Formalization without Certification? Experimental Evidence on Property Rights and Investment*

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Abstract

We present evidence from the first large-scale randomized-controlled trial of a land formalization program. We examine the link 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 23 to 43 percent shift toward long-term investment on treated parcels. The model further points to gender and parcel location as relevant dimensions of heterogeneity. We find that female-managed landholdings in treated villages are more likely to be left fallow—an important soil fertility investment. Women respond to an exogenous tenure security change by shifting investment away from relatively secure, demarcated land and toward less secure land outside the village to guard those parcels.

Keywords: property rights, agricultural investment, land administration, gender, natural resources

JEL Classification: O12, O17, P48, Q15, J16

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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. The structures that support these systems may lead to under-investment and sub-optimal yields (Goldstein and Udry, 2008). Codification of private property rights should in theory increase agricultural investment and productivity and spur economic development (Besley, 1995; Besley and Ghatak, 2010). Yet, 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 (Lawry et al., 2014). 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).

We make two central contributions to the literature on property rights and investment. First, we use a large-scale policy experiment in Benin to present evidence on the impact of a key step of land formalization, land demarcation, on farming households' investment behavior.[1] The random assignment of Benin's *Plans Fonciers Ruraux* (PFR) program at the village level allows us to circumvent issues of reverse causality commonly faced in the literature. Changes in land rights are typically 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). By overcoming these identification concerns, we provide a clear causal measure of the impact of land formalization.[2]

[1] Ali et al. (2014) randomly assign inducements to claim land titles in Tanzania. However, Benin's *Plans Fonciers Ruraux* is the first program to have randomized the actual access to a land tenure security program.

[2] In Ethiopia, three studies use a simple difference approach to exploit time-varying, plot-level information on production and the issuance of land certificates (Deininger et al., 2011; Holden et al., 2011, 2009). 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 for identification. They use spatial fixed effects to compare

Second, we exploit early evidence of the PFR to decompose the channels through which land formalization affects investment decisions. Formalizing land rights is typically modeled as affecting investment behavior through an improvement in tenure security and the issuance of formal rights that can be transferred or used as a collateral (Banerjee et al., 2002; Besley, 1995). Early evidence on the PFR's formalization process presents a rare opportunity to unpack this causal chain. The PFR 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 secure parcel boundaries; second, customary land ownership is formally and legally documented in the form of transferable certificates. The first step increases tenure security, while the second step confers transferable property rights. Akin to the case of barbed wire fencing studied by Hornbeck (2010) in the Great Plains of North America, laying cornerstones clarifies frontiers and protects farmers from encroachment. The process that surrounds demarcation additionally establishes property rights, as each community works to unify competing and overlapping conceptions of land rights. We present evidence on the impact of the first step, land demarcation, on farming households' investment behavior pending full land 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 is typically prohibitive.[3] Even in the presence of a dedicated land formalization program, it often takes years for the final stage of property rights delivery, the actual *de jure* certification, to occur (Teyssier and Legendre, 2013).

As land demarcation clarifies uncertainty over land claims, the risk of expropriation should decrease, reinforcing tenure security and incentives to invest (Banerjee et al., 2002; Besley, 1995; Feder and Feeny, 1991). With this mechanism in mind, we model the main cultivation decisions (inputs into production, choice of crop maturity, and decision to fallow) as a response to exogenous tenure security improvements. In our model, some of these investments may involve reallocation from land-guarding practices to more productive activities (Besley and Ghatak, 2010; Goldstein and Udry, 2008). Given pre-existing gender differences in customary

households in pilot villages to their counterparts in adjacent neighborhoods. This strategy cannot address the identification challenges related to endogenous roll out and spatial spillovers, and, given the Rwandan context of planned land consolidation and husbandry, they cannot reject that pilot areas may have benefited from additional land investments other than land tenure regularization.

[3]In the case of Benin, the World Bank's 2016 *Doing Business* report finds that registering property entails four procedures over approximately 140 days, for a cost amounting to 11.7 percent of the total property value. Benin ranks 172$^{\text{nd}}$ in property registration out of 189 surveyed economies.

land rights in Benin, the extent of these effects may also differ for men and women (Ali et al., 2014).[4] Hence we explicitly model changes in investment decisions as a function of the initial level of tenure security.

Two years after the start of implementation, in line with our model, treatment households are 23 to 43 percent more likely to grow perennial cash crops and invest in trees on their parcels. The overall program impact masks heterogeneity in effects by gender. Treated female-headed households boost their fallowing investments in land, fully offsetting the gender gap observed in control villages. When facing multiple tenure regimes, women further respond to an exogenous change in their relative tenure security in a way consistent with our theoretical predictions and the findings of Goldstein and Udry (2008), shifting labor and fertilizer investment away from relatively secure, demarcated land to less secure parcels outside the village perimeter to protect their claim to that land.

