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Formalizing Rural Land Rights in West Africa

Early Evidence from a Randomized Impact Evaluation in Benin

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Abstract

This paper presents early evidence from the first large-scale randomized-controlled trial of a land formalization program. The study examines the links between land demarcation and investment in rural Benin in light of a model of agricultural production under insecure tenure. The demarcation process involved communities in the mapping and attribution of land rights; cornerstones marked parcel boundaries and offered lasting landmarks. Consistent with the model, improved tenure security under demarcation induces a shift toward long-term investment on treated parcels. This investment does not yet coincide with gains in agricultural productivity. The analysis also identifies significant gender-specific effects. Female-managed landholdings in treated villages are more likely to be left fallow—an important soil fertility investment. Women further respond to an exogenous tenure security change by moving production away from relatively secure, demarcated land and toward less secure land outside the village to guard those parcels.

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Formalizing Rural Land Rights in West Africa:

Early Evidence from a Randomized Impact Evaluation in Benin*

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1 Introduction

Throughout rural Sub-Saharan Africa, the allocation and enforcement of land rights involve a diverse and complex set of customary arrangements made and upheld by local stakeholders such as village chiefs, councils of elders, and land chiefs (Le Bris et al., 1982). Customary land tenure systems often coexist with formal land administration systems, where proof of ownership or of use rights is documented with registered titles or deeds. Yet only a small proportion of the population holds formal land titles for the land they *de facto* own. This lack of formal land rights may lead to under-investment and sub-optimal yields (Goldstein and Udry, 2008). Codification of private property rights within an effective legal framework should in theory increase agricultural investment and productivity, and spur economic development (Besley, 1995; Besley and Ghatak, 2010). Hence, the policy response to undocumented property rights has often been the "formalization" of land tenure (i.e., the incorporation of "informal", customary, undocumented tenure claims into the formal system of property rights), often through the provision of freehold titles.[1]

While land titling programs have met with relative success in rural (Deininger and Feder, 2009; Feder et al., 1988) and urban settings (Field, 2007; Galiani and Schargrodsky, 2010), the evidence from Africa is less positive (Jacoby and Minten, 2007). This contrast is perhaps due to oversimplified interventions that neglect the complexity of customary land relations in rural areas, the limited capacity of central land administrations for the delivery of titles, or the difficulties in establishing decentralized institutions (Teyssier and Selod, 2012). The distributional impacts of land formalization programs are also ambiguous: Despite some claims of the possibly deleterious effects of individualizing land rights for women (Lastarria-Cornhiel, 1997), there is scant rigorous evidence from impact evaluations to support or refute these claims.[2] In response to these challenges, Udry (2012) observes that a shift in policy guidance "from direct provision of individual title to support for better integration of customary tenure with the formal legal system" might prove more effective in improving tenure security and promoting

[1] See Durand-Lasserve and Selod (2009) on the different types of, and contexts for, land tenure formalization.

[2] To our knowledge, a recent impact evaluation in Rwanda is the only rigorous study to offer some evidence on the gender effects of land certification in Africa (Ali et al., 2014). They find that land tenure regularization registered an impact on soil conservation investments among female-headed households that was nearly twice as large as the effect observed on male-headed households. While new experimental evidence from urban Tanzania shows that small price discounts can induce households to adopt joint land titling for males and females, the effects of this intervention on subsequent investment decisions, productivity, and welfare have not yet been documented (Ali et al., 2014).

rural development in Africa.[3] As such, documenting the impact of the different steps towards formalization of land rights is necessary to understand the underlying behavioral mechanisms and to formulate credible policy recommendations.

We present early evidence from the first large-scale randomized-controlled trial of a land formalization policy. Specifically, we examine the link between land demarcation and investment in Benin. This study makes two central contributions to the literature: first, we exploit early evidence to decompose the process of formalization, and look at the causal effect of land demarcation on on-farm investment behavior; second, we overcome the typical identification challenges in this literature by exploiting the first large-scale randomized-controlled trial (RCT) of a land formalization program.

Unpacking the causal chain of land formalization is particularly relevant in the context of new, alternative approaches to land formalization that challenge standard titling approaches. The case of Benin's Rural Land Use Plans, or PFR (*Plans Fonciers Ruraux*), exemplifies this shift in perspective among formalization programs in Africa in two important respects. First, the program considers that existing customary arrangements – which are to be collectively identified during implementation – provide legitimate claims to property that can be formalized. Second, it sets up a decentralized procedure for the establishment of formal property rights, in contrast to the more costly and complex centralized registration of ownership titles within a national cadastre.

The PFR's formalization process presents a rare opportunity to isolate the mechanisms underlying changes in investment behavior due to a shift in land rights. The PFR embeds the recognition of land rights within existing customary practices. As such, the program consists of two key steps: first, each community identifies and demarcates all parcels, with the mapping of customary ownership in the form of a full land survey, and the laying of cornerstones to explicitly mark parcel boundaries; second, customary land ownership is formally and legally documented in the form of certificates. This study examines the impact of the first step, the land demarcation intervention, on farming households' investment behavior in Benin. These short-term effects shed light on the investment impact of integrating customary tenure with the formal system of land rights.

[3] At the same time, Udry (2012) also stresses the need to understand the "political and social ramifications of such policies" to ensure that benefits are not captured by the powerful.

Land demarcation is a key stage in the formalization of land rights. The demarcation process consists of the documentation of land claims through the consensual delimitation and mapping of all agricultural lands within a rural village, and the surveying and physical demarcation of corresponding parcels. During the land demarcation activities, land conflicts are discussed and settled in the presence of stakeholders (including neighbors), primary land right holders are identified, and landholdings are demarcated through the implantation of cornerstones. The cornerstones serve as immediate, long-lasting benchmarks to detect and resolve future land encroachment disputes. Moreover, they represent a more standardized substitute to traditional methods, such as tree-planting, used by landholders to mark the frontier of their parcels.[4] In that sense, demarcation in the context of the PFR corresponds to a first key step in securing land rights, akin to that used by Hornbeck (2010) to examine the case of barbed wire fencing in the Great Plains of North America. Demarcation *per se* does not necessarily amount to enforceable land rights, but the process of laying cornerstones clarifies frontiers and may protect farmers from encroachment. The process that surrounds demarcation allows each community to unify competing and overlapping conceptions of land rights. This is particularly relevant to contexts where several individuals claim rights over the same parcel (Lavigne-Delville, 2014). Yet the resolution of overlapping land claims could be to the detriment of the least powerful (Goldstein and Udry, 2008). Women in particular often only obtain secondary land use rights through a male spouse or relative (Lastarria-Cornhiel, 1997).[5] Since land demarcation is the first step of the land certification program, landholders with demarcated parcels expect to receive land certificates at some unspecified point. As such, we document the impact of land demarcation pending certification.

Documenting the effect of a critical first step in formalizing land rights, in the form of community-based land demarcation, is of particular policy relevance. The sum of bureaucratic processes required for a government to issue proof of property are typically prohibitive. The World Bank's 2014 *Doing Business* report indicates that registering property in Sub-Saharan Africa involves on average six different procedures, taking 59 days each to complete, and generates costs of about 9 percent of the property value.[6] At this rate, it is unsurprising that the final stage of

[4]Indeed, tree-planting, which is a customary practice to demarcate land borders, is seen in some places as a tantamount to land ownership. Landholders with secondary land rights are usually discouraged from planting trees on their landholdings.

[5]At inception of the PFR, secondary rights were meant to be recorded during the process. In practice, the main focus was on recording ownership claims.

[6]The figures reported in the case of Benin are four procedures of 120 days each, for a cost amounting to 11.7 percent of the total property value.

property rights delivery, the actual *de jure* certification, occurs several years after the start of a program.[7] Hence, studying the impact of partial and alternative forms of land protection on investment in agriculture is of particular relevance to understanding determinants of economic development (Hornbeck, 2010).

The initial effect of land demarcation on farming households' behavior is *a priori* ambiguous. Land demarcation may increase investment through two main channels. First, as land ownership disputes are resolved during demarcation activities, conflicts over demarcated parcels and the risk of expropriation should decrease, reinforcing incentives to invest (Banerjee et al., 2002; Besley, 1995; Feder and Feeny, 1991). A corollary is that households may reallocate resources from land-guarding practices to more productive activities (Besley and Ghatak, 2010; Goldstein and Udry, 2008). Second, demarcation could facilitate land market activity as clear parcel boundaries may render land easier to sell or rent. Yet the lack of clarity around the second step of the certification process – the issuance of certificates – may, in the short run, discourage investment. Households may, for instance, temporarily limit their engagement in land market activities, such as renting, until their claims are formally confirmed through the issuance of land certificates. Given pre-existing gender differences in customary land rights in Benin, we also have ample reason to expect that these channels could lead to a differential impact for men and women—as they have elsewhere (Ali et al., 2014).

This study is the first to provide experimental evidence on the impact of the first key step of land formalization, namely land demarcation, on farming households' investment behavior. The identification of causal impact relies on the random assignment of the program at the village level, allowing us to circumvent issues of reverse causality commonly faced in the literature. Typically, changes in land rights are endogenous to parcel and household characteristics, as some latent variables can plausibly predict land demarcation, tenure security, investment, and productivity simultaneously (Besley, 1995). For instance, the expectation of land loss or encroachment on a given parcel can prompt a household to invest in land delimitation strategies. Households may also seek to obtain a land certificate for their higher quality plots (Besley, 1995; Brasselle et al., 2002). As a result of these methodological challenges, very few studies provide a credible counterfactual analysis of the impact of land formalization. In Ethiopia, three studies use a simple difference approach to exploit time varying, plot-level information on production

[7] See Teyssier and Legendre (2013) for a discussion of the Madagascar case.

and the issuance of land certificates (Deininger et al., 2011; Holden et al., 2011, 2009).[8] This approach does not address the issue of reverse causality between certification and investment or productivity. In Rwanda, Ali et al. (2014) employ a boundary discontinuity design to address some of these endogeneity concerns. They use spatial fixed effects to compare households in pilot villages to their counterparts in adjacent neighborhoods.[9] This strategy cannot address the identification challenges related to endogenous roll out and spatial spillovers, and cannot reject that pilot areas may have benefited from additional policy investments other than land tenure regularization.

Finally, we exploit rich household survey data to add to the literature on the distributional implications of the codification of land rights on land-related conflicts. Initial levels of tenure security will likely affect individual responses to a change in land rights (Goldstein and Udry, 2008). In rural Benin, women vie for secondary land rights while *de facto* ownership and control over land is mostly allotted to men who have the power to enforce their claims. In this context, demarcation activities could in fact reduce tenure security in places where many individuals hold claims to the same piece of land and to different dimensions of use of that land (Lavigne-Delville, 2010, 2014; Udry, 2012). This may be a particularly salient concern for women, who typically obtain land use rights via a male intermediary. We shed light on these mechanisms by presenting the parcel level, sex-differentiated effects of land demarcation on agricultural investment.

Two years after the start of implementation, treatment households are 39 to 43 percent more likely to grow perennial cash crops and invest in trees on their parcels. The increase in investment coincided with an expansion in the right to sell land—a proxy for tenure security. These results are in line with our theoretical predictions. Meanwhile, in line with evidence from other contexts (Place, 2009), we find no short-term impact on agricultural productivity, or use of improved inputs such as fertilizer and high-yield seeds. The overall program impact, meanwhile, masks heterogeneity in effects by gender. Treated female-headed households boost their fallowing investments in land, fully erasing the gender gap observed in control villages.

[8] Holden et al. (2009) find that, up to eight years after the issuance of land certificates, plot productivity increased by 45 percent, though no impact was found on investment in soil conservation. Holden et al. (2011) find that female-headed households with access to formal land rights engage more in land rental markets as landlords. Deininger et al. (2011) find that, twelve months after the issuance of land certificates, the fear of land loss is reduced, households are more likely to rent out their land, and investment in soil and water conservation measures increase.

[9] Ali et al. (2014) find that tenure regularization increases soil conservation investments by about ten percentage points and nineteen percentage points among male-headed and female-headed households, respectively. They find no effect on credit and land market activities.

Women further respond to an exogenous change in their relative tenure security in a way consistent with the findings of Goldstein and Udry (2008) by shifting their agricultural production away from relatively secure, demarcated land and toward less secure land outside the village perimeter to guard those parcels.

The remainder of the paper is organized as follows. Section 2 situates our study within the growing literature on property rights in Africa and the ongoing land policy reform process in Benin, and details the process of PFR implementation. Section 3 outlines a theoretical model from which we derive expected effects on crop and production choices following the initial stages of program implementation. The model also highlights the possibility of gender-differentiated effects. The first portion of Section 4 describes our identification strategy and the data collection process, and reports relevant descriptive statistics. Section 4.5 through Section 4.7 present the estimates of the impact of PFR land demarcation activities in Benin. Section 5 offers a set of conclusions for researchers and policymakers to consider.

2 Context

2.1 Rural land rights

Throughout much of Sub-Saharan Africa, customary land tenure systems coexist with formal, or so-called *modern* systems, where proof of ownership or of use rights is given by formal documents such as titles or deeds. In rural West Africa, the allocation and enforcement of land rights mostly operate through a diverse and overlapping set of customary arrangements at the village or local level. Increasing pressure on natural resources and the absence of written documentation regarding land use have given rise to land conflicts over inheritance, as well as disputes among villages, farmers and pastoralists. These elements suggest that tenure insecurity may limit access to land and deter investment in agriculture.

Yet the issue of incomplete and undocumented land rights is not specific to West Africa. In many parts of the world, such as Latin America, the policy response has often been the *formalization* of land tenure rights (i.e., the incorporation of informal tenure into the formal system) through the provision of fully-fledged formal titles, a procedure known as *land titling*. Such programs, however, have not succeeded in West Africa, perhaps due to the complexity of customary land relations and a limited capacity of central land administrations to deliver titles. More decentralized approaches have thus been proposed to embed the recognition of land

rights within customary practices themselves, and to provide relatively weaker, though more affordable, forms of formal recognition. The Rural Land Use Plans or PFRs (*Plans Fonciers Ruraux*) in Benin, in operation since 1993, represent one such approach. The PFRs consist of documenting land claims by consensually mapping all agricultural uses within a village, surveying and demarcating the corresponding parcels, and issuing land use certificates to smallholders.

In recent years, several countries in Sub-Saharan Africa – including Benin, Burkina Faso, Côte d'Ivoire, Ethiopia, Ghana, Madagascar, Rwanda, and Tanzania – have implemented some form of systematic land formalization program (see Byamugisha, 2013).[10] In rural areas, formalization policies typically take the form of freehold land titling or land certification. Both types of programs use topographical surveys to demarcate land and provide formal documentary evidence of the land rights recorded during the adjudication process. However, the rights provided under land titling and land certification programs may differ. In some contexts, land certificates – in contrast to freehold tenure – may only recognize use rights and entail restrictions on land transfer. In Benin, the certificate provides a right akin to ownership, and the law has provisions for its conversion into an ownership title. The main difference between the certificate and the title in Benin is the decentralized and participatory process (the PFR) through which the certificate is issued. The systematic and decentralized approach for certification through PFRs could thus result in a lower-cost policy option for developing countries.

2.2 Rural land registration in Benin

Benin is one of the countries in West Africa where the design and implementation of policies to consolidate land rights is furthest advanced. The *Plan Foncier Rural* (PFR), first tried in Côte d'Ivoire in 1989 and piloted in Benin since 1993, is a key policy experiment in this respect. The program is currently in the initial stages of a planned implementation scale-up in Benin. The objectives of the program are to improve tenure security and stimulate agricultural investment in rural areas through the registration of land rights.

