coefficients, standard errors in parentheses

	Pooled N	Mean R3	Impact by Round (OLS) R1	R2	R3	Pooled Impact	Impact by Round (SAR) R1	R2	R3
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A: Reported by Women									
Any repaid loan in the last 12 months [yes=1]	2,295	.256	.007	-.015	-.012	-.007	-.003	-.020	-.020
			(.030)	(.030)	(.029)	(.018)	(.03)	(.030)	(.030)
Value of current outstanding loan [in Cedis]	2,261	259	-28.4	-56.1*	59.6*	-6.80	-29.3	-58.2*	55.0*
			(34.4)	(33.1)	(32.4)	(19.5)	(34.2)	(32.9)	(32.3)
Panel B: Reported by Men									
Any repaid loan in the last 12 months [yes=1]	1,775	.186	.033	.047	-.003	.026	.030	.040	.004
			(.031)	(.030)	(.030)	(.018)	(.030)	(.030)	(.030)
Value of current outstanding loan [in Cedis]	1,755	310	52.8	19.7	106**	59.4**	51.6	19.3	109**
			(44.3)	(42.9)	(43.3)	(25.5)	(44.2)	(42.9)	(43.2)

Notes: Standard errors are reported in parenthesis and are clustered at the individual level. *** denotes significance at 1%, ** at 5% and * at 10%. Standard errors are clustered by respondent and are shown in brackets. All outcome variables in Panel A (B) are measured conditional on the existence of a female (male) plot. Control variables include household structure, household size, number of females in the household, number of household members under five years of age, dummy variable for household head being male, age of household head, dummy for whether household head has ever been to school, three different dummies for the predominant chieftaincy institution in the community, number of sampled households situated around respondents' house within a 200m radius (household density), distance between the house of the respondent and the main road demarcation.

Table 13: Asset Ownership at the Individual Level
Coefficients, standard errors in parentheses

	Pooled N (1)	Mean R3 (2)	Impact by Round (OLS) R1 (3)	R2 (4)	R3 (5)	Pooled Impact (6)	Impact by Round (SAR) R1 (7)	R2 (8)	R3 (9)
Panel A: Reported by Women									
Value of livestock, conditional on screening question [in Cedis]	2,300	130	-20.0	-21.7	-39.3*	-27.2**	-18.1	-18.1	-36.9*
			(21.1)	(20.9)	(20.4)	(12.2)	(21.0)	(20.9)	(20.4)
Value of tools, conditional on screening question [in Cedis]	2,256	17.0	-1.21	-1.64	2.60	-.012	-.500	-1.00	3.20*
			(1.82)	(1.75)	(1.71)	(1.03)	(1.8)	(1.7)	(1.7)
Value of durable goods, conditional on screening question [in Cedis]	2,300	495	.755	5.56	219***	77.6***	1.70	6.00	226***
			(45.3)	(44.9)	(44.0)	(26.3)	(45.1)	(44.7)	(44.1)
Panel B: Reported by Men									
Value of livestock, conditional on screening question [in Cedis]	1,780	556	-56.5	3.21	220***	55.7	-49.2	4.5	214***
			(63.2)	(62.6)	(63.1)	(37.0)	(63.0)	(62.3)	(62.8)
Value of tools, conditional on screening question [in Cedis]	1,752	65.5	-4.88	-6.24	11.1*	.066	-4.40	-5.60	11.5*
			(6.19)	(5.98)	(6.03)	(3.56)	(6.20)	(6.00)	(6.00)
Value of durable goods, conditional on screening question [in Cedis]	1,778	1,609	66.8	-146	765***	227**	68.8	-138.1	798***
			(192)	(190)	(191)	(112)	(192)	(190)	(192)

Notes: Standard errors are reported in parenthesis and are clustered at the individual level. *** denotes significance at 1%, ** at 5% and * at 10%. Standard errors are clustered by respondent and are shown in brackets. All outcome variables in Panel A (B) are measured conditional on a female (male) respondent interviewed. Control variables include household structure, household size, number of females in the household, number of household members under five years of age, dummy variable for household head being male, age of household head, dummy for whether household head has ever been to school, three dummies for the predominant chieftaincy institution in the community, number of sampled households situated around respondents' house within a 200m radius (household density), distance between the house of the respondent and the main road demarcation.

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Appendix Figure A1: GPS Location of Sampled households