The remainder of the paper is organized as follows. Section 2 places our study within the land policy reform process in Benin and details the formalization intervention. 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 and spatially differentiated effects. Section 4 describes our identification strategy and the data collection process, and reports relevant descriptive statistics. Section 5 presents the estimates of the impact of PFR land demarcation activities in Benin. Section 6 provides a set of conclusions.

2 Context

2.1 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. We study the 2006-11 large-scale roll-out of the program financed and supervised by the Millennium Challenge Corporation (MCC). Under this effort, approximately US$34 million was put toward land formalization activities.

[4] In Benin, women primarily obtain secondary land use rights through a male spouse or relative.

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 and transferable 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).[5] 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.

2.2 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. 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 used by landholders to mark the frontier of their parcels. 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—the issuance of a transferable land certificate.

Specifically, 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. 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 inquiry, 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

[5] 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*).

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 A theoretical framework of cultivation decisions

Building on Besley (1995) and Besley and Ghatak (2010), we present a simple framework to model the impact of a property right improvement on cultivation choices.

3.1 The decision to cultivate or leave the plot fallow

Let us start by considering a household which owns land under a customary property right conferring a level of recognition R. The household has to decide *(i)* whether to cultivate the land (choice variable $t = C$) or leave the plot fallow ($t = U$), and *(ii)* how much labor l to allocate to the plot (out of a total labor endowment of $\bar{l}$). If the plot is cultivated using an amount of labor l, production is $Q(l)$, with the standard assumptions that $Q'(l) \equiv \frac{\partial Q(l)}{\partial l} > 0$ and $Q''(l) \equiv \frac{\partial^2 Q(l)}{\partial l^2} < 0$. The production is valued at a unit price normalized to 1. If the plot is left fallow (a productive investment),[6] the household anticipates greater yields in the future, with the present value of a fallow plot amounting to Ω.[7] When making cultivation and labor decisions, the household considers the impacts of its choices on the probability σ that it will retain ownership of the plot until it can reap the benefits from its investment—with σ being a function of *(i)* cultivation status, *(ii)* the labor allocated to the plot (which also serves as guarding labor), and *(iii)* the property right. Let us denote $\sigma_C(l, R)$ and $\sigma_U(l, R)$ the respective probabilities that the ownership of the plot will be retained when cultivated and when left fallow, given the labor allocation l and the property right R. We have the following three properties: Firstly, all else being equal, because cultivation signals ownership, a cultivated plot is more secure than a fallow plot, implying $\sigma_C(l, R) > \sigma_U(l, R)$ for any given l and R. Secondly, the amount of labor allocated to a plot protects it from land grab attempts, so that $\frac{\partial \sigma_t(l,R)}{\partial l} > 0$ for $t \in \{C, U\}$. Note here that we assume that the labor allocated to the plot simultaneously

[6]Leaving land fallow restores soil fertility. This is a common practice worldwide (De Rouw, 1995; Valentin et al., 2004).

[7]Ω can be thought of as the difference between the net present value of future cash flows from the plot when fallow and when cultivated.

serves production and security purposes (see Houngbedji, 2015, in Ethiopia), except on fallow plots, where it only serves a protective purpose.[8] Thirdly, the strength of a property right (level of recognition for the use of the land) increases the probability of retaining ownership of a plot, and $\frac{\partial \sigma_t(l,R)}{\partial R} > 0$ for $t \in \{C, U\}$.

For simplification, we assume that the household does not face an opportunity cost of supplying labor. It is therefore in the interest of the household to allocate as much labor as possible to the plot, so that the labor constraint is binding.[9] Hence, the household makes its cultivation decision according to the following program:

$$\max_{t \in \{C,U\}} \quad \Pi_t = \sigma_t \left(\bar{l}, R\right) . V_t \left(\bar{l}\right) \tag{1}$$

with $V_t(\bar{l})$ the value of the investment under cultivation choice t such that $V_C \left(\bar{l}\right) = Q \left(\bar{l}\right)$ and $V_U \left(\bar{l}\right) = \Omega$. Comparing expected profits Π_C and Π_U, it is easy to see that the plot is left fallow if and only if the present value of the fallow plot satisfies the following inequality:

$$\Omega \geq \frac{\sigma_C \left(\bar{l}, R\right)}{\sigma_U \left(\bar{l}, R\right)} . Q \left(\bar{l}\right) \equiv Z \tag{2}$$

Ω accounts for the quality of the plot, as higher-quality plots will yield greater returns from fallowing. Because plots may differ in quality, we assume that Ω is a random variable that follows cumulative distribution function F (and associated density function f). The probability that a plot will be left fallow is thus $1 - F(\Omega)$. We investigate how that probability is affected by an improvement in the property right. We have the following proposition:

Proposition 1. *An improvement in the property right has an ambiguous effect on the decision to cultivate. If property rights and cultivation are substitutes with respect to tenure security,* ***an improvement in the property right increases the likelihood that a plot is left fallow.***[10]

Proof: see Appendix A-1

[8]Our assumption differs from Besley and Ghatak (2010), who consider that labor time is split between production and guarding activities that are *exclusive* of one another.