The PFR was originally conceived to demarcate landholdings held by households in rural areas and to protect forests and natural resources from further encroachment by farmers. Its

[10] To our knowledge, there is, to date, no peer-reviewed counterfactual analysis on the effect of land formalization programs in Burkina Faso, Côte d'Ivoire, Ghana, Madagascar, or Tanzania. In Madagascar, Bellemare (2013) uses cross-sectional data and finds no evidence of an impact of land titles on agricultural productivity. Using a similar method, Fenske (2011) documents the relationship between land tenure and investment in six West African countries, including Benin, where he finds no difference in investment across owned and not-owned plots. However, he detects gender differences in investment patterns, with male labor being used more intensively on husbands' plots, while wives' instead use fertilizer and pesticide inputs more intensively.

scope was initially limited to villages near watersheds and other natural resources.[11] The establishment of a Millennium Challenge Corporation (MCC) compact between the United States and Benin in 2006 considerably increased the resources available for these interventions and changed the scale of experimentation. Under the compact, approximately US$34 million was put towards land formalization activities, including the establishment of PFR Rural Land Use Plans, policy reform activities, and land information systems. With MCC's technical and financial support, the PFR intervention in Benin enables producers to formalize rural land rights obtained under customary arrangements.

The PFR exemplifies the aforementioned paradigm shift in land formalization programs, as it embeds the recognition of land rights within existing, customary practices. The program consists of two key steps: first, each community identifies and demarcates all land parcels, mapping out customary rights through a full topographic land survey, and laying cornerstones to explicitly mark parcel boundaries; second, land ownership is formally documented in the form of certificates. The capstone step of the program is the delivery of a legally valid land certificate (*Certificat Foncier Rural*) to individual landholders, resulting in a formal recognition of existing customary land rights (with the option of upgrading to a fully-fledged title at a later stage).[12] At the time of our field work, this second phase of the program had not taken place. We exploit this timing to examine the early effects of the land formalization program's demarcation activities.

2.3 Land demarcation intervention

The demarcation process clarifies claims and facilitates land-related conflict resolution, and culminates with a written documentation of existing land rights as well as the physical marking of parcel boundaries with cornerstones. As such, land demarcation is the opportunity for the community to resolve disputes and overlapping claims on the land, and sets the stage for the second key step of the formalization process—land certification.

Land demarcation is marked by a series of sub-interventions at the village level, where the parcel (i.e., the landholding) is the primary unit of treatment. The demarcation process is led, with support from the PFR program, by local land management commissions (*Sections villa-*

[11] The original program was implemented in Benin by the *Projet de Gestion des Ressources Naturelles*, funded by the World Bank, Agence Française de Développement (AFD), and German Technical Cooperation (GTZ), and the *Projet de Gestion des Terroirs et des Ressources Naturelles*, funded by AFD and GTZ.

[12] The distinction between land use certificates and titles will soon be abolished with the recent creation of a single property right, the land property certificate (*Certificat de Propriété Foncière*).

geoises de gestion foncière). In each community, these commissions work with program implementers through the following four steps of the village-level demarcation intervention: first, an awareness raising campaign; second, a socio-legal study to take stock of all land claims of the population; third, the systematic topographic surveying (referred to here as *enquêtes topo-foncières*, ETF) that produces a full land registry and lays down cornerstones to mark the parcel boundaries; lastly, from the ETF and the socio-legal enquiry, each identified parcel is associated with its respective owners and users, in the terms stated by the owners/users themselves (Hounkpodote, 2007). Figure A-1 offers a visual representation of a finalized ETF. Recipients of the PFR intervention expect that, after completion of the demarcation activities, the local administration will publish, validate, and finalize the village landholding plans, and issue a land certificate for each parcel in the land registry. It is important to note that this step in the land formalization process does not involve the landholders and is purely administrative. Nevertheless, our estimates cannot separate the effect of the actual demarcation from that of a pending certification.

3 Theoretical Model

Building on Besley (1995), we present a simple framework to model the expected impact of property rights improvement on crop and parcel cultivation choices in the context of Rural Land Use Plans.

3.1 Investment in short-term and long-term crops

We consider a household which owns land in the village and has an endowment $\bar{k}$ of available labor.[13] The household must decide which quantity of labor k_S to invest in a short-term crop (seasonal) and which quantity k_L to invest in a long-term crop (perennial). The landholding will then be subdivided accordingly, with a portion of the parcel allocated to one crop and the rest to the other crop. We take the short-term crop as the numeraire and denote p as the price of the long-term crop. The respective production functions for the two crops are denoted $F_i(k_i)$ for $i = S, L$, with $F_i^{'}(k_i) > 0$ and $F_i^{''}(k_i) < 0$. In addition to different market prices and production functions, the key difference between the short-term and the long-term crop is that the short-term crop can be harvested at $T = T_S$ and the long-term crop at $T = T_L$, with $T_L > T_S$. These different maturities have implications for tenure security, as we assume that a

[13] For simplification, we assume that labor from household members is available up to a fixed quantity and abstract from modeling the opportunity cost of time or cost of hiring external labor.

parcel (or the portion of the parcel) on which a longer-maturity crop is planted faces a higher risk of being grabbed due to longer exposure to risk.[14]

Technically, we denote $\tau(T, R)$ as the probability that the parcel will be lost before harvest when harvest takes place at time T for a given level of property right R, and we assume that $\frac{d}{dT}\tau(T, R) > 0$. We also assume $\frac{d}{dR}\tau(T, R) < 0$ to reflect that stronger property rights reduce the risk of losing the parcel for all maturities. Under customary tenure (e.g., before implementation of a Rural Land Use Plan), R has a relatively low value, implying that τ is relatively large. We further assume that $\frac{d^2}{dRdT}\tau(T, R) < 0$: there are greater gains in tenure security (reduction in τ) associated with an improvement in property rights for long-term crops than for short-term crops.[15] This is consistent with the idea that property rights matter a lot for long-term crops which are more insecure than short-term crops.

We now model the first stage of the formalization procedure (demarcation) as a partial improvement in property rights (a marginal change in R). The household chooses k_S and k_L to maximize its expected profit (W) subject to the endowment constraint $k_S + k_L \leq \bar{k}$. Considering an interior solution, and assuming a zero discount rate for simplicity and without any loss of generality, the household thus faces the following program:

$$\max_{k_L} \; W = [1 - \tau(T_S, R)]\, F_S(\bar{k} - k_L) + p\,[1 - \tau(T_L, R)]\, F_L(k_L)$$

which is concave in k_L.

Differentiating W with respect to k_L and equating the result to zero gives the first-order condition (FOC):

$$\Phi(k_L, R) \equiv -\,[1 - \tau(T_S, R)]\, F_S'(\bar{k} - k_L) + p\,[1 - \tau(T_L, R)]\, F_L'(k_L) = 0$$

It is easy to see that the FOC simply equalizes the expected marginal gains from investments in the short-term and the long-term crops.

Applying the Implicit Function Theorem to the FOC, we obtain:

[14] The risk is measured at the time of planting. With a constant level of risk over time, since longer-maturity crops take longer to yield a harvest, they will stand a higher risk of being expropriated before harvest.

[15] The negative cross derivative can also be interpreted as saying that the risk of expropriation increases faster with crop maturity under weaker property rights.

$$\frac{dk_L}{dR} = -\frac{\frac{d\Phi}{dR}}{\frac{d\Phi}{dk_L}} = -\frac{\frac{d}{dR}\tau(T_S,R)F_S^{'}(\bar{k}-k_L) - p.\frac{d}{dR}\tau(T_L,R)F_L^{'}(k_L)}{[1-\tau(T_S,R)]\,F_S^{''}(\bar{k}-k_L) + p.\,[1-\tau(T_L,R)]\,F_L^{''}(k_L)} \tag{1}$$

Since the production functions are concave, the Second Order Condition (SOC) $\frac{d^2W}{dk_L^2} < 0$ is satisfied and the denominator $\frac{d\Phi}{dk_L}$ (which is the same as $\frac{d^2W}{dk_L^2}$) is always negative. $\frac{dk_L}{dR}$ is thus of the same sign as the numerator $\frac{d\Phi}{dR}$. We thus have the following proposition:

Proposition 1. *An improvement in the property right leads to a shift away from cultivation of the short-term crop towards cultivation of the long-term crop.*

Proof: We have:

$$\frac{dk_L}{dR} > 0 \iff \frac{d\Phi}{dR} > 0 \iff \frac{p.F_L^{'}(k_L)}{F_S^{'}(\bar{k}-k_L)} > \frac{\frac{d}{dR}\tau(T_S,R)}{\frac{d}{dR}\tau(T_L,R)}$$

Because $\frac{d^2}{dTdR}\tau(T,R) < 0$, $\frac{d}{dR}\tau(T,R)$ is a decreasing function of T, implying $\frac{d}{dR}\tau(T_S,R) > \frac{d}{dR}\tau(T_L,R)$, which in turns implies that $\frac{d\Phi}{dR} > \frac{d}{dR}\tau(T_L,R).\left[F_S^{'}(\bar{k}-k_L) - p.F_L^{'}(k_L)\right]$. Observe that $\frac{d}{dR}\tau(T_L,R)$ is negative and, using the FOC, that $F_S^{'}(\bar{k}-k_L) - p.F_L^{'}(k_L) = -\tau(T_S,R)F_S^{'}(\bar{k}-k_L) - p\tau(T_L,R)F_L^{'}(k_L)$ is also negative. It follows that $\frac{dk_L}{dR}$ is always positive: an improvement in the property right unambiguously leads to a shift away from the short-term crop and towards the long-term crop. The intuition is simple: an improvement in property rights lowers the likelihood of expropriation more for the long-term crop than the short-term crop, requiring a shift toward investment in the long-term crop to restore the optimality of investments.

3.2 Investment on parcels within and outside the border of villages

We now consider that the household has two parcels, one inside the village (V) and one outside the village border (O). The household decides on the amount of labor k_i to allocate to each parcel $i \in \{V, O\}$ (with $k_V + k_O \leq \bar{k}$). In this modified setting, we reason with one type of crop and thus consider a single specification of the production function $F(k_i)$, with $F^{'}(k_i) > 0$ and $F^{''}(k_i) < 0$. Because the time spent by the household on each parcel will vary, we now consider that the household's presence on each parcel affects tenure security ("guarding labor" assump-

tion) in addition to being a direct input into production.[16] Formally, the probability of losing parcel $i\epsilon\{V, O\}$, $\tau(k_i, R_i)$ depends on the labor investment k_i on that parcel in addition the level of property right R_i enjoyed on the parcel. We assume that $\frac{d}{dk}\tau(k, R) < 0$ (guarding labor assumption) and $\frac{d}{dR}\tau(k, R) < 0$ (as previously). We further assume that $\frac{d^2}{dRdk}\tau(k, R) > 0$: there are greater gains in tenure security (reduction in τ) associated with a marginal increase in guarding labor for parcels that benefit from a weak property right than for parcels that benefit from a stronger property right.

For given levels of property rights R_V and R_O, the program of the household is:

$$\max_{k_O} \; W = \left[1 - \tau(\bar{k} - k_O, R_V)\right] F(\bar{k} - k_O) + \left[1 - \tau(k_O, R_O)\right] F(k_O)$$

The FOC is:

$$\Psi(k_O, R_V) = \frac{d}{dk}\tau(\bar{k} - k_O, R_V)F(\bar{k} - k_O) - \left[1 - \tau(\bar{k} - k_O, R_V)\right] F^{'}(\bar{k} - k_O)$$
$$-\frac{d}{dk}\tau(k_O, R_O)F(k_O) + \left[1 - \tau(k_O, R_O)\right] F^{'}(k_O) = 0$$

The FOC equates the marginal gains from labor investment in the village parcel and in the parcel outside the village, taking into account both the impact of guarding labor on tenure security and on production.

We can now consider the impact on investment decisions following a *partial* implementation of a Rural Land Use Plan, which improves R_V while keeping R_O constant—in line with the fact that the Rural Land Use Plans aim to formalize only parcels within village borders. Applying the Implicit Function Theorem to Ψ, we have:

$$\frac{dk_O}{dR_V} = -\frac{\frac{d\Psi}{dR_V}}{\frac{d\Psi}{dk_O}}$$

When the Second Order Condition is satisfied, $\frac{d\Psi}{dk_O}$ is negative and $\frac{dk_O}{dR_V}$ is thus of the same sign as:

[16] In the previous setting with one parcel and two crops, the amount of time spent on the parcel $\bar{k}$ was constant so we abstracted from modeling the impact of labor on tenure security.

$$\frac{d\Psi}{dR_V} = \frac{d}{dRdk}\tau(\bar{k} - k_O, R_V)F(\bar{k} - k_O) + \frac{d}{dR}\tau(\bar{k} - k_O, R_V)F^{'}(k_O) \gtrless 0 \tag{2}$$

Because the first term is positive (under the natural assumption that $\frac{d^2}{dRdk}\tau(k, R) > 0$) and given that the second term is negative, $\frac{d\Psi}{dR_V}$ cannot be signed. We thus have the following proposition:

Proposition 2. *An improvement in village property rights has an ambiguous impact on the reallocation of labor between parcels located within and outside the village. If labor more efficiently reduces tenure insecurity on parcels with weaker property rights than on parcels with stronger property rights, then labor may be shifted away from parcels within the village to parcels outside the village.*

Note that $\frac{d}{dRdk}\tau(\bar{k} - k_O, R_V)F(\bar{k} - k_O)$ is likely to be greater for lower values of R_V, implying that, following an improvement in property rights, households with initially weaker property rights in the village (e.g., female-headed households) may be more likely to shift cultivation effort to outside parcels than households with initially stronger property rights in the village (e.g., male-headed households).

4 Experimental Design, Data and Econometric Approach

4.1 Experimental design

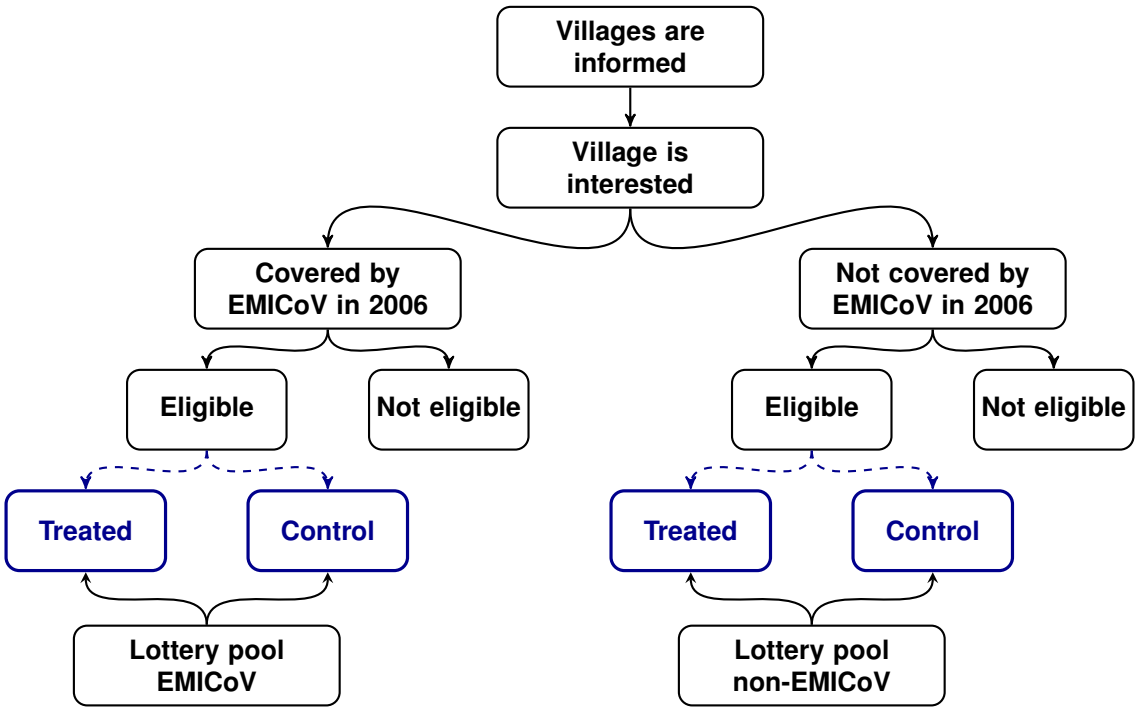
The MCC-supported PFR program aimed to produce 300 ETFs in 40 *communes* throughout Benin and deliver more than 70,000 land use certificates.[17] The selection in the program was done in two steps. First, villages in each of the 40 communes received an information campaign. The intention was to inform villages about the program and invite them to apply for a chance to receive one of the 300 PFRs. Second, proposals were reviewed against pre-established selection criteria.[18] From this review a list of eligible villages was produced. Third, each commune organized lotteries to randomly select villages within the eligible pool into the program. Overall, 1,235 villages applied for the program, out of the 1,543 that were targeted. Of these 1,235 villages, 576 met the eligibility criteria. To select treatment and control villages, 80 public lotteries were organized, two in each commune; the process started rolling out in 2008 (MCC,

[17] *Communes* are sub-regional units equivalent to districts. There are 77 communes in Benin.

[18] The following criteria were used: poverty index, potential for commercial activities, regional market integration, local interest in promoting gender equality, infrastructure for economic activities, adhesion to the PFR application procedure, incidence of land conflicts, and the production of main crops.

2011).[19] Figure 1 shows the different steps of the selection process. As the outcome of each public lottery was shared with those attendance, no promises were made to the control group in terms of future coverage. Yet, during the information campaign, the villages were reassured that further negotiations were on the way to scale-up the program at a later stage (see MCA, 2009, p. 9). To this day, the program has not taken place in the randomly-selected control villages.

Figure 1: Selection of treated villages within commune



Source: Author's illustration based on information collected during the field survey.
Note: See Table A-1 for further details about the number of villages in each category across communes.

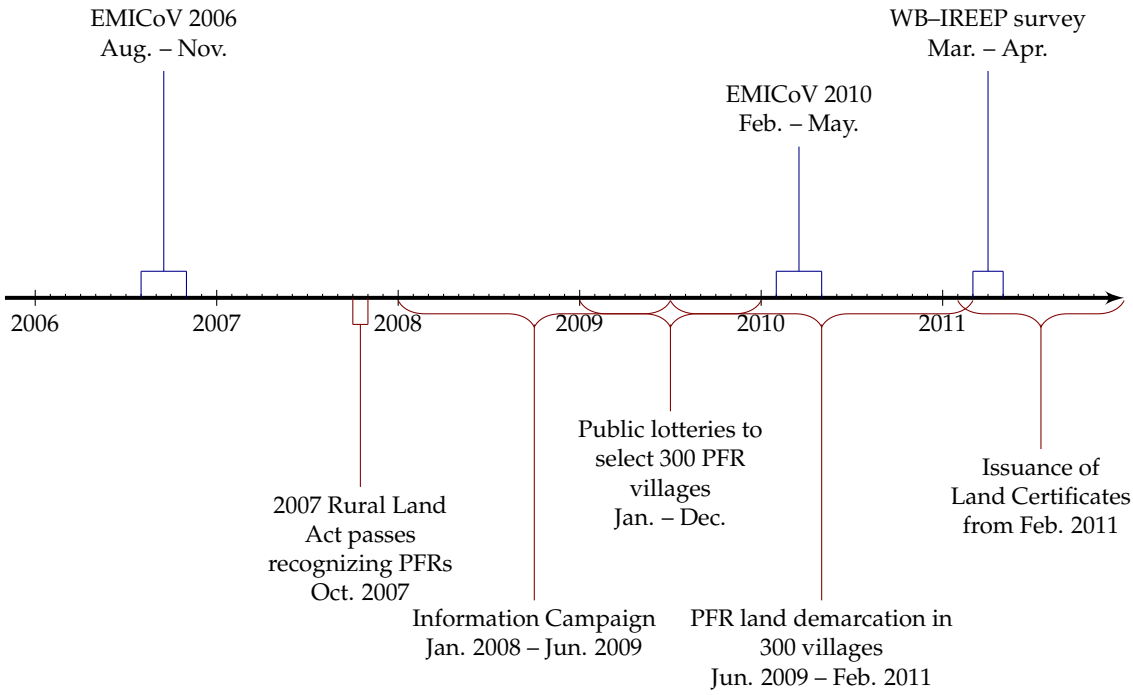
According to MCC's administrative data, land demarcation activities were completed in 283 treated villages of the 300 villages assigned to the PFR intervention at the time of our survey. Land demarcation was still ongoing in an additional eight villages, and had not started in three villages. Six villages refused to cooperate towards the production of an ETF and were dropped by the program.

[19] Each set of two lotteries was structured to allow for villages sampled in the 2006 national household survey (*enquête modulaire integrée sur les conditions de vie*, EMICoV) to be over-represented in the program, thus allowing for the EMICoV to be used for this evaluation. Since the EMICoV employs a random sampling strategy at the commune level, this should not affect the validity of our identification. For robustness, we account for this lottery stratification in our econometric analysis.

4.2 Data

We exploit three sources of data to analyze the impact of land demarcation in Benin: administrative data compiled from the PFR implementation units help us establish the intervention roadmap and verify execution of the land demarcation activities; secondary national household survey data provide pre-intervention balance checks; and primary national household survey data formally document impact.

Figure 2: PFR implementation and data collection timeline



Source: Author's illustration based on data collected during the field survey.

First, we use administrative monitoring and evaluation data from the MCC and Millennium Challenge Account-Benin to document the village-level eligibility for the PFR, the outcome of the program assignment lottery, and the implementation schedule across treated villages.[20] A timeline of relevant implementation and data collection milestones is presented in Figure 2.

Second, we exploit the 2006 national EMICoV survey data to establish pre-intervention balance between treatment and control communities. This survey was conducted by the National Institute of Statistics and Economic Analysis (INSAE), and its sample covers 3,900 households in 160 villages (91 treated and 69 control) of our experimental sample. We use the 2006 EMICoV

[20] Implementation data are only provided conditional on being selected in the lottery. From our field work and interaction with the implementation partners, we understand that no contamination took place in control villages.

to establish pre-intervention balance on a set of outcome variables.

Third, we rely on a rural household follow-up survey conducted by the World Bank and the Institute for Empirical Research in Political Economy (IREEP) in March/April 2011. Our sample followed the 2010 EMICoV sampling frame at the village level: 160 villages from the 2006 EMICoV sample were revisited, and an additional 129 villages were randomly selected to complement the 2006 sample.[21] In sum, our 2011 survey sample covers 291 villages: 191 treated and 98 control (see Table A-8). The selection of villages was done randomly and stratified at the level of the commune, with on average 7 villages surveyed per commune.[22] The geographic coverage of our survey is expansive, spanning the entire range of Benin's agro-climatic zones with data in nine of Benin's twelve regions (*départements*). Overall, 3,507 households were interviewed (approximately 12 per village), with detailed information on 6,572 parcels used by these households.[23]

The 2011 multi-topic household survey instrument covers a detailed set of questions related to basic demographics, parcel land use, intra-household control of resources, and agricultural production. The land modules elicit a rich set of information on perceived tenure security, perceived land rights, market participation, and investment at the parcel level, while the agricultural modules allow for productivity estimates at the agricultural plot level. A community questionnaire was also administered to a set of key respondents with diverse responsibilities in each village. It includes information on village-level demographics, infrastructure, social services, economic activities, mode of land acquisition, land market activity, and conflicts (see Table A-7 for descriptive statistics of villages and Table A-8 for a comparison of treated and control villages).

[21]The initial vision for the evaluation was to build a panel dataset using the 2006, 2010, and 2011 survey rounds. There were two sets of challenges with this undertaking: survey fieldwork issues and analytical limitations. From a fieldwork standpoint, the tracking information from the 2006 EMICoV was insufficient to verify household-to-household or parcel-to-parcel matching. This problem persisted in the 2010 EMICoV survey, and the replacement rate was too high to take advantage of the panel. In addition, the EMICoV questionnaire did not ask about outcomes which are critical for our analysis. Given these challenges, we exploit our 2011 cross-section for our main analysis.

[22]The number of villages sampled varied slightly from commune to commune since the EMICoV randomly sampled enumeration areas (EAs) in both rural and urban strata, and EAs do not always correspond to one village. We dropped all urban EAs, and our 2011 individual sample was drawn from village listings, however, to align with the program implementation.

[23]Our definition of "parcel" mimics that used by the PFR program in establishing its primary unit of intervention. A parcel thus refers to a contiguous tract of land used and/or controlled by an individual in a given household for any of a range of purposes (including agricultural). A parcel can be sub-divided into one or several agricultural plots. An "agricultural plot" is a contiguous piece of land that is managed under a common crop management system, with one or multiple crops being grown on it. In our analysis, while we record information at the plot level within a given parcel, we aggregate the responses up to the parcel level to be consistent with the primary unit of intervention.

In line with the program coverage, we limit our study sample to households with at least one parcel landholding in their village of residence. In practice, 85% of households have at least one landholding in the same village as their homestead, 9% have all of their landholding(s) outside their village of residence, and 6% have no landholdings (see Table A-3). This yields a working sample of 2,972 households with a total of 6,094 parcels (5,329 of which are located in the household's village of residence).[24] Although retrospective agronomic data were collected for both rainy seasons in Benin, we limit our analysis to the major rainy season to ensure comparability with northern Benin's uni-modal rainfall distribution.

4.3 Balance

We perform two classes of balance checks. First, we employ the 2006 EMICoV data from 160 of our sampled villages to establish pre-intervention balance on a range of covariates and outcomes. Table 1 presents differences in means across treatment and control households in the 2006 EMICoV sample. While this balance check does not refer to our study sample, it helps further validate the lottery across the outcome space. We confirm balance across treatment and control communities on a range of key observable characteristics prior to program implementation. The average household head is, however, significantly older by 1.59 years and has 0.22 fewer year of education in the treatment group relative to the control. Although these differences vanish in our full 2011 sample, we control for these observables in all regression models.

Second, we establish balance on plausibly exogenous characteristics in our 2011 follow-up survey, which is important since the 2006 and 2011 survey samples do not fully overlap. Mean comparisons reported in Table 2 show that households (Panel A) and parcels (Panel B) are balanced across treatment and control groups, with the exception of a marginally significant difference in household size and the presence of sandy soil. We next check for balance in non-varying village characteristics (see Table A-8). Access to a paved road and the presence of commercial activity are the only potential observable challenges to our identification. Overall, we conclude that the program lotteries yielded balance across the treatment and control sub-samples.

[24] A threat to our identification could stem from differences in migratory patterns across treatment, or from a farming household switching out of agriculture as a result of the land demarcation process. Should this be the case, our sampling frame would not be adequate, and our outcome space would fail to capture relevant changes in investment. While we do not have data on migration patterns over the duration of the program, we do not find that land demarcation activities affected participation in agricultural activities (see Table A-10), and the proportion of parcels cultivated during the twelve months preceding the survey is the same across treated and control villages. Likewise, cultivated landholdings were harvested at the same rate across treatment and control groups.

Table 1: Household characteristics across treatment groups in 2006

	Treated		Control		Diff.	
	Mean	Std. Dev.	Mean	Std. Dev.	coeff.	s.e.
Female headed hh†	0.19	0.39	0.20	0.40	-0.00	(0.02)
Age of hh head (years)	45.30	16.56	43.35	15.55	1.59	(0.64)**
Education (years)	1.31	2.61	1.52	2.80	-0.22	(0.13)*
Household size	5.26	3.12	5.28	3.21	-0.01	(0.14)
Household has a landholding†	0.85	0.36	0.85	0.36	0.02	(0.02)
HH sold a land in last 3 years†	0.02	0.15	0.03	0.16	-0.00	(0.01)
Landholder cultivated a plot†	0.88	0.33	0.88	0.33	0.02	(0.02)
Number of landholdings	1.82	1.37	1.85	1.41	0.10	(0.12)
Landholder can sell land†	0.44	0.50	0.45	0.50	-0.01	(0.04)
Household has a female landholder†	0.31	0.46	0.39	0.49	-0.04	(0.03)
- Number of landholdings	1.39	0.76	1.45	0.87	-0.03	(0.08)
Household with female land tiller†	0.66	0.47	0.67	0.47	0.03	(0.03)
- cultivated her plot	0.26	0.44	0.32	0.46	-0.02	(0.03)
- helped a fellow member	0.53	0.50	0.52	0.50	0.04	(0.04)
Daily consumption per cap. (2005 $)	1.04	0.93	1.08	0.80	-0.02	(0.06)
Own food production (2005 $)	0.10	0.13	0.10	0.17	-0.00	(0.01)
Number of of households	1,394		1,137		2,531	

Note: The table compares household characteristics across *treated* and *control* villages that were preselected for the land registration program. The sample used for this table is restricted to those households in treated and control villages which are covered by the EMICoV survey in 2006. The statistics reported under the heading "Treated" refer to the sub-sample of households located in one of the villages selected for a PFR. Under the heading "Control" we report the statistics from households living in villages that took part in and lost the lotteries. The column "diff." describes the variation of household characteristics across treatment and control groups in 2006.
Standard errors are in parentheses and are clustered at the primary sampling unit level. The coefficients reported in column "coeff." are obtained by regressing each variable on the treatment variable while controlling for the lottery pool fixed effects. Significance levels for coefficients are reported for t-tests of the equality of the means across treatment groups. Significance levels are reported as follows: * p<0.10, ** p<0.05, *** p<0.01.
† Indicates dummy variables.