[9]This simplified approach allows us to more easily compare the impact of different cultivation decisions. An alternative model with leisure time, hired labor, and a possibly non-binding resource constraint as in Besley and Ghatak (2010) would complicate the analysis without changing the main insights regarding the impact of property rights improvements.

[10]Note that the assumption of substitutability, though natural, does not drive our result. The likelihood of fallowing may still increase with improvement in the property right, even if property rights and cultivation were complements (on the condition that the complementarity be not too strong).

The following corollary complements Proposition 1:

Corollary 1. *If property rights and cultivation are substitutes with respect to tenure security,* ***groups with weaker property rights (female-headed households in particular) are less likely to leave land fallow.***

The latter corollary is a direct implication of property rights increasing the probability of fallowing (Proposition 1) and of women having weaker property rights under customary tenure in rural Benin (see Dijoux, 2002).

3.2 The decision to invest in short-term and long-term crops

Let us now consider the case of a household which has decided to cultivate its plot and needs to choose a combination of crops. For simplification, we consider that there are two crops (or groups of crops) which differ according to maturity: a short-term crop (denoted S), the price of which we normalize to 1, and a long-term or perennial crop (denoted L), valued at a unit price P. We now have two production functions indexed by the crop type, $Q_t(l_t)$ for $t \in \{S, L\}$. As previously, we assume that labor and property rights increase tenure security: $\frac{\partial \sigma_t(l,R)}{\partial l} > 0$ and $\frac{\partial \sigma_t(l,R)}{\partial R} > 0$ for $t \in \{S, L\}$.

The household chooses the amounts of labor l_S and l_L to allocate to the short-term and the long-term crop respectively, so as to maximize its expected profit subject to the labor constraint $l_S + l_L \leq \bar{l}$. Recognizing that the constraint will be binding, the household faces the following program:[11]

$$\max_{l_L} \quad \mathit{\Pi} = \sigma_S \left(\bar{l} - l_L, R\right) .Q_S \left(\bar{l} - l_L\right) + \sigma_L \left(l_L, R\right) .P.Q_L \left(l_L\right) \tag{3}$$

where $\mathit{\Pi}$ is the total expected profit from cultivation of both crops. The interior solution to this problem is to allocate labor so as to equalize the expected marginal gains from investments in the short-term and the long-term crops given the protective and productive roles of labor (see Appendix A-2). Exploring how a marginal improvement in the property right affects the allocation of labor between the two crops, we have the following proposition:

Proposition 2. *An improvement in the property right has an ambiguous effect on labor allocation between the two crops.* ***An improvement in the property right will result in a shift away from the short-term crop toward production of the long-term crop*** *when (i) increased property rights more*

[11]This recognizes that the household may lose part of its parcel or only one of the two crops.

efficiently increase tenure security under long-term crops than under short-term crops, and/or when (ii) labor and property rights are stronger substitutes with respect to tenure security under short-term crops than under long-term crops.

Proof: see Appendix A-2

We also have the following corollary:

Corollary 2. *Groups with initially low levels of property rights (female-headed households in particular) are more likely to respond to an improvement in the property right by investing labor away from the short-term crop and toward the long-term crop.*

Proof: see Appendix A-3

3.3 Investment across tenure regimes (within and outside village borders)

We now consider that the household has two plots, one inside the village border (V) and one outside the village border (O), and decides on the amounts of labor l_V and l_O to allocate to each plot such that $l_V + l_O \leq \bar{l}$. For simplicity, we assume that the plots are identical and we only consider one type of crop which is produced according to a production function $Q(l)$, with $Q'(l) > 0$ and $Q''(l) < 0$.[12] One unit of production is valued at a price normalized to 1. The plots, however, may be held under different property rights, denoted R_V and R_O. We assume that the probabilities of retaining ownership of the within-village and out-of-village plots are $\sigma(l_V, R_V)$ and $\sigma(l_O, R_O)$ respectively. As previously, these probabilities are increasing with both labor investment (guarding labor assumption) and property rights: $\frac{\partial\sigma(l,R)}{\partial l} > 0$ and $\frac{\partial\sigma(l,R)}{\partial R} > 0$ for any given l and R. Because labor and property rights are substitutes with respect to tenure security, we assume as previously that $\frac{\partial^2\sigma(l,R)}{\partial l \partial R} < 0$ for any given l and R.

Since the labor constraint is binding, the household now faces the following program:

$$\max_{l_O} \quad \tilde{\Pi} = \sigma\left(\bar{l} - l_O, R_V\right).Q\left(\bar{l} - l_O\right) + \sigma\left(l_O, R_O\right).Q\left(l_O\right) \tag{4}$$

for which the interior solution consists of choosing a labor allocation that equates the marginal gains from investment in the village and outside-of-the-village plots given the productive and protective impacts of labor (see Appendix A-4).

[12] Without loss of generality, we neglect issues of travel time to each plot. This could be incorporated in the model with a tax on labor or on production but would introduce unnecessary complications.