4.4 Program Implementation

We now present empirical evidence on program implementation. At the time of the follow-up survey that we conducted, the land demarcation activities had started in all the villages randomly selected for the land registration program. The activities were completed in 96% of the treated villages of our sample and took on average three months for completion. On average, the demarcation activities had been completed for 11 months by March 2011 (see Table 3). Hence, for most households located in the treated villages land disputes had been resolved and agricultural parcels located in the villages had been demarcated with cornerstones by the beginning of the 2010–11 agricultural season.[25]

[25]Endogenous timing of the demarcation activities is a concern to our identification. While the ITT estimates are, by construction, immune to this source of bias, the land demarcation activities were not completed in all the treated villages at the time of the survey (see Figure A-2 for a visual representation of the distribution of treated villages where land demarcation activities ended twelve months in advance of our March 2011 survey). We find

Table 2: Household and Parcel characteristics across treatment groups

	Treated		Control		Diff.	
	Mean	Std. Dev.	Mean	Std. Dev.	coeff.	s.e.
Panel A: Household characteristics						
Female-headed HH†	0.17	0.37	0.16	0.37	0.01	(0.02)
Age of HH head (years)	46.78	15.21	47.12	15.38	-0.32	(0.64)
Household head can read/write†	0.24	0.43	0.23	0.42	0.03	(0.02)
Household size	6.28	3.27	6.50	3.37	-0.22	(0.13)*
Number of households	2,002		970		2,972	
Panel B: Parcel characteristics						
Type of soil :						
- *sandy*	0.19	0.39	0.14	0.35	0.04	(0.02)*
- *lateritic*	0.31	0.46	0.30	0.46	0.01	(0.03)
- *hydromorphic*	0.17	0.38	0.15	0.35	0.00	(0.03)
- *ferralitic*	0.27	0.45	0.36	0.48	-0.03	(0.03)
- *other*	0.05	0.22	0.05	0.23	-0.01	(0.01)
Walking distance from homestead:						
- *00–05 minutes*	0.16	0.36	0.15	0.36	-0.02	(0.01)
- *06–15 minutes*	0.15	0.35	0.12	0.33	0.02	(0.01)
- *16–30 minutes*	0.17	0.38	0.18	0.39	-0.00	(0.01)
- *31–45 minutes*	0.14	0.35	0.15	0.36	-0.01	(0.01)
- *46–60 minutes*	0.12	0.33	0.12	0.33	0.01	(0.01)
- *> 1 hour*	0.26	0.44	0.27	0.44	0.00	(0.02)
Number of parcels	3,559		1,770		5,329	

Note: The table compares household and parcel characteristics across treated and control villages. Standard errors (s.e.) are reported in parentheses and are clustered at the village level. The coefficients reported in column "coeff." are obtained from regressing each variable on the treatment variable controlling for the lottery pool fixed effects. Significance levels are reported as follows: * p<0.10, ** p<0.05, *** p<0.01.

† Indicates dummy variables.

Table 3: Status of land demarcation activities in treatment villages in March 2011

	Obs	Min	Mean	Median	Std. dev.	Max
Land survey has started†	191	1	1	1	0	1
- *nb. of months since start*	191	1	13.9	14	4.42	21
- *land survey is completed*†	191	0	0.96	1	0.19	1
- *nb. of months since completion*	184	0	11.4	11	4.05	19
- *duration in months*	184	1	2.95	3	1.75	14
Land survey ended 12 months ago	191	0	0.48	0	0.50	1

Note: The table shows statistics on the implementation of land demarcation activities — *enquêtes topo-foncieres* (ETF) — in treated villages in our sample as of March 2011.

† Indicates dummy variables.

no significant difference between treated villages where the survey started earlier and those where the survey started later (see Table A-9) except for the fact that the program started earlier in the northern region of the country

Table 4: Awareness of the land registration program across treatment groups

	Treated		Control		Difference	
	Mean	Std. Dev.	Mean	Std. Dev.	coeff.	s.e.
HH head involved in LMC[†] [a]	0.05	0.22	0.03	0.16	0.03	(0.01)***
HH head heard of PFR[†]	0.86	0.35	0.25	0.43	0.59	(0.03)***
HH head attended meeting on PFR[†]	0.49	0.50	0.06	0.23	0.41	(0.02)***
If yes, how often?	1.37	2.37	0.12	0.60	1.18	(0.09)***
HH head says PFR took place in the village[†]	0.84	0.36	0.06	0.24	0.77	(0.02)***
HH has official evidence of land right[†]	0.09	0.29	0.11	0.31	-0.01	(0.01)
Number of households	2,002		970		2,972	

Note: The table compares different measures related to awareness of the ongoing land registration program across treatment status. Standard errors (s.e.) are reported in parentheses and are clustered at the village level. The coefficients reported in column "coeff." are obtained from regressing each variable on the treatment variable controlling for the lottery pool fixed effects. Significance levels are reported as follows: * p<0.10, ** p<0.05, *** p<0.01.

[a] LMC stands for local land management commissions (LMC).

[†] Indicates dummy variables.

Turning to awareness of and participation in the program (Table 4), we find that more than eight out of ten households confirmed that a land registration program was ongoing in their village compared to less than one in ten households in the control villages. Likewise, information about the program was easier to access in the treated villages. Half of all households in treated villages attended at least one meeting about the land registration program against less than one in ten households in the control villages (Table 4). We find no marked differences between households in treated and control villages with regard to trust toward formal institutions for matters of land dispute settlement. Furthermore, across treatment groups, around one in ten households reports having an official evidence of land right. This confirms that no land certificate was issued at the time of the survey and that very few households have documentary evidence of their land rights.

However, awareness of and participation in the PFR program varies significantly across gender of the household head (Table A-6, Panel B). Female-headed households in treated villages are 14 p.p. less likely to have heard about the program (relative to male-headed households in treated villages), and are less likely to have taken part in PFR meetings both at the extensive (23 p.p.) and intensive (0.79) margins (differences significant at the 1% level). These differences could be the result of gender-specific demand-side constraints, due to customary law practices. Under customary law, women-headed households would only have ownership rights over land that they purchased or that was gifted to them. Since the PFR formalizes existing

where the density of early treated villages is higher. Selection concerns are further attenuated by the fact that the identification strategy compares each village selected for a PFR to its randomly non-selected peer(s) that took part in the same lottery pool.

customary rights, women-headed households may be less likely to have an interest in the program. However, we cannot reject that a supply-side gender bias may also be at play, whereby program implementation teams were less likely to engage with female-headed households.

Table 5: Landholding delimitation across treatment status

	Treated		Control		Difference	
	Mean	Std. Dev.	Mean	Std. Dev.	coeff.	s.e.
Type of land delimitation:						
- no border	0.25	0.43	0.35	0.48	-0.12	(0.02)***
- trees	0.37	0.48	0.53	0.50	-0.11	(0.03)***
- corner stones	0.32	0.47	0.06	0.24	0.25	(0.02)***
- other	0.06	0.24	0.07	0.25	-0.01	(0.01)
Number of parcels	4,071		2,023		6,094	

Note: The table describes the type of delimitation applied to each landholding across treatment status. Standard errors (s.e.) are reported in parentheses and are clustered at the village level. The coefficients reported in column "coeff." are obtained by regressing each variable on the treatment variable while controlling for the lottery pool fixed effects. Significance levels are reported as follows: * p<0.10, ** p<0.05, *** p<0.01.

In addition, assignment to the PFR also affected the type of markers used to delimit parcels (see Table 5). Households in treated villages were more likely to report that their parcel is demarcated with cornerstones, as opposed to trees in the control villages. The proportion of parcels demarcated with cornerstones increased by 25 p.p., from 6% in the control villages to 32% in the treated villages.[26] We also observe that the proportion of parcels without a clear delimitation decreased by 12 p.p. in the treated villages.

4.5 Results

To estimate the impact of demarcation, we regress the program dummy $\mathbf{t}_{ijk}$ on parcel and household level measures of tenure security, crop choice, input use and investment, land use, and productivity using the following model:

$$\mathbf{y}_{ijk} = \alpha + \beta \cdot \mathbf{t}_{jk} + \phi \cdot \mathbf{x}_{ijk} + \gamma_k \cdot \mathbf{lottery}_k + \varepsilon_{ijk} \tag{3}$$

where $\mathbf{y}_{ijk}$ is the outcome of parcel i in village j that took part in lottery pool k, is a variable equal to one if village j in lottery k is randomly selected for a PFR, $\mathbf{x}_{ijk}$ is a vector of exogenous controls (at the household and parcel levels), $\mathbf{lottery}_k$ is a lottery fixed-effect, and ε_{ijk}

[26] We are likely underestimating the proportion of parcels with cornerstones in treated villages. The households whose parcels were demarcated both with trees and with new cornerstones could have reported either marker during the survey.

is a random error component.[27] The random assignment of the program at the village level establishes our identification, and we exploit within-lottery variations to recover the intention-to-treat (ITT) effect of demarcation.[28] All standard errors are clustered at the unit of randomization (villages) to account for possible intra-village correlation in the outcomes of interest (Duflo et al., 2008).

The four panels of Table 6 report regression results using Equation 3 for the following categories of outcomes: tenure security (Panel A); investment and land transfers (Panel B); agricultural activities (Panel C); and agricultural production (Panel D).[29] For each outcome, we report the mean of the control group, as well as the standard deviations of non-binary outcomes, to assign a relative magnitude to our point estimates. The results from Table 6 also allow us to test the predictive power of the model presented in Section 3.[30]

We first estimate in Table 6 the effect of land demarcation on a key intermediate outcome, parcel delineation. As expected, we find strong evidence of a higher share of delineated parcels in treatment villages. The program increases the likelihood of having borders by 27 percentage points relative to control parcels, an almost five-fold increase relative to the control mean (6%). This border effect translates into a significant (at the 10% level) four percentage point improvement in perceived tenure security, as measured by a household head's self-reported right to sell agricultural land (Table 6, Panel A). This finding is suggestive of a market-oriented shift toward perceived land ownership among treated households.[31] However, no treatment effect is detected on a household's fear of expropriation during fallow, the incidence of land conflict, or other rights over land. The null result on self-reported fear of land loss is not surprising, given

[27]For the analysis at the household level, the control variables include the gender, age and level of education of the household head, the number of male members and female members, the number of children, the religion of the head, the marital status of the household head and status in the village (village chief, village group leader, village group member, member of village council, lineage chief),and a binary variable equal to 1 when the household head is a public servant. Parcel-level regressions additionally control for area of the parcel, gender of the parcel manager, and parcel-home travel time. All regressions also control for enumerator fixed effects.

[28]All regressions include lottery pool fixed effects to account for the randomization procedure (Bruhn and McKenzie, 2009).

[29]See Table A-2 for more details on the outcomes of interest. An analysis of the intra-household impact of the PFR was also conducted. The PFR registered no significant impact on women's involvement in household land decisions, their self-reported control over household agricultural revenue, or on spousal disputes (results available upon request).

[30]When looking at production outcomes, observe that $\mathbf{y}_{ijk}$ is the analog of $F(.)$ in the model presented in Section 3, where $F(.)$ may measure the production of perennials or the production on outside-village parcels. Similarly, a change in treatment status $\mathbf{t}_{ijk}$ is analogous to a property right improvement dR. Since the parameter of interest β identifies $\frac{\mathbf{y}_{ijk}}{\mathbf{t}_{ijk}}$, it is an estimate of the overall effect on production $\frac{dF(k)}{dR} = F'(k).\frac{dk}{dR}$ in the model. When $\mathbf{y}_{ijk}$ is taken to be an input, then the corresponding β in that regression is an estimate of $\frac{dk}{dR}$.

[31]Interestingly, this increase in the self-reported right of treated heads to sell their land does not coincide with a decline in the rights of other household or family members. The full set of results on perceived land rights is reported in Table A-12.

Table 6: Effects of land demarcation activities

	Obs.	Control		ITT	
		Mean	Std. dev.	Coeff.	s.e.
Parcel has clear borders[†]	6,094	0.061		0.270***	(0.02)
Panel A: Tenure security					
Fear of land loss during fallow[†]	6,094	0.116		0.007	(0.01)
Land conflict[a †]	6,094	0.052		-0.009	(0.01)
Perceived land rights					
- A HH member will inherit land	3,582	0.829		-0.007	(0.02)
- The HH head can lend/rent-out/give the parcel	3,582	0.731		0.017	(0.02)
- The HH head can pledge land	3,582	0.719		0.000	(0.02)
- The HH head can sell land	3,582	0.554		0.040*	(0.02)
Panel B: Investment and land transfers					
Investment in tree planting[a †]	6,094	0.040		0.017**	(0.01)
Started fallowing parcel[a †]	6,094	0.010		0.004	(0.00)
Parcel is rented in/out[†]	6,094	0.147		-0.014	(0.01)
- rented in	6,094	0.082		0.002	(0.01)
- rented out	6,094	0.065		-0.016*	(0.01)
Panel C: Agricultural activities[b]					
Total land size (ha)	2,972	6.236	13.827	0.320	(0.54)
Participation in agriculture[†]	2,972	0.902		0.006	(0.01)
Share of land size cultivated	2,675	0.538	0.323	-0.001	(0.01)
Panel D: Agricultural production[c]					
Type of crop cultivated					
Cereals[†]	6,094	0.505		0.001	(0.02)
Pulses[†]	6,094	0.150		0.003	(0.01)
Roots and tubers[†]	6,094	0.245		-0.005	(0.02)
Vegetables[†]	6,094	0.052		-0.004	(0.01)
Cash crops[d †]					
- annual	6,094	0.037		0.001	(0.01)
- perennial	6,094	0.067		0.026**	(0.01)
Inputs					
- farm labor supply (person-days/ha)	3,994	202.854	261.071	1.690	(9.88)
- fertilizer/high-yield seeds[†]	3,994	0.272		0.018	(0.02)
Output					
- total output (Log USD)	3,677	6.135	1.358	-0.043	(0.06)
- yield (Log USD of total output/ha)	3,677	6.379	1.064	0.023	(0.05)

Note: The table shows estimates of village-wide land demarcation activities on several variables. Each row corresponds to an estimation where the dependent variable (reported in the first column) is regressed on a dummy variable equal to 1 when the household lives in a village that carried out a village wide land demarcation activities (see Equation 3) The column "Obs." reports the number of households and the column "Control mean" shows the average level of the dependent variable in the control villages. Column "Coeff. ITT" shows the effect of being in a PFR village.

The standard errors are clustered at the village level and are reported in parentheses. Each estimation includes the lottery pool fixed effects. Significance levels are denoted as follows: * p<0.10, ** p<0.05, *** p<0.01.

[a] The reference period is the previous twelve months.

[b] These estimations are performed at the household level; all others are performed at the parcel level.

[c] Yield and inputs are reported for the agricultural season that starts with the main rainy season.

[d] Annual cash crops are cotton, pineapple, and sesame. Perennial cash crops include cashew, oil palm, teak, and acacia trees.

[†] Indicates dummy variables.

the methodological challenges associated with the measurement of perceived tenure security.

In line with our theoretical predictions, land demarcation also leads to a substantial increase in long-term investment (Table 6, Panel B). Treated parcels are 1.7 percentage points more likely to have a newly-planted tree—an effect that is nearly half the size of the control mean (4%). Meanwhile, the PFR land demarcation also leads to an initial tightening in land rental markets, with a 1.6 percentage point decline in the proportion of parcels rented or sharecropped out in treated villages. This effect is statistically different from zero (at the 10% level) and represents a 25% drop in rental market activity relative to control parcels. This result is consistent with the idea that land markets may have temporarily contracted as a result of land demarcation activities. Landowners may have reclaimed parcels that they rented or sharecropped out in an effort to reassert their land rights before the issuance of land certificates. Households in treated villages might also be waiting for the issuance of these land certificates before engaging in new land transactions.

Next, we assess the impact of demarcation activities on household participation in agriculture (Table 6, Panel C). We find that assignment to the program does not affect the total size of a household's landholdings in hectares, nor does it influence a household's decision to farm their land or the share of land that they cultivate.

Turning our attention to parcel-level agricultural outcomes, we find that PFR land demarcation increases the share of parcels growing perennial cash crops such as oil palm and teak (Table 6, Panel D). The intent-to-treat estimate, at 2.6 percentage points, corresponds to a 39% increase relative to the control mean. This finding is consistent with our model's prediction of a shift in investment toward long-term crop production under a partial improvement in property rights (as in Proposition 1 of our model). The result also aligns with the observed increase in tree investments. No effects on seasonal crops or annual cash crops are observed.

While demarcation activities do lead to an increase in long-run investments, they do not generate an initial increase in agricultural output, farm yields (measured as the log of the value harvested per hectare), or the use of productivity-enhancing inputs such as labor, fertilizer, or improved seeds. Given that it takes more than one year for these long-term investments to bear fruit, it is unsurprising that demarcation does not generate productivity gains at this early stage in implementation.[32]

[32] The gestation period for cashew and oil palm trees, for example, is at least four to five years.

4.6 Gender

We now explore heterogeneity in the impact of land demarcation activities by gender of the household head. In practice, we augment Equation 3 as follows:

$$\mathbf{y}_{ijk} = \alpha + \beta \cdot \mathbf{t}_{jk} + \psi \cdot \mathbf{gender}_{ijk} + \lambda \cdot \mathbf{t}_{jk} \cdot \mathbf{gender}_{ijk} + \phi \cdot \mathbf{x}_{ijk} + \gamma_k \cdot \mathbf{lottery}_k + \varepsilon_{ijk} \quad (4)$$

where $\mathbf{gender}_{ijk}$ takes a value of 1 if parcel i is operated by a female-headed household. We report the coefficients β, ψ, and λ on our outcomes of interest (tenure security and investment; agricultural activities; crop choice; and, labor supply) in Table 7a through Table 7d. Relative to the existing gender gap (i.e., the gender gap observed within control villages), a significant coefficient for λ indicates that the program led to a narrowing (or widening) of the gender gap within treated communities for that specific outcome.[33]

Table 7a: Gender differentiated effects of land demarcation activities on tenure security and investment

	Border	Fear	Conflict	Fallow	Tree planting	Land rental	
						Rented in	Rented out
Female-headed HH (ψ)	0.0441*	0.0533**	0.0018	-0.0077	-0.0332**	0.0468*	-0.0191
	(0.024)	(0.025)	(0.017)	(0.005)	(0.014)	(0.027)	(0.022)
Treated village (β)	0.2822***	0.0087	-0.0103	0.0025	0.0159**	0.0057	-0.0192*
	(0.023)	(0.013)	(0.015)	(0.003)	(0.008)	(0.013)	(0.010)
× *Female-headed HH* (λ)	-0.0845**	-0.0134	0.0055	0.0125*	0.0078	-0.0272	0.0178
	(0.037)	(0.032)	(0.019)	(0.007)	(0.016)	(0.035)	(0.024)
Number of parcels	6,094	6,094	6,094	6,094	6,094	6,094	6,094
$\beta + \lambda$	0.1977***	-0.0047	-0.0047	0.0150**	0.0237*	-0.0214	-0.0013
	(0.039)	(0.032)	(0.019)	(0.006)	(0.014)	(0.036)	(0.023)

Note: Robust standard errors are reported in parentheses. They are clustered at the village level and all regressions include household and landholding control variables, enumerator fixed effects, and lottery pool fixed effects. Significance levels are denoted as follows: * p<0.10, ** p<0.05, *** p<0.01.

We first observe a significant gender difference in program coverage across male and female-headed households (col. 1, Table 7a). Land demarcation activities caused a 28 p.p. increase in the proportion of delineated parcels among male-headed households. The effect on parcels managed by female-headed households – though still within the 95% confidence interval of male results – is 8.5 p.p. lower (difference significant at the 5% level). This gender gap in coverage is in line with significant gender differences in awareness and participation presented previously. Yet we fail to detect a differential impact of the program on measures of tenure security, including the perceived fear of land loss or the prevalence of land conflict, across parcels

[33] Further evidence on gender gaps within control villages is presented in Table A-5.

managed by male- and female-headed households.[34] The large and significant coefficient for fear of land loss among female-headed households in control communities, meanwhile, points to a substantial gender gap in perceived tenure security in rural Benin.

Second, we investigate gender differences in the impact of land demarcation on patterns of investment and land market participation (cols. 4-6, Table 7a). We use two measures of investment in the past year: leaving a parcel fallow and planting trees. Our estimates suggest that assignment to the PFR fully increases fallowing exclusively among women-headed households. This is a large effect: fallowing increases by 1.5 p.p. for female-headed households in PFR villages, relative to 1% of households practicing fallowing in the control group (significant at the 5% level).[35] This finding suggests that PFR land demarcation activities may have allayed the fear of land loss during fallow for women—leading them to undertake an important investment to replenish parcel soil fertility. Additionally, we find that the significant effect of the program on tree investment documented in Table 6 holds equally for male- and female-headed households. Similarly, the observed significant contraction in the renting out of parcels (Table 6) does not vary by gender of the household head.

Table 7b: Gender differentiated effects of land demarcation activities on agricultural activities

	Parcel size (ha)	Cultivation	Labor	Fertilizer	Output	
					total	per ha
Female-headed HH (ψ)	-0.9130***	-0.0097	10.9172	-0.0277	-0.4799***	-0.0155
	(0.328)	(0.034)	(21.381)	(0.041)	(0.123)	(0.101)
Treated village (β)	0.1575	-0.0022	2.3366	0.0103	-0.0305	0.0542
	(0.331)	(0.016)	(10.427)	(0.021)	(0.065)	(0.052)
$\times$ *Female-headed HH* (λ)	-0.7671	0.0455	-0.7462	0.0528	-0.0861	-0.2158*
	(0.571)	(0.043)	(28.005)	(0.049)	(0.146)	(0.123)
Number of parcels	6,094	6,094	3,994	3,994	3,677	3,677
$\beta + \lambda$	-0.6096	0.0433	1.5904	0.0631	-0.1166	-0.1616
	(0.464)	(0.041)	(26.350)	(0.049)	(0.141)	(0.121)

Note: Robust standard errors are reported in parentheses. They are clustered at the village level and all regressions include household and landholding control variables, enumerator fixed effects, and lottery pool fixed effects. Significance levels are denoted as follows: * p<0.10, ** p<0.05, *** p<0.01.

In Table 7b, we test for gender differences in the effects of demarcation on agricultural production. We observe no significant difference in impact (nor any overall impact) on self-reported land size, cultivation use, farm labor intensity, or fertilizer/improved seed use. Yet initial de-

[34] The program also yielded no significant gender differences in impact on self-reported land rights (results available upon request).

[35] The mean level of fallowing for female-headed household parcels in control villages is nearly 0.

marcation activities do lead to a gender gap in agricultural yields. Parcels held by female-headed households have yields (measured as the log of harvested value per hectare) that are 22% lower (significant at the 10% level) than yields found on treated parcels held by male-headed households.[36] This striking result warrants further examination.

Table 7c: Gender differentiated effects of land demarcation activities on types of crop cultivated

	Cereals	Pulses	Roots	Vegetables	Cash crops[a]	
					Annual	Perennial
Female-headed HH (ψ)	-0.0139	0.0265	-0.0309	0.0131	-0.0164**	-0.0460**
	(0.032)	(0.026)	(0.030)	(0.024)	(0.007)	(0.018)
Treated village (β)	-0.0082	0.0023	-0.0164	-0.0022	0.0008	0.0223**
	(0.017)	(0.012)	(0.015)	(0.008)	(0.008)	(0.011)
$\times$ *Female-headed HH* (λ)	0.0343	-0.0086	0.0227	0.0020	0.0116	0.0117
	(0.043)	(0.030)	(0.037)	(0.026)	(0.009)	(0.021)
Number of parcels	6,094	6,094	6,094	6,094	6,094	6,094
$\beta + \lambda$	0.0260	-0.0062	0.0062	-0.0002	0.0124	0.0340*
	(0.042)	(0.027)	(0.037)	(0.024)	(0.008)	(0.020)

Note: The standard errors are clustered at the village level and are reported in parentheses. Each estimation includes household and landholding control variables, enumerator fixed effects, and lottery pool fixed effects. Significance levels are denoted as follows: * p<0.10, ** p<0.05, *** p<0.01.

[a] Annual cash crops are cotton, pineapple, and sesame. Perennial cash crops include cashew, oil palm, teak, and acacia trees.

Table 7d: Gender differentiated effects of land demarcation activities on agricultural activities

	Household level			Hired	Unpaid
	Children	Women	Men	workers	workers
Female-headed HH (ψ)	11.4983***	20.8179***	-28.5540***	13.3049	-6.1499*
	(3.691)	(7.425)	(7.367)	(13.393)	(3.651)
Treated village (β)	1.0959	1.3784	0.7164	-0.0020	-0.8521
	(1.414)	(3.158)	(5.264)	(7.198)	(2.879)
$\times$ *Female-headed HH* (λ)	-6.1889	16.1626	1.9612	-23.0988	10.4178
	(4.920)	(12.042)	(8.595)	(15.434)	(6.829)
Number of parcels	3,994	3,994	3,994	3,994	3,994
$\beta + \lambda$	-5.0930	17.5410	2.6776	-23.1009	9.5657
	(4.717)	(11.499)	(7.438)	(14.179)	(6.975)

Note: Robust standard errors are reported in parentheses. They are clustered at the village level and all regressions include household and landholding control variables, enumerator fixed effects and lottery pool fixed effects. Significance levels are denoted as follows: * p<0.10, ** p<0.05, *** p<0.01.

We next examine whether gender differences in crop choice (Table 7c) or farm labor (Table 7d)

[36] The overall treatment effect on female-headed household yields, however, is insignificant.

could be driving the differential impact on farm yields. The results from Table 7c suggest that selection into the PFR did not result in any overall gender differences in crop choice. Indeed, parcels from male- and female-headed households are equally likely to have perennial cash crops as a result of PFR demarcation activities. The disaggregated farm labor results from Table 7d also fail to reveal a discernible pattern across male- and female-controlled parcels.

4.7 Gender and parcel location

Our gender-differentiated analysis provides evidence that the effects of land demarcation vary by sex of the household head. However, a puzzle from Table 7b remains: why do agricultural yields drop on treated parcels held by female-headed households (relative to treated male-headed households)? To shed light on this question and to test the predictions from our model, we exploit the partial coverage of the PFR demarcation process. The program only demarcated those parcels situated within the boundaries of treated villages. This feature of the program allows us to test for differences in treatment effects on parcels located within and outside of the village.[37] Moreover, as the model presented in Section 3 suggests, these effects also likely vary with initial levels of tenure security. Given the relatively weaker tenure security initially experienced by female-headed households, we explore gender as a source of heterogeneity and report our results by gender of the household head.

In practice, we revise Equation 3 as follows:

$$\mathbf{y}_{ijk} = \alpha + \beta \cdot \mathbf{t}_{jk} + \eta \cdot \mathbf{outside}_{ijk} + \nu \cdot \mathbf{t}_{jk} \cdot \mathbf{outside}_{ijk} + \phi \cdot \mathbf{x}_{ijk} + \gamma_k \cdot \mathbf{lottery}_k + \varepsilon_{ijk} \quad (5)$$

where $\mathbf{outside}_{ijk}$ takes a value of 1 if parcel i is located outside the village boundaries.[38] We report the coefficients β, η, and ν on our outcomes of interest (tenure security and investment; agricultural activities; crop choice; and, labor supply) in Table 8a through Table 8d. To document the differential effects by gender, we present our results for both split (Panels A and B) and pooled (Panel C) samples.

We begin by examining the location-specific effects of land demarcation on tenure security and investment in Table 8a. We find that, in line with program implementation, assignment to the

[37] A given parcel's likelihood of being inside the landholder's village does not vary by gender (see Table A-4).

[38] This indicator variable is based on the household's self reported location of the parcel. The location variable is also consistent with other parcel distance measures. For example, parcels located more than one hour's walking distance from the dwelling are significantly more likely to be located outside of the village (see Table A-4).

Table 8a: Differentiated effects of land demarcation activities on tenure security and investment across location of the parcels

	Border	Fear	Fallow	Tree planting	Land rental	
					Rented in	Rented out
Panel A: Female-headed households						
Parcel is outside the village (η)	0.032	0.017	0.046	0.031	0.174**	0.063
	(0.051)	(0.087)	(0.040)	(0.035)	(0.075)	(0.077)
HH lives in treated village (β)	0.159***	-0.035	0.020**	0.004	0.018	0.024
	(0.041)	(0.038)	(0.009)	(0.015)	(0.036)	(0.028)
$\times$ *parcel is outside the village* (ν)	-0.077	0.117	-0.054	-0.006	-0.093	-0.131*
	(0.071)	(0.094)	(0.041)	(0.041)	(0.083)	(0.075)
Number of parcels	907	907	907	907	907	907
$\beta + \nu$	0.082	0.082	-0.034	-0.002	-0.075	-0.107
	(0.07)	(0.10)	(0.03)	(0.04)	(0.10)	(0.07)
Panel B: Male-headed households						
Parcel is outside the village (η)	0.027	0.015	-0.015***	-0.017	0.052*	0.029
	(0.03)	(0.03)	(0.00)	(0.01)	(0.03)	(0.02)
HH lives in treated village (β)	0.310***	0.004	0.001	0.017*	0.007	-0.021**
	(0.02)	(0.01)	(0.00)	(0.01)	(0.01)	(0.01)
$\times$ *parcel is outside the village* (ν)	-0.179***	0.055	0.012*	-0.005	-0.003	-0.003
	(0.04)	(0.04)	(0.01)	(0.01)	(0.04)	(0.03)
Number of parcels	5,187	5,187	5,187	5,187	5,187	5,187
$\beta + \nu$	0.131***	0.059	0.013**	0.012	0.004	-0.024
	(0.04)	(0.04)	(0.01)	(0.01)	(0.03)	(0.03)
Panel C: All households						
Parcel is outside the village (η)	0.032	0.016	-0.007*	-0.012	0.073**	0.033
	(0.03)	(0.03)	(0.00)	(0.01)	(0.03)	(0.02)
HH lives in treated village (β)	0.292***	-0.000	0.004	0.018**	0.005	-0.014
	(0.02)	(0.01)	(0.00)	(0.01)	(0.01)	(0.01)
$\times$ *parcel is outside the village* (ν)	-0.170***	0.057	0.004	-0.005	-0.021	-0.018
	(0.04)	(0.04)	(0.01)	(0.01)	(0.04)	(0.02)
Number of parcels	6,094	6,094	6,094	6,094	6,094	6,094
$\beta + \nu$	0.122***	0.057	0.008	0.013	-0.017	-0.033
	(0.04)	(0.04)	(0.01)	(0.01)	(0.04)	(0.02)

Note: Robust standard errors are reported in parentheses. They are clustered at the village level and all regressions include household and landholding control variables, enumerator fixed effects, and lottery pool fixed effects. Significance levels are denoted as follows: * p<0.10, ** p<0.05, *** p<0.01.