Because the PFR program aimed only to formalize plots within village borders, we consider next the impact of an improvement in R_V while keeping R_O constant. We have the following proposition:

Proposition 3. *An improvement in property rights only in the village has an ambiguous impact on the reallocation of labor between plots located within and outside the village. If labor and property rights are sufficiently strong substitutes with respect to tenure security, then* ***labor will be shifted away from plots within the village to plots outside the village****.*

Proof: see Appendix A-4

We have the following corollary:

Corollary 3. *If labor and property rights are stronger substitutes with respect to tenure security under weak property rights, then households holding initially weaker property rights in the village are, all else being equal, more likely to respond to a marginal improvement in the within-village property right by shifting their cultivation away from the village plot toward cultivation of the plot outside the village.*

Proof: see Appendix A-5

4 Experimental Design and Data

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.[13] Selection into 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.[14] 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 (Mil-

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

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

lennium Challenge Corporation, 2011).[15] Figure A-2 shows the different steps of the selection process. To this day, the program has not taken place in the randomly-selected control villages.

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 2011 follow-up survey. Land demarcation was still ongoing in an additional eight villages, and had not started in three villages. Six villages refused to cooperate toward the production of an ETF and were dropped by the program.

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 road-map and verify execution of the land demarcation activities; secondary national household survey data provide pre-intervention balance checks; and primary household survey data formally document impact.

"Insert Figure 1 about here"

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.[16] A timeline of relevant implementation and data collection milestones is presented in Figure 1.

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.

Third, we conducted a rural household follow-up survey in March/April 2011. Our sample covered the sample of 2010 rural EMICoV villages: 160 villages from the 2006 EMICoV sample were revisited, and an additional 129 villages were randomly selected to complement the 2006

[15]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.

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

sample.[17] In sum, our 2011 survey sample covers 289 villages: 191 treated and 98 control. The selection of villages was done randomly and stratified at the level of the commune, with on average 7 villages surveyed per commune.[18] 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.[19]

The 2011 survey instrument covers a detailed set of questions related to basic demographics, parcel land use, and agricultural production. The land modules elicit a rich set of information on cultivation and investment decisions at the parcel level, while the agricultural modules allow for productivity estimates at the agricultural plot level. Table A-1 defines the main outcome variables used in this study.

In line with the program coverage, we limit our study sample to households with at least one 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-2).[20] This yields an analysis 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).[21] We limit our analysis to the major rainy season to ensure comparability with northern Benin's uni-modal rainfall distribution.

[17] 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.

[18] 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 to align with the program implementation.

[19] 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.

[20] These proportions do not vary with treatment status.

[21] 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 find no significant difference in the years of tenure for treatment and control parcels (15.6 and 14.6, respectively). Moreover, we do not find that land demarcation activities affected participation in agricultural activities, while 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.

4.3 Balance

We perform two classes of balance checks. First, we use 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 2011 analysis sample, it validates 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.

"Insert Table 1 about here"

Second, we establish balance on plausibly exogenous characteristics in our 2011 analysis sample, which is important since the 2006 and 2011 survey samples do not fully overlap. Mean comparisons reported in Table A-3 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.[22] Although the difference in the age of household head noted in the 2006 sample vanishes in our 2011 analysis sample, we control for this variable (and household size) in all regression models. Overall, we conclude that the program lotteries yielded balance across the treatment and control sub-samples.

5 Econometric Approach and Results

We estimate the impact of demarcation on parcel-level measures of tenure security, cultivation and investment decisions, and agricultural production using the following model:

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

where $\mathbf{y}_{ijk}$ is the outcome of parcel i in village j that took part in lottery pool k, $\mathbf{t}_{jk}$ 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} is a ran-

[22] We also check for balance in non-varying village characteristics in 2011 and find that access to a paved road and the presence of commercial activity are the only observable challenges to our identification. See Goldstein et al. (2015) for details.

dom error component.[23] The random assignment of the program at the village level establishes our identification, and we exploit within-lottery variation to recover the intention-to-treat (ITT) effect of demarcation.[24] All standard errors are clustered at the unit of randomization (village) to account for possible intra-village correlation in the outcomes of interest (Duflo et al., 2008).[25]

"Insert Table 2 about here"

The three panels of Table 2 report regression results using Equation 5 for the following categories of outcomes: tenure security (Panel A); cultivation and investment decisions (Panel B); and agricultural production (Panel C).[26] 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. These results allow us to test our theoretical predictions (Section 3).[27]

We first estimate the effect of the land demarcation process on a key intermediate outcome, the presence of clear borders (Table 2). This outcome serves as a proxy for tenure security, as the implantation of cornerstones endows the landholder with a visible marker of security from encroachment and expropriation. As expected, and echoing Table A-4, we find strong evidence of a higher share of parcels with clear borders in treatment villages. The program increases the likelihood of having borders by 27 percentage points relative to control parcels, significant at

[23]For the analysis, 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. The regressions additionally control for parcel-level characteristics including area of the parcel, gender of the parcel manager, and parcel-home travel time. All regressions also control for enumerator fixed effects.