PFR significantly increases the use of clear borders on parcels within rather than outside the village (Panel C). Parcels located within the boundaries of a treated village are 58% (17 pp.) more likely to have clear borders, relative to those located just outside treated villages (difference significant at the 1% level). While the larger sample and point estimates on male-headed household parcels allows for a more precise estimation of the spatial differences (Panel B), the point estimates on the female sample suggest the same pattern: parcels outside the village are

Table 8b: Differentiated effects of land demarcation activities on agricultural activities across location of the parcels (Parcel level)

	Parcel size (ha)	Cultivation	Labor	Fertilizer	Output	
					total	per ha
Panel A: Female-headed households						
Parcel is outside the village (η)	0.052	-0.038	-62.377	-0.197	-0.033	-0.549*
	(0.241)	(0.100)	(60.793)	(0.129)	(0.375)	(0.322)
HH lives in treated village (β)	-0.627**	0.011	-26.219	0.061	-0.294*	-0.427***
	(0.306)	(0.048)	(37.233)	(0.061)	(0.150)	(0.148)
$\times$ *parcel is outside the village* (ν)	0.414	0.099	74.770	0.253**	0.197	0.775**
	(0.328)	(0.121)	(63.866)	(0.124)	(0.431)	(0.351)
Number of parcels	907	907	604	604	555	555
$\beta + \nu$	-0.213	0.109	48.551	0.314**	-0.098	0.348
	(0.22)	(0.11)	(49.50)	(0.13)	(0.38)	(0.30)
Panel B: Male-headed households						
Parcel is outside the village (η)	0.184	-0.068	-49.832***	-0.047	0.291**	-0.042
	(0.28)	(0.05)	(18.70)	(0.04)	(0.12)	(0.10)
HH lives in treated village (β)	0.206	0.001	-1.130	0.003	0.002	0.082
	(0.38)	(0.02)	(10.60)	(0.02)	(0.07)	(0.05)
$\times$ *parcel is outside the village* (ν)	-0.333	-0.017	26.062	0.070	-0.121	-0.101
	(0.60)	(0.06)	(29.56)	(0.05)	(0.16)	(0.14)
Number of parcels	5,187	5,187	3,390	3,390	3,122	3,122
$\beta + \nu$	-0.128	-0.016	24.932	0.073	-0.119	-0.019
	(0.54)	(0.06)	(29.50)	(0.05)	(0.15)	(0.14)
Panel C: All households						
Parcel is outside the village (η)	0.096	-0.066	-42.067***	-0.061	0.261**	-0.089
	(0.26)	(0.05)	(16.04)	(0.04)	(0.12)	(0.10)
HH lives in treated village (β)	0.061	0.005	-0.365	0.009	-0.043	0.018
	(0.31)	(0.02)	(10.14)	(0.02)	(0.07)	(0.05)
$\times$ *parcel is outside the village* (ν)	-0.153	-0.002	25.851	0.090**	-0.058	0.026
	(0.53)	(0.06)	(25.03)	(0.05)	(0.15)	(0.13)
Number of parcels	6,094	6,094	3,994	3,994	3,677	3,677
$\beta + \nu$	-0.092	0.003	25.486	0.099**	-0.101	0.044
	(0.46)	(0.06)	(24.91)	(0.05)	(0.14)	(0.13)

Note: Robust standard errors are reported in parentheses. They are clustered at the village level and all regressions include household and landholding control variables, enumerator fixed effects, and lottery pool fixed effects. Significance levels are denoted as follows: * p<0.10, ** p<0.05, *** p<0.01.

48% less likely than those within village boundaries to receive clear borders. We also uncover a spatial difference in fallowing when analyzing the sub-sample of male-headed household parcels. Male-headed households are significantly more likely (at the 10% level) to leave their parcels outside the village fallow as a result of demarcation. In contrast, the significant increase in fallowing among female-headed households associated with land demarcation is not spatially differentiated. Interestingly, the significant drop (at the 10% level) in renting out is

Table 8c: Differentiated effects of land demarcation activities on type of crop cultivated across location of the parcels

	Cereals	Pulses	Roots	Vegetables	Cash crops[a]	
					Annual	Perennial
Panel A: Female-headed households						
Parcel is outside the village (η)	0.068	-0.100***	-0.077	-0.063	0.007	0.047
	(0.109)	(0.037)	(0.051)	(0.052)	(0.005)	(0.045)
HH lives in treated village (β)	0.035	-0.037	-0.032	-0.013	0.012*	-0.000
	(0.055)	(0.031)	(0.049)	(0.027)	(0.006)	(0.021)
$\times$ *parcel is outside the village* (ν)	-0.063	0.094*	0.051	0.071	-0.008	-0.001
	(0.126)	(0.050)	(0.077)	(0.064)	(0.006)	(0.055)
Number of parcels	907	907	907	907	907	907
$\beta + \nu$	-0.029	0.057	0.019	0.058	0.004	-0.001
	(0.12)	(0.04)	(0.09)	(0.05)	(0.01)	(0.06)
Panel B: Male-headed households						
Parcel is outside the village (η)	-0.045	-0.046**	-0.044	-0.036***	-0.010	-0.026*
	(0.05)	(0.02)	(0.03)	(0.01)	(0.01)	(0.01)
HH lives in treated village (β)	0.000	0.001	-0.019	-0.007	0.001	0.023*
	(0.02)	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)
$\times$ *parcel is outside the village* (ν)	-0.042	0.003	0.033	0.027*	0.007	0.005
	(0.06)	(0.02)	(0.04)	(0.02)	(0.01)	(0.02)
Number of parcels	5,187	5,187	5,187	5,187	5,187	5,187
$\beta + \nu$	-0.042	0.003	0.014	0.020	0.008	0.028
	(0.05)	(0.02)	(0.04)	(0.02)	(0.01)	(0.02)
Panel C: All households						
Parcel is outside the village (η)	-0.032	-0.049***	-0.049*	-0.042***	-0.010	-0.017
	(0.05)	(0.02)	(0.03)	(0.01)	(0.01)	(0.01)
HH lives in treated village (β)	0.002	0.000	-0.018	-0.006	0.001	0.023**
	(0.02)	(0.01)	(0.02)	(0.01)	(0.01)	(0.01)
$\times$ *parcel is outside the village* (ν)	-0.041	0.009	0.038	0.032*	0.008	0.003
	(0.06)	(0.02)	(0.04)	(0.02)	(0.01)	(0.02)
Number of parcels	6,094	6,094	6,094	6,094	6,094	6,094
$\beta + \nu$	-0.039	0.009	0.020	0.026*	0.009	0.027
	(0.05)	(0.02)	(0.04)	(0.02)	(0.01)	(0.02)

Note: Robust standard errors are reported in parentheses. They are clustered at the village level and all regressions include household and landholding control variables, enumerator fixed effects, and lottery pool fixed effects. Significance levels are denoted as follows: * p<0.10, ** p<0.05, *** p<0.01.

[a] Annual cash crops are cotton, pineapple and sesame. Perennial cash crops are trees (teak, acacias ...), cashew and palm oil.

limited to parcels located outside the village boundaries for female-headed households (Panel A) but not for male-headed households, who reduce their renting out uniformly across parcel locations (Panel B).

We now investigate spatial differences in the treatment effect on agricultural activities (Table 8b). We report a marked drop – by nearly two-thirds of an acre – in within-village parcel

Table 8d: Differentiated effects of land demarcation activities on labor supply across source of labor and location of the parcels

	Household level			Hired	Unpaid
	Children	Women	Men	workers	workers
Panel A: Female-headed households					
Parcel is outside the village (η)	-5.034	-19.249	-1.855	-38.238	1.999
	(4.826)	(23.155)	(16.078)	(25.042)	(4.593)
HH lives in treated village (β)	-11.433**	15.984	3.978	-37.096**	2.348
	(5.439)	(19.877)	(10.711)	(16.927)	(4.826)
$\times$ *parcel is outside the village* (ν)	3.939	15.812	-0.639	58.049*	-2.391
	(8.777)	(30.558)	(16.974)	(30.521)	(5.985)
Number of parcels	604	604	604	604	604
$\beta + \nu$	-7.494	31.796	3.339	20.953	-0.043
	(8.14)	(25.56)	(11.33)	(22.54)	(5.29)
Panel B: Male-headed households					
Parcel is outside the village (η)	-2.967	-14.811**	-24.638***	-8.224	0.809
	(2.55)	(6.87)	(5.99)	(11.81)	(6.31)
HH lives in treated village (β)	0.600	0.014	-0.227	-0.165	-1.352
	(1.53)	(2.97)	(5.18)	(7.00)	(2.87)
$\times$ *parcel is outside the village* (ν)	1.722	0.555	6.604	19.237	-2.055
	(4.02)	(9.78)	(9.23)	(20.55)	(6.93)
Number of parcels	3,390	3,390	3,390	3,390	3,390
$\beta + \nu$	2.322	0.569	6.376	19.072	-3.406
	(3.51)	(9.16)	(9.98)	(21.49)	(6.96)
Panel C: All households					
Parcel is outside the village (η)	-2.643	-15.311***	-20.990***	-5.152	2.029
	(2.38)	(5.36)	(4.75)	(11.78)	(5.80)
HH lives in treated village (β)	0.175	3.703	-0.106	-5.196	1.060
	(1.57)	(3.43)	(4.99)	(6.37)	(3.04)
$\times$ *parcel is outside the village* (ν)	1.093	3.407	7.259	17.995	-3.904
	(3.77)	(8.11)	(7.62)	(17.87)	(6.57)
Number of parcels	3,994	3,994	3,994	3,994	3,994
$\beta + \nu$	1.268	7.110	7.154	12.799	-2.845
	(3.36)	(7.71)	(7.80)	(18.45)	(6.30)

Note: Robust standard errors are reported in parentheses. They are clustered at the village level and all regressions include household and landholding control variables, enumerator fixed effects and lottery pool fixed effects. Significance levels are denoted as follows: * p<0.10, ** p<0.05, *** p<0.01.

size for female-headed households (Panel A, Table 8b). We revisit this result in the following sub-section. The input and output results point to a significant spatial reallocation in agricultural activities among female-headed households away from relatively secure parcels (within the village) to lower tenure security land (outside the village; cols. 2-6, Panel A). First, we find that distant parcels operated by female-headed households are 25 p.p. more likely to have fertilizer and high-yield seeds applied to them relative to treated parcels within the village. In

line with this spatial reallocation of inputs, we detect an overall drop in the log of output by 29% (significant at the 10% level) and a 43% drop in yields on within-village parcels following demarcation activities. The yields on parcels outside treated villages, meanwhile, are 78% higher than those within treated villages. In contrast, we observe no significant differences in treatment impact by parcel location for male-headed households in Panel B of Table 8b.

Table 8c offers evidence of spatial variation in crop choice following demarcation activities. Among parcels controlled by female-headed households (Panel A), we find a 9 p.p. higher likelihood of growing pulses (e.g., beans) outside of the village relative to treated parcels within the village (significant at the 10% level). For male-headed household parcels, a significant (at the 10% level) treatment difference is observed on the production of vegetables (2.7 p.p. higher on distant parcels).

Next, we test whether the spatial reallocation of women's agricultural production observed in Table 8b is also reflected in the labor allocation of farm labor (see Table 8d). Consistent with Proposition 2 of the model, we observe that demarcation leads female-headed households to shift hired labor away from parcels located within the village and toward parcels located outside the village. An extra 58 person-days (per hectare) of hired farm labor are applied on distant parcels relative to treated within-village parcels, while the within-village treatment coefficient falls by 37 person-days per hectare (significant at the 10% and 5% levels, respectively). Land demarcation also causes female-headed households to reduce their use of child labor by 11 person-days per hectare on all parcels. However, we do not detect any differential impact on labor intensity by location of male-headed household parcels (Panel B) or from the pooled sample (Panel C). The results lend further support to the argument that female-headed households – when faced with a relative imbalance in parcel tenure security following demarcation – shift their production activities toward their less secure land outside of the village.

4.8 Robustness

Before concluding, we closely examine the apparent reduction in self-reported land size for treated parcels operated by female-headed households (see Table 8b, Panel A). This effect appears to be concentrated within treated villages.[39] Such a finding could be driven by (i) a reduction in measurement bias following demarcation or by (ii) land expropriation during the

[39] However, the positive coefficient on the outside-village interaction term, while large in magnitude, is statistically insignificant.

demarcation process.

We find evidence in support of the first hypothesis. Female-headed households have smaller landholdings than male-headed households in Benin, and this finding holds across a range of contexts in Africa (Doss et al., 2015). This fact has implications for land size measurement, given the tendency of households to systematically over-estimate the size of small tracts of land and – to a lesser extent – over-estimate the size of larger tracts (Carletto et al., 2015). When computing the size of agricultural plots (as well as measures of yield and input intensity), we rely primarily on precise GPS measurements of land area.[40] However, for the comparatively larger parcels, which can be used for a range of purposes (including agricultural), we rely instead on self-reported land size.

To test for a gender difference in measurement bias, we exploit the fact that, during the demarcation process, households learn the true size of their landholdings within the village. We would thus expect treated female-headed households to revise their self-reported parcel size downwards following demarcation activities. Male-headed households, meanwhile, would be less likely to fall prey to this over-reporting bias since they hold larger parcels of land on average. If this bias is indeed driving our result, we should expect no significant gender difference in treatment when comparing similarly-sized parcels located in the village. Our results confirm this conjecture. When comparing parcels under 0.5 ha within in the village, we detect no significant difference in impact on land size across gender of the household head (Table A-11, Panel B).[41] Similarly, we find no gender difference in treatment when restricting the sample to parcels larger than 4 hectares in size (Table A-11, Panel C). These findings suggest that demarcation reduces the systematic bias in self-reported land size in treated villages and this dampening effect is particularly salient for smaller landholders—a group in which women are disproportionately represented.

5 Discussion

We exploit the first randomized controlled trial of a land certification program to investigate changes in household investments following the first key step of land rights formalization–demarcation. We follow Besley and Ghatak (2010) and provide a theoretical framework to

[40] Our findings on agricultural yields, for example, are robust to the restriction of the sample to those parcels for which we have GPS-measured agricultural plot sizes (results available upon request).

[41] Half a hectare is the median parcel size for female-headed households and the 26th percentile for male-headed households. Carletto et al. (2015) find that the over-reporting bias is concentrated in parcels under 0.5 ha.

model household investment in the presence of a marginal change in land rights, and under partial program coverage. Insights from our model motivate an empirical approach that allows for gender and spatial heterogeneity in program impacts.

Our results show that, in line with predictions from our model, improved tenure security from PFR demarcation activities leads households to shift their investment decisions from subsistence crops to long-term and perennial cash crops—an important step towards commercialization. Moreover, as outlined in our model, as lower levels of tenure security amplify the impact of a marginal change in land rights, female-headed households respond to demarcation by closing the gender gap in fallowing, a key land fertility investment. These results contribute to a literature documenting that a marginal increase in tenure security has the potential to lead to intensified, commercial modes of production (Hornbeck, 2010).

Taking a broader view to examine the effects on parcels owned by treatment households but not covered by the program, we find that female-headed households respond to an exogenous change in their relative tenure security in a way consistent with predictions from our model, and with the literature (Besley, 1995; Goldstein and Udry, 2008). The demarcation process leads female-headed households to shift their agricultural activities away from their relatively secure land (i.e., demarcated parcels within the village) toward less secure land outside the village perimeter, allowing them to protect their claim to that land and reduce the risk of expropriation. That we do not observe a similar spatial reallocation of production among male-headed households can be explained in our model (Proposition 2) by the initially higher levels of tenure security in that group.

Taken together, these results show both how individuals respond to differences in tenure across their different fields and how they invest in response to strengthened rights over land. As countries throughout the developing world undertake policy reforms to strengthen land tenure rights and systems, these results provide both motivation and implementation considerations. Our results show that, even in contexts where issuance of formal titles or certificates may occur long after initial implementation of a program, marginal shifts in tenure security can positively affect investment decisions. In terms of implementation, the differing response of women across more and less secure parcels suggests that, where possible, interventions should be as spatially comprehensive as possible. More broadly, our results show that strengthening property rights can contribute to growth in agriculture and the economy as a whole. Further

research is needed to complete the picture and establish the causal effect of a full formalization of property rights.

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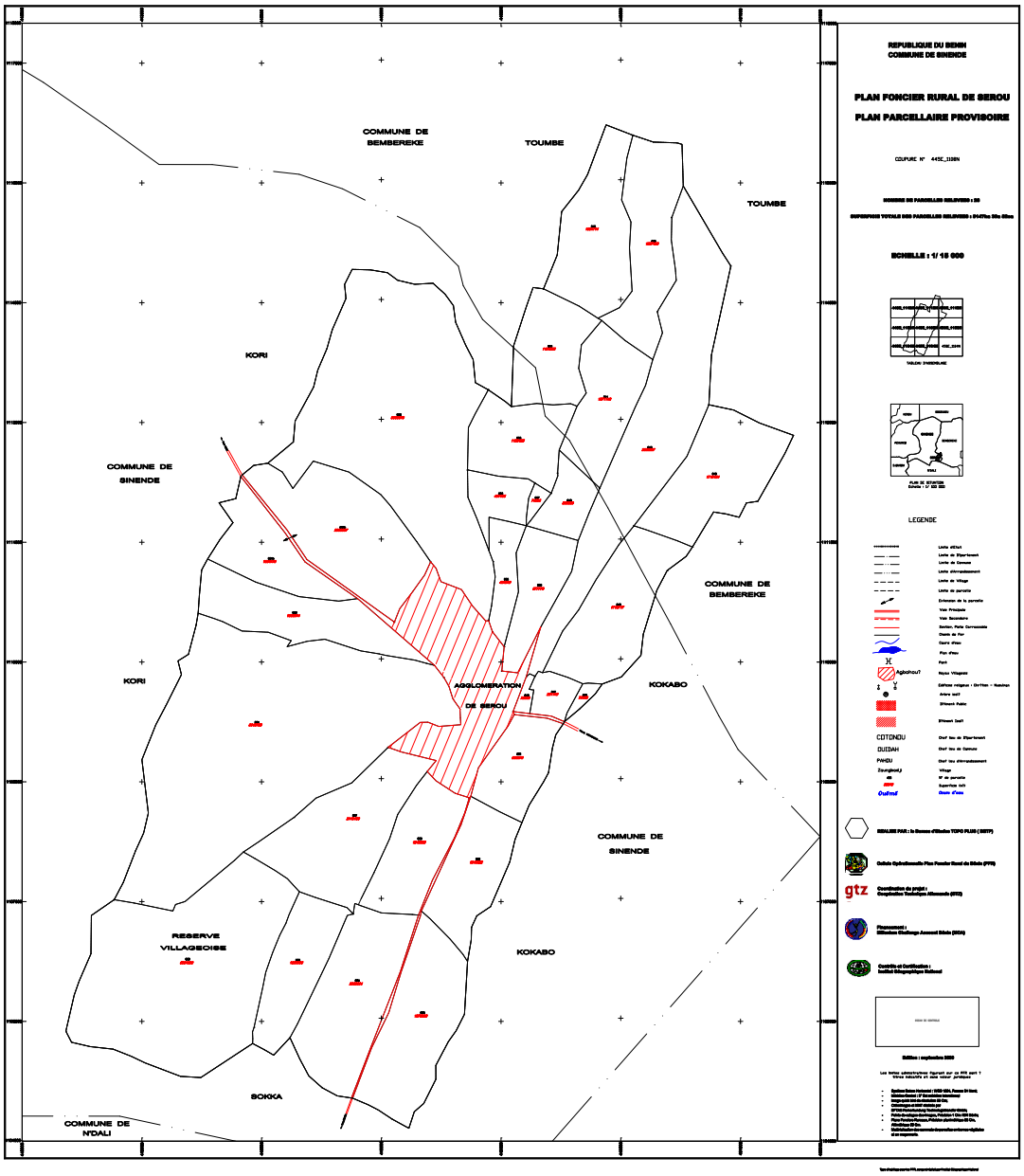
Appendix

Figure A-1: Example of a village's PFR



Source: Designed and drawn by the *Institut Géographique National*.

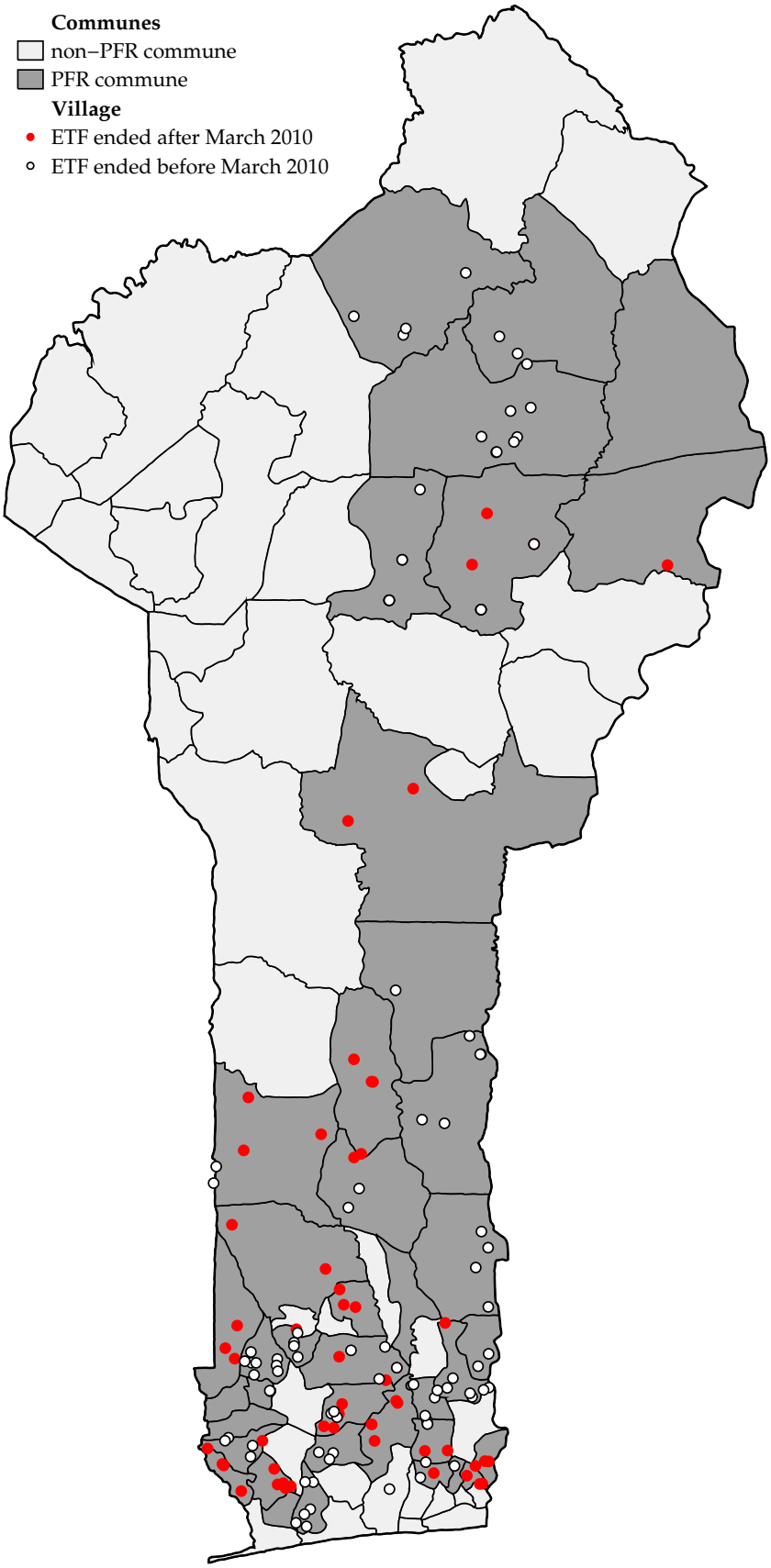


Figure A-2: PFR land demarcation surveys across treated villages (before and after March 2010)

Table A-1: Selection process of villages across communes

	Covered by EMICoV in 2006 ?									
	No					Yes				
Communes	Informed	Demanded	Preselected	Selected	Lost	Informed	Demanded	Preselected	Selected	Lost
BANIKOARA	53	32	2	1	1	17	16	10	5	5
GOGOUNOU	28	n.a.	13	5	8	6	n.a.	4	3	1
KANDI	42	21	8	4	4	6	5	4	2	2
SEGBANA	26	20	19	12	7	3	2	2	2	0
ALLADA	67	30	6	3	3	16	10	6	3	3
KPOMASSE	57	37	5	3	2	11	6	6	3	3
TOFFO	43	35	12	6	6	12	12	8	4	4
ZE	56	49	16	8	8	17	15	6	4	2
BEMBEREKE	31	30	14	7	7	12	12	10	5	5
KALALE	37	n.a.	10	5	5	7	n.a.	3	2	1
SINENDE	28	n.a.	12	7	5	7	n.a.	3	1	2
TCHAOUROU	27	n.a.	10	5	5	9	n.a.	3	2	1
DASSA-ZOUME	60	36	6	3	3	8	7	6	3	3
GLAZOUE	36	30	4	2	2	12	8	8	4	4
OUESSE	30	n.a.	10	9	1	9	n.a.	2	1	1
SAVALOU	59	37	4	2	2	12	9	8	4	4
SAVE	34	15	10	5	5	4	4	2	1	1
APLAHOUE	58	22	10	4	6	8	3	3	2	1
DJAKOTOME	58	23	8	2	6	14	4	4	4	0
DOGBO	45	22	10	5	5	8	2	2	1	1
KLOUEKANME	47	22	12	6	6	13	10	8	4	4
TOVIKLIN	50	31	8	4	4	7	5	4	2	2
ATHIEME	41	19	11	4	7	6	3	3	2	1
COME	30	11	11	4	7	8	2	2	2	0
HOUEYOGBE	52	35	18	8	10	8	5	5	4	1
LOKOSSA	38	20	13	7	6	10	4	2	1	1
ADJOHOUN	41	34	4	2	2	16	12	8	4	4
AKPRO-MISSERETE	28	n.a.	7	3	4	12	n.a.	5	3	2
AVRANKOU	37	19	8	4	4	15	7	6	3	3
BONOU	21	20	10	5	5	7	6	6	3	3
DANGBO	34	23	6	3	3	11	9	8	4	4
ADJA-OUERE	39	14	14	5	9	8	5	5	3	2
IFANGNI	33	22	18	11	7	8	7	5	3	2
KETOU	31	17	5	1	4	7	7	5	4	1
POBE	43	35	7	3	4	4	3	3	2	1
AGBANGNIZOUN	42	n.a.	12	6	6	9	n.a.	4	2	2
DJIDJA	67	47	6	3	3	10	10	6	3	3
ZAGNANADO	27	24	6	3	3	7	5	4	3	1
ZA-KPOTA	47	31	6	3	3	9	7	5	3	2
ZOGBODOMEY	53	47	2	1	1	13	10	8	5	3

Source: Author's illustration based on administrative files about land registration programme in Benin.
Note: n.a. = not available.

Table A-2: Definitions of main outcomes of interest

Variable name	Definition
Parcel has clear borders	Binary variable equal to 1 when the parcel is demarcated with cornerstones and 0 otherwise
Fear of land loss during fallow	Binary variable equal to 1 when the household expressed fear of losing the land parcel if left fallow and 0 otherwise
Land conflict	Binary variable equal to 1 when the landholding has been subject to a conflict during the previous twelve months and 0 otherwise
Investment in tree planting	Binary variable equal to 1 when the landholding has received a tree-planting investment during the previous twelve months and 0 otherwise
Started fallowing parcel	Binary variable equal to 1 when the parcel has newly been left fallow and 0 otherwise
Parcel rented in/out	Binary variable equal to 1 when the parcel has been rented or share-cropped in (out) during the previous twelve months and 0 otherwise
Yield	Agricultural yield (in log US $ per hectare) following harvest during the main agricultural season
Labor supply	Total time in person-day per hectare allocated to farming activities during the main agricultural season
Fertilizer/high-yield seeds	Binary variable equal to 1 when the household used either a fertilizer or high-yield seeds as input during the main agricultural season and 0 otherwise

Table A-3: Locations of household landholdings

Location	Freq.	Percent	Cum.
In village	2,972	84.74	84.74
Outside village	304	8.67	93.41
No landholding	231	6.59	100.00
Total	3,507	100.00	

Table A-4: Household characteristics and landholding location

	Marginal effects	
	coeff.	s.e.
Female headed household†	0.0052	(0.006)
Age of household head (years)	-0.0002	(0.000)
Household head can read/write†	-0.0060	(0.004)
Household size	-0.0010	(0.001)
Household head is polygamous†	-0.0013	(0.004)
Landholding size (ha)	0.0029	(0.001)**
Walking distance from home to land > 1 hour †	-0.0895	(0.023)***
Mode of acquisition:		
- *bequest*	0.0224	(0.015)
- *gift*	0.0130	(0.012)
- *rental*	-0.0101	(0.008)
- *purchase*	-0.0158	(0.006)**
- *clearing*	0.0367	(0.023)
Number of landholdings	6,094	
$\mathbb{P}$ (**land is inside village** $= 1$)	0.874	

Note: The table shows marginal effects of various variables on the likelihood that a parcel is located inside the landholder's village of residence.
The model is estimated using a logit specification and the marginal effects are reported. The standard errors are clustered at household level and are reported in parentheses.
† Indicates dummy variables. Significance levels are reported as follows: * p<0.10, ** p<0.05, *** p<0.01.

Table A-5: Characteristics of female and male-headed households in control villages

	Female-headed		Male-headed		Difference	
	Mean	Std. Dev.	Mean	Std. Dev.	coeff.	s.e.
Panel A: Household characteristics						
Age of HH head (years)	50.50	14.81	46.49	15.41	4.01	(1.21)***
Household head can read/write†	0.08	0.27	0.25	0.44	-0.18	(0.03)***
Household size	4.62	2.42	6.85	3.40	-2.24	(0.24)***
Total land size (ha)	2.96	5.08	6.85	14.83	-3.90	(0.89)***
Number of parcels	1.68	1.01	1.85	1.17	-0.17	(0.09)*
Land size per aeu (ha)	0.95	1.50	1.38	2.48	-0.44	(0.16)***
Number of households	154		816		970	
Panel B: Parcel characteristics						
Female land manager†	0.93	0.26	0.30	0.46	0.63	(0.04)***
Parcel area (ha)	1.62	3.48	3.34	10.10	-1.72	(0.50)***
Mode of acquisition:						
- *bequest*	0.32	0.47	0.51	0.50	-0.19	(0.04)***
- *gift*	0.25	0.44	0.20	0.40	0.05	(0.04)
- *rental*	0.11	0.31	0.08	0.27	0.03	(0.03)
- *purchase*	0.17	0.38	0.16	0.37	0.01	(0.04)
- *clearing*	0.01	0.09	0.04	0.19	-0.03	(0.01)***
Parcel has an official document†	0.07	0.26	0.08	0.28	-0.01	(0.03)
Fear land loss during fallow†	0.17	0.38	0.10	0.30	0.07	(0.03)**
Land conflict†	0.05	0.23	0.06	0.23	-0.00	(0.02)
Parcel is delimited (trees, stones, . . .)†	0.61	0.49	0.62	0.48	-0.01	(0.05)
Invested on parcel †	0.07	0.25	0.13	0.33	-0.06	(0.02)***
Started fallowing parcel†	0.00	0.00	0.01	0.11	-0.01	(0.00)***
Parcel rented out†	0.05	0.23	0.05	0.21	0.01	(0.02)
Panel C: Agricultural activities						
Landholding is cultivated†	0.64	0.48	0.67	0.47	-0.03	(0.04)
Land size cultivated (ha)	0.64	0.68	1.68	2.42	-1.04	(0.17)***
Labor input (person-day/ha)	227.49	281.85	201.58	263.32	25.91	(36.04)
Used improved inputs†	0.30	0.46	0.27	0.44	0.04	(0.07)
Used pesticide/herbicide†	0.11	0.31	0.12	0.33	-0.01	(0.04)
Crop was harvested†	0.93	0.26	0.93	0.25	-0.00	(0.02)
Yield (Log USD/ha)	6.33	1.06	6.38	1.05	-0.05	(0.12)
Number of parcels	259		1,511		1,770	

Note: The table compares household and parcel characteristics across female-headed and male-headed households in the control villages. Standard errors (s.e.) are reported in parentheses and are clustered at the village level. Significance levels are reported for t-tests of the equality of the means for each of the variables between female and male-headed households.