[24]At the time of the 2011 follow-up survey, the land demarcation activities were completed in 96% of the treated villages in our sample. The process took on average three months and, in the average treated village, the demarcation activities had been completed for 11 months by March 2011 (see Table A-4). Endogenous timing of the demarcation activities is a potential concern. We employ an intention-to-treat approach to ensure our estimates are immune to this source of bias. We find no significant difference between treated villages where the survey started earlier and those where the survey started later except for the fact that the program started earlier in the northern region of the country 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.

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

[26]See Table A-1 for more details on the outcomes of interest. We also analyze of the intra-household impact of the PFR and find 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).

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

the 1% level, an almost five-fold increase relative to the control mean (6%).[28]

Next, we assess the impact of demarcation on cultivation and investment decisions over the parcel (Table 2, Panel B). Drawing on our theoretical framework (see Section 3.1), we first examine whether the PFR prompted a change in the decision to cultivate land or leave it fallow. Over the pooled sample, a marginal increase in property rights does not affect the decision to leave land fallow. Yet we do uncover a shift toward long-term crop investment (p-value < 0.05), in line with our theoretical framework (Proposition 2). Treated parcels are 2.4 percentage points more likely than control parcels to be used primarily for perennial crops, and they 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%). The observed increase in tree investment is similar in magnitude to other tree-planting effects found in the literature (e.g., Bandiera, 2007).

Turning our attention to agricultural production (Table 2, Panel C), we find that, despite the observed increase in long-run investment, land demarcation does not initially increase agricultural output, farm yields (measured as the log of the value harvested per hectare), or input use (labor, fertilizer, and improved seeds). This result is not surprising given that it takes more than one year for long-term crop investments to generate productivity gains.[29] We also note a null result on parcel size, consistent with our previous household-level analysis on participation in agriculture following demarcation.[30]

5.1 Gender

Motivated by our theoretical predictions (Section 3.2), we explore heterogeneity in the impact of land demarcation activities by gender of the household head. In practice, we augment Equation 5 as follows:

$$\mathbf{y}_{ijk} = \alpha + \beta \cdot \mathbf{t}_{jk} + \psi \cdot \mathbf{gender}_{ijk} + \lambda \cdot \mathbf{t}_{jk} \cdot \mathbf{gender}_{ijk} + \phi \cdot \mathbf{x}_{ijk} + \gamma_k \cdot \mathbf{lottery}_k + \varepsilon_{ijk} \quad (6)$$

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; cultivation

[28] 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.

[29] The gestation period for tree crops such as cashews and oil palm, for example, is at least four to five years.

[30] In Goldstein et al. (2015) We show that the demarcation treatment leads to no changes in the total land size used by a household, the share of land under cultivation, or the household's decision to engage in agriculture.

and investment decisions; and agricultural production) in Table 3a and Table 3b. 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.[31] We also report the total program effect on female-headed households $\beta + \lambda$ in a bottom row, with the corresponding standard error and significance level.

"Insert Table 3a about here"

First, we note that the program differentially affects male and female-headed households' use of clear borders to delineate their parcels (col. 1, Table 3a). Land demarcation activities cause a 28 p.p. increase in the proportion of parcels with clear borders among male-headed households. In contrast, the effect on parcels managed by female-headed households is 8.5 p.p. lower (difference significant at the 10% level).

Second, we investigate gender differences in the impact of land demarcation on cultivation and investment decisions (cols. 2-4, Table 3a). Our estimates suggest that assignment to the PFR increases the likelihood of fallowing land 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 that practice fallowing in the control group (significant at the 5% level).[32] In line with our model predictions (Corollary 1), this finding suggests that PFR land demarcation activities disproportionately increased the probability of fallowing among those with weaker initial property rights—leading them to undertake an important investment to replenish parcel soil fertility.

Additionally, we find that the significant effects of the program on both perennial crops and tree investments documented in Table 2 hold equally for male- and female-headed households (p-value < 0.1 and p-value < 0.05, respectively). If anything, in line with theoretical predictions, the point estimate on females for perennial crops is nearly twice as large as that for males, although the difference is imprecisely estimated (Corollary 2).

"Insert Table 3b about here"

[31] Further evidence on gender gaps within control villages is presented in Table A-6.
[32] The mean level of fallow for female-headed household parcels in control villages is nearly 0.

In Table 3b, 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 demarcation activities increase the gender gap in agricultural yields. Parcels held by female-headed households have yields that are 20% lower (significant at the 5% level) than yields found on parcels held by male-headed households in treated villages. Adding up the treatment effect with its gender interaction produces negative point estimates on both total revenue and yield, although we cannot reject a null overall treatment effect on female-headed households.

The results from Table 3b show that the widening of the gender gap in yields was not accompanied by gender differences in impact on farm labor input intensity or on the use of fertilizer and high yield seeds. Moreover, the small (and imprecise) gender differences in long-term crop investment found in Table 3a cannot explain this divergence in yields. This result warrants further examination through the framework of our model (Section 3.3).