† Indicates dummy variables. Significance levels are reported as follows: * p<0.10, ** p<0.05, *** p<0.01.

Table A-6: Awareness of the land registration program across gender of the household head

	Female-headed		Male-headed		Difference	
	Mean	Std. Dev.	Mean	Std. Dev.	coeff.	s.e.
Panel A: Households in control villages						
HH head involved in LMC[†] [a]	0.01	0.11	0.03	0.17	-0.02	(0.01)
HH head heard of PFR[†]	0.19	0.40	0.26	0.44	-0.07	(0.04)
HH head attended meeting on PFR[†]	0.04	0.19	0.06	0.24	-0.02	(0.01)
If yes, how often?	0.09	0.48	0.12	0.62	-0.03	(0.03)
HH head says PFR took place in the village[†]	0.06	0.25	0.06	0.23	0.01	(0.02)
For land dispute settlement HH head trusts:						
- *traditional leader*	0.57	0.50	0.62	0.49	-0.04	(0.05)
- *city hall*	0.73	0.45	0.76	0.43	-0.03	(0.04)
- *local council*	0.68	0.47	0.68	0.47	-0.00	(0.05)
- *courthouse*	0.72	0.45	0.76	0.43	-0.04	(0.04)
- *police*	0.73	0.45	0.68	0.47	0.04	(0.04)
HH has official evidence of land right[†]	0.09	0.29	0.11	0.32	-0.02	(0.03)
Number of households	154		816		970	
Panel B: Households in treated villages						
HH head involved in LMC[†] [a]	0.02	0.12	0.06	0.23	-0.04	(0.01)***
HH head heard of PFR[†]	0.74	0.44	0.89	0.32	-0.14	(0.04)***
HH head attended meeting on PFR[†]	0.29	0.46	0.53	0.50	-0.23	(0.03)***
If yes, how often?	0.71	1.64	1.50	2.46	-0.79	(0.12)***
HH head says PFR took place in the village[†]	0.73	0.45	0.86	0.34	-0.14	(0.04)***
For land dispute settlement HH head trusts:						
- *traditional leader*	0.67	0.47	0.67	0.47	-0.00	(0.03)
- *city hall*	0.77	0.42	0.80	0.40	-0.03	(0.03)
- *local council*	0.70	0.46	0.73	0.44	-0.03	(0.03)
- *courthouse*	0.76	0.43	0.76	0.43	0.00	(0.03)
- *police*	0.75	0.44	0.73	0.45	0.02	(0.03)
HH has official evidence of land right[†]	0.09	0.28	0.09	0.29	-0.01	(0.02)
Number of households	332		1,670		2,002	

Note: The table compares different measures related to awareness of the ongoing land registration program across gender of the household head in treated and control villages. Standard errors are reported in parentheses and are clustered at the village level. The coefficients reported in column "coeff." are obtained by regressing each variable on the treatment variable while controlling for the lottery pool fixed effects.

[a] LMC stands for local land management commissions (LMC).

[†] Indicates dummy variables. Significance levels are reported as follows: * p<0.10, ** p<0.05, *** p<0.01.

Table A-7: Summary statistics of village characteristics

	Obs	Min	Mean	Median	Std. dev.	Max
Number of households	288	18	531.0	364	678.0	7000
Number of ethnic groups	287	0	3.09	3	2.16	12
Accessible infrastructure[a]						
- *public and private primary schools*	289	0	0.94	1	0.23	1
- *secondary school*	289	0	0.42	0	0.49	1
- *market place*	289	0	0.60	1	0.49	1
- *well*	289	0	0.90	1	0.30	1
- *healthcare center*	289	0	0.61	1	0.49	1
- *micro-finance institution*	289	0	0.42	0	0.49	1
Secondary activity in the village[b]						
- *commerce*	289	0	0.41	0	0.49	1
- *husbandry*	289	0	0.24	0	0.42	1
Village is connected to electric grid[†]	289	0	0.35	0	0.48	1
Distance to nearest paved road (km)	288	0	13.6	8	16.2	90
Modes of land acquisition						
- *bequest*	289	0	0.99	1	0.10	1
- *gift or free loan*	289	0	0.77	1	0.42	1
- *rental*	289	0	0.66	1	0.48	1
- *purchase*	289	0	0.72	1	0.45	1
- *clearing*	289	0	0.24	0	0.43	1
North of Benin	289	0	0.19	0	0.39	1
Center of Benin	289	0	0.26	0	0.44	1
Village has a land committee (LMC)[†]	289	0	0.62	1	0.49	1
Village experienced a land conflict[b †]	289	0	0.73	1	0.44	1
- *encroachment between villagers*	289	0	0.67	1	0.47	1
- *farmer vs. herder*	289	0	0.16	0	0.36	1
- *cross-village borders*	289	0	0.71	1	0.46	1

[a] The infrastructure has to be either in the village or located within a 10 km radius of the village.
[b] The reference period is the previous twelve months.
[†] Indicates dummy variables.

Table A-8: Village characteristics across treatment groups

	Treated		Control		Difference	
	Mean	Std. Dev.	Mean	Std. Dev.	coeff.	s.e.
Number of households	558.33	727.05	478.02	570.72	4.82	(61.40)
Number of ethnic groups	3.20	2.25	2.89	1.97	0.19	(0.22)
Accessible infrastructure[a]						
- *public and private primary schools*	0.95	0.22	0.94	0.24	-0.01	(0.03)
- *secondary school*	0.43	0.50	0.39	0.49	0.04	(0.05)
- *market place*	0.62	0.49	0.56	0.50	-0.01	(0.06)
- *well*	0.90	0.30	0.91	0.29	-0.01	(0.04)
- *healthcare center*	0.61	0.49	0.61	0.49	-0.05	(0.06)
- *micro-finance institution*	0.41	0.49	0.42	0.50	-0.03	(0.06)
Secondary activity in the village						
- *commerce*	0.38	0.49	0.47	0.50	-0.12	(0.06)*
- *husbandry*	0.24	0.43	0.23	0.43	0.02	(0.06)
Village is connected to electric grid[†]	0.34	0.48	0.36	0.48	-0.03	(0.05)
Distance to nearest paved road (km)	14.64	16.71	11.48	14.89	2.53	(1.46)*
Mode of land acquisition						
- *bequest*	0.98	0.12	1.00	0.00	-0.01	(0.01)
- *gift or free loan*	0.79	0.41	0.73	0.44	0.02	(0.04)
- *rental*	0.66	0.47	0.64	0.48	-0.01	(0.04)
- *purchase*	0.70	0.46	0.76	0.43	-0.05	(0.04)
- *clearing*	0.22	0.42	0.29	0.45	-0.06	(0.04)*
Village has a land committee (LMC)[†]	0.75	0.43	0.35	0.48	0.36	(0.05)***
Village experienced a land conflict[b†]	0.73	0.45	0.73	0.44	-0.01	(0.05)
- *encroachment between villagers*	0.65	0.48	0.70	0.46	-0.08	(0.05)
- *farmer vs. herder*	0.16	0.36	0.15	0.36	0.01	(0.04)
- *cross-village borders*	0.66	0.47	0.79	0.41	-0.11	(0.05)**
Number of villages	191		98		289	

Robust standard errors (s.e.) are reported in parentheses. Significance levels are reported for t-tests of the equality of the means for each of the variables between treated and control villages.

[a] The infrastructure has to be either in the village or located within a 10 km radius of the village.

[b] The reference period is the previous twelve months.

[†] Indicates dummy variables. Significance levels are reported as follows: * p<0.10, ** p<0.05, *** p<0.01.

Table A-9: Village characteristics and probability of ETF completion by March 2010.

	Marginal effects	
	coeff.	s.e.
Number of households	-0.0000	(0.000)
Number of ethnic groups	-0.0211	(0.020)
Accessible infrastructure[a]		
- *public and private primary schools*	-0.1436	(0.216)
- *secondary school*	-0.0450	(0.104)
- *market place*	0.1024	(0.104)
- *well*	0.0964	(0.119)
- *healthcare center*	0.0708	(0.099)
- *micro-finance institution*	-0.0501	(0.091)
Secondary activity in the village		
- *commerce*	-0.0231	(0.083)
- *husbandry*	0.0439	(0.096)
Village is connected to electricity grid[†]	0.0642	(0.084)
Distance to nearest paved road (km)	-0.0036	(0.003)
Land can be acquired through		
- *rental*	0.1985	(0.124)
- *purchase*	-0.2260	(0.193)
Frequency of land conflicts over previous 5 years		
- *higher*	-0.0576	(0.119)
- *lower*	0.1595	(0.093)*
North of Benin	0.2356	(0.149)
Center of Benin	0.0569	(0.101)
Number of villages[b]	189	
$\mathbb{P}$ (ETF ended by March 2010 = 1)	0.476	

Note: In this table we correlate village characteristics with the probability that the land surveys (ETF) were completed at least twelve months prior to the time of our interviews in March, 2011. The sample is restricted to villages selected to receive a PFR and the model is estimated using a logit specification with the marginal effects are reported. Robust standard errors are reported in parentheses.

[a] The infrastructure has to be either in the village or located within a 10 km radius from the village.

[b] Number of ethnic groups is missing for 2 treated villages.

[†] Indicates dummy variables. Significance levels are reported as follows: * p<0.10, ** p<0.05, *** p<0.01.

Table A-10: Participation in agricultural activities across treatment groups

	Treated		Control		Difference	
	Mean	Std. Dev.	Mean	Std. Dev.	coeff.	s.e.
Landholding is cultivated[†]	0.66	0.47	0.66	0.47	0.01	(0.02)
Land size cultivated (ha)	1.56	2.31	1.54	2.29	-0.04	(0.11)
Crop was harvested[†]	0.92	0.27	0.93	0.25	0.01	(0.01)
Number of parcels	3,559		1,770		5,329	

Note: The table describes changes in participation in agricultural activities across parcels in treated and control villages. Standard errors are reported in parentheses and are clustered at the village level. The coefficients reported in column "coeff." are obtained by regressing each variable on the treatment variable while controlling for the lottery pool fixed effects.

[†] Indicates dummy variables. Significance levels are reported as follows: * p<0.10, ** p<0.05, *** p<0.01.

Table A-11: Differentiated effects of household headship on land area

	Coeff.
Panel A: All parcels in control villages	
Constant	0.818
	(1.697)
Female-headed household†	-0.710***
	(0.267)
Number of parcels	1,770
Panel B: All parcels with less than 0.5 ha of land size[a]	
Constant	0.280***
	(0.03)
Female-headed household†	0.002
	(0.01)
HH lives in treated village	-0.010
	(0.01)
× *Female-headed household*	0.011
	(0.02)
Number of parcels	1,935
Panel C: All parcels with more than 4 ha of land size[a]	
Constant	-0.433
	(5.90)
Female-headed household†	-1.330
	(1.56)
HH lives in treated village	0.131
	(1.40)
× *Female-headed household*	-0.528
	(2.15)
Number of parcels	1,091

Note: Robust standard errors are reported in parentheses. They are clustered at the village level and all regressions include household and landholding control variables, enumerator fixed effects and lottery pool fixed effects. Significance levels are denoted as follows: * p<0.10, ** p<0.05, *** p<0.01.

[a] The sample is restricted to the parcels located inside the village where the household lives.

Table A-12: Effects of land demarcation activities on perception of land rights.

	Obs.	Control Mean	ITT Coeff.	ITT s.e.
Panel A: Who will inherit the parcel?				
A household member[a]	3,582	0.829	-0.007	(0.02)
- *Household head*	3,582	0.013	-0.002	(0.00)
- *Children of the head*	3,582	0.815	-0.007	(0.02)
Someone outside the household	3,582	0.047	-0.007	(0.01)
Do not know	3,582	0.123	0.013	(0.02)
Panel B: Who can lend/rent-out/give the parcel?				
A household member	3,582	0.768	0.001	(0.02)
- *Household head*	3,582	0.731	0.017	(0.02)
- *Spouse(s) of the head*	3,582	0.024	-0.009	(0.01)
- *Children of the head*	3,582	0.010	-0.007*	(0.00)
Someone outside the household	3,582	0.174	-0.003	(0.02)
No one	3,582	0.057	0.001	(0.01)
Panel C: Who can pledge or mortgage the parcel?				
A household member	3,582	0.751	-0.011	(0.02)
- *Household head*	3,582	0.719	0.000	(0.02)
- *Spouse(s) of the head*	3,582	0.022	-0.006	(0.01)
- *Children of the head*	3,582	0.007	-0.006*	(0.00)
Someone outside the household	3,582	0.167	-0.000	(0.02)
No one	3,582	0.081	0.011	(0.01)
Panel D: Who can sell the parcel?				
A household member	3,582	0.581	0.030	(0.02)
- *Household head*	3,582	0.554	0.040*	(0.02)
- *Spouse(s) of the head*	3,582	0.020	-0.007	(0.01)
- *Children of the head*	3,582	0.004	-0.004	(0.00)
Someone outside the household	3,582	0.154	0.013	(0.02)
No one	3,582	0.264	-0.043**	(0.02)

Note: The table shows estimates of village-wide land demarcation activities on several variables. Each row corresponds to an estimation where the dependent variable (reported in the first column) is regressed on a dummy variable equal to 1 when the household lives in a village that carried out a village wide land demarcation activities (see Equation 3) The column "Obs." reports the number of households and the column "Control mean" shows the average level of the dependent variable in the control villages. Column "Coeff. ITT" shows the effect of being in a PFR village.

The standard errors are clustered at the village level and are reported in parentheses. Each estimation includes the lottery pool fixed effects. Significance levels are denoted as follows: * p<0.10, ** p<0.05, *** p<0.01.

Control variables: gender and age of household head, number of male members, number of female members, number of children, religion of the head, marital status of the head, status in the village (village chief, village group leader, village group member, member of village council, lineage chief), and head is public servant.

[a] There is only one case where the spouse of the household head was listed as inheritor of a parcel, so this category is omitted here.

[†] Indicates dummy variables.