5.2 Gender and parcel location

The program only demarcated those parcels situated within the boundaries of treated villages. This feature of the program allows us to capture shifts in investment across tenure regimes, comparing parcels located within and outside treated villages (Proposition 3). As our model suggests, these effects also likely vary with initial levels of tenure security (Corollary 3). We continue exploring gender as a source of heterogeneity and report our results by gender of the household head.[33]

In practice, we revise Equation 5 as follows:

$$\mathbf{y}_{ijk} = \alpha + \beta \cdot \mathbf{t}_{jk} + \eta \cdot \mathbf{outside}_{ijk} + \nu \cdot \mathbf{t}_{jk} \cdot \mathbf{outside}_{ijk} + \phi \cdot \mathbf{x}_{ijk} + \gamma_k \cdot \mathbf{lottery}_k + \varepsilon_{ijk} \quad (7)$$

where $\mathbf{outside}_{ijk}$ takes a value of 1 if parcel i is located outside the village boundaries, and where ν is our parameter of interest, capturing shifts in investment across tenure regimes.[34] We report the coefficients β, η, and ν on our outcomes of interest (tenure security; cultivation and investment decisions; and agricultural production) in Table 4a and Table 4b. To document

[33]For our inference, it is important to note that the gender of the household head does not predict parcel location (see Table A-5).

[34]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-5).

the differential effects by gender, we present our results for both split (Panels A and B) and pooled (Panel C) samples.

"Insert Table 4a about here"

In line with program implementation, assignment to the PFR significantly increases the use of clear borders on parcels within rather than outside the village (Panel C, Table 4a). Parcels located within the boundaries of a treated village are 58% (17 p.p.) 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 allow for a more precise estimation of the spatial differences on male-headed household parcels (Panel B), the point estimates on the female sample suggest the same pattern: parcels outside the village are 48% less likely than those within village boundaries to receive clear borders.

Next, we examine the location-specific effects of land demarcation on fallowing and investment decisions in Table 4a. Interestingly, and in line with Corollary 3, male and female-headed households respond differently to a marginal increase in village property rights. Male-headed households are significantly more likely (at the 10% level) to leave their parcels outside of the village fallow as a result of demarcation, with no effect on within-village parcels, with an overall effect of the program on outside parcels significant at the 5% level (not reported). In contrast, the significant increase in fallowing among female-headed households associated with land demarcation only occurs within the village.

Overall, we find that the increased investment in long-term crops and trees is circumscribed to within-village parcels (Panel C, Table 4a). Small sample sizes do not allow us to capture these effects across gender lines (Panels A and B).

"Insert Table 4b about here"

We now investigate agricultural production across tenure regimes (Table 4b). In line with our theoretical assumption that property rights and investment (in the form of labor and other inputs) are strong substitutes, 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; Corollary 3).

First, we find that land demarcation causes female-headed households to increase their use of fertilizer by 31 percentage points on parcels outside the village (p-value < 0.05), with no effect on within-village parcels (Panel A, Table 4b). This is particularly interesting in the light of the increase in fallowing within the village, since fertilizer use and fallowing are (imperfect) substitutes–with fallowing allowing for a fuller replenishment of the soil while inorganic fertilizer application only targets a few nutrients. Second, demarcation leads female-headed households to shift hired labor away from parcels located within the village and toward parcels located outside the village (Panel A, Table 4b). An additional 56 person-days (per hectare) of non-household (including hired) farm labor are applied on parcels outside the village relative to village parcels, while the within-village treatment coefficient falls by 35 person-days per hectare (significant at the 10% and 5% levels, respectively). 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).

A puzzle from Table 3b remains: why do we observe a widening of the gender yield gap on treated parcels? In line with the spatial reallocation of inputs across tenure regimes, we detect a significant 26% decline in output and a 36% drop in yields on within-village parcels following demarcation activities (Panel A, Table 4b). Though imprecise, the yields on parcels outside treated villages, meanwhile, are more than twice the size of those within treated villages.[35] In contrast, we observe no significant differences in treatment impact by parcel location for male-headed households in Panel B of Table 4b. Consistent with Corollary 3 of the model, these results suggest that the reallocation of productive resources across tenure regimes in large part explains the deleterious yield effect of the program on female-headed households.

Finally, we observe a marked drop – by nearly two-thirds of an hectare – in within-village parcel size for female-headed households (Panel A, Table 4b). We revisit this result in the following sub-section.

5.3 Robustness

Before concluding, we closely examine the apparent reduction in self-reported land size for treated parcels operated by female-headed households (see Table 4b, Panel A). This effect ap-

[35]Since output and yields are in log, the transformation of the point estimate into the marginal effect of a dummy variable compounds the inference problem (see Kennedy, 1981). Before transformation, the point-estimate difference of yields between parcels located inside and outside treated villages is .78 and is significant at the 5% level in Panel A.

pears to be concentrated within treated villages.[36] Such a finding could be driven by (i) a reduction in measurement bias following demarcation or by (ii) land expropriation during the 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.[37] 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 the village, we detect no significant difference in impact on land size across gender of the household head (Table A-7, Panel B).[38] Similarly, we find no gender difference in treatment when restricting the sample to parcels larger than 4 hectares in size (Table A-7, 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.

We verify that our previous results are not driven by this difference in land size and include the size of the plot as a regressor in all specifications (not reported). We find that our conclusions

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

[37]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).

[38]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.

are robust to this exercise.

6 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. Following Besley (1995), we provide a theoretical framework of household investment as a response to a marginal change in land rights. 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 program demarcation activities leads households to shift their investment decisions from subsistence crops to long-term and perennial cash crops. Moreover, as outlined in our model, as initial 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 soil fertility investment. These results contribute to a literature documenting that an increase in tenure security has the potential to lead to intensified, commercial modes of production (Hornbeck, 2010).

Taking advantage of the limited spatial program coverage (within and beyond village boundaries), we study the reallocation of investment across tenure regimes. In line with our model, we find that female-headed households are more responsive than males to an exogenous change in their relative tenure security. 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) and toward less secure land outside the village perimeter, allowing them to protect their claim to that land and reduce the risk of expropriation. The initially higher levels of tenure security of men explain why a similar spatial reallocation of production is not observed among male-headed households.

Our results show that, by increasing tenure security, the initial stages of formalization can positively affect investment decisions. Further research is needed to complete the picture and establish the causal effect of a full formalization of property rights, up to the delivery of a transferable title.

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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 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.

Table 2: Average effects of land demarcation activities

	Obs.	Control		ITT	
		Mean	Std. dev.	Coeff.	s.e.
Panel A: Tenure security					
Parcel has clear borders[†]	6,094	0.061		0.270***	(0.02)
Panel B: Cultivation and investment					
Started fallowing parcel[a †]	6,094	0.010		0.004	(0.00)
Investment in tree planting[a †]	6,094	0.040		0.017**	(0.01)
Perennial crops[†]	6,094	0.103		0.024**	(0.01)
Panel C: Agricultural production[b]					
Parcel size (ha)	6,094	2.908	8.903	0.047	(0.29)
Inputs					
- *HH members labor supply (person-days/ha)*	3,994	108.170	168.578	4.532	(6.94)
- *non-HH members labor supply (person-days/ha)*	3,994	94.684	182.618	-2.814	(6.98)
- *fertilizer/high-yield seeds*[†]	3,994	0.272		0.018	(0.02)
Output					
- *total value of output (Log USD)*	3,677	6.135	1.358	-0.044	(0.06)
- *yield (Log USD/ha)*	3,677	6.379	1.064	0.022	(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 randomly selected for a land demarcation activities (see Equation 5). 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] Yield and inputs are reported for the agricultural season that starts with the main rainy season.
[†] Indicates dummy variables.

Table 3a: Gender differentiated effects of land demarcation activities on tenure security and investment

	Border	Fallow	Tree planting	Perennial crops
Female-headed HH (ψ)	0.0441*	-0.0077	-0.0332**	-0.0376*
	(0.024)	(0.005)	(0.014)	(0.020)
Treated village (β)	0.2822***	0.0025	0.0159**	0.0215*
	(0.023)	(0.003)	(0.008)	(0.011)
$\times$ *Female-headed HH* (λ)	-0.0845**	0.0125*	0.0078	0.0196
	(0.037)	(0.007)	(0.016)	(0.023)
Number of parcels	6,094	6,094	6,094	6,094
$\beta + \lambda$	0.1977***	0.0150**	0.0237*	0.0411*
	(0.039)	(0.006)	(0.014)	(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.

Table 3b: Gender differentiated effects of land demarcation activities on agricultural activities

	Parcel	Labor supply		Fertilizer	Output	
	size (ha)	HH	non HH		total	per ha
Female-headed HH (ψ)	-0.9130***	3.7754	7.1600	-0.0277	-0.3858***	-0.0204
	(0.328)	(13.043)	(14.232)	(0.041)	(0.076)	(0.099)
Treated village (β)	0.1575	3.2151	-0.8450	0.0103	-0.0321	0.0544
	(0.331)	(7.634)	(7.515)	(0.021)	(0.063)	(0.055)
× *Female-headed HH* (λ)	-0.7671	11.9162	-12.6880	0.0528	-0.0922	-0.2002**
	(0.571)	(19.529)	(17.384)	(0.049)	(0.133)	(0.098)
Number of parcels	6,094	3,994	3,994	3,994	3,677	3,677
$\beta + \lambda$	-0.6096	15.1313	-13.5330	0.0631	-0.1189	-0.1553
	(0.464)	(17.914)	(15.795)	(0.049)	(0.124)	(0.102)

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.

Table 4a: Differentiated effects of land demarcation activities on tenure security and investment across location of the parcels

	Border	Fallow	Tree planting	Perennial crops
Panel A: Female-headed households				
Parcel is outside the village (η)	0.032	0.046	0.031	-0.043**
	(0.051)	(0.040)	(0.035)	(0.021)
HH lives in treated village (β)	0.159***	0.020**	0.004	0.031
	(0.041)	(0.009)	(0.015)	(0.020)
× *parcel is outside the village* (ν)	-0.077	-0.054	-0.006	0.046
	(0.071)	(0.041)	(0.041)	(0.048)
Number of parcels	907	907	907	907
Panel B: Male-headed households				
Parcel is outside the village (η)	0.027	-0.015***	-0.017	0.031
	(0.028)	(0.004)	(0.011)	(0.024)
HH lives in treated village (β)	0.310***	0.001	0.017*	0.018
	(0.025)	(0.004)	(0.009)	(0.011)
× *parcel is outside the village* (ν)	-0.179***	0.012*	-0.005	0.003
	(0.040)	(0.006)	(0.014)	(0.036)
Number of parcels	5,187	5,187	5,187	5,187
Panel C: All households				
Parcel is outside the village (η)	0.032	-0.007*	-0.012	0.022
	(0.027)	(0.004)	(0.010)	(0.023)
HH lives in treated village (β)	0.292***	0.004	0.018**	0.023**
	(0.024)	(0.003)	(0.008)	(0.011)
× *parcel is outside the village* (ν)	-0.170***	0.004	-0.005	0.007
	(0.038)	(0.006)	(0.013)	(0.033)
Number of parcels	6,094	6,094	6,094	6,094

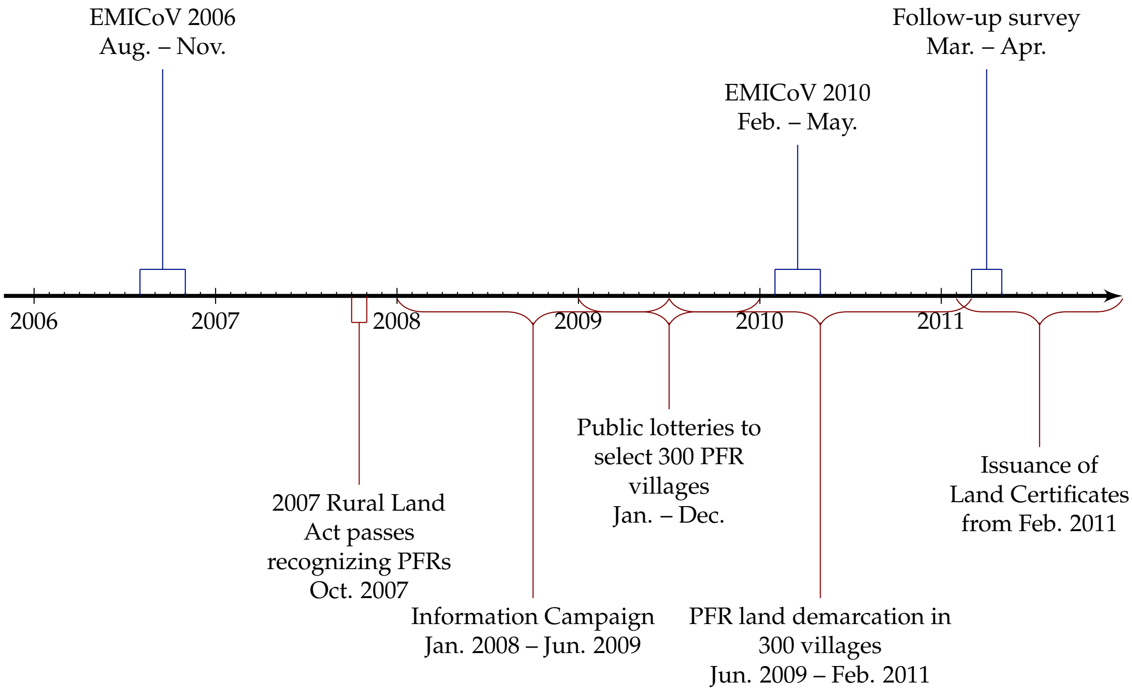
Note: Robust standard errors are reported in parentheses. They are clustered at the village level and all regressions include household and landholding control variables, enumerator fixed effects and lottery pool fixed effects. Significance levels are denoted as follows: * p<0.10, ** p<0.05, *** p<0.01.

Table 4b: Differentiated effects of land demarcation activities on agricultural activities across location of the parcels

	Parcel	Labor		Fertilizer	Output	
	size (ha)	HH	non-HH		total	per ha
Panel A: Female-headed households						
Parcel is outside the village (η)	0.052	-26.138	-36.238	-0.197	-0.098	-0.452**
	(0.241)	(40.228)	(25.153)	(0.129)	(0.338)	(0.177)
HH lives in treated village (β)	-0.627**	8.529	-34.748**	0.061	-0.263**	-0.355***
	(0.306)	(27.623)	(17.199)	(0.061)	(0.110)	(0.095)
$\times$ *parcel is outside the village* (ν)	0.414	19.111	55.659*	0.253**	0.109	1.041
	(0.328)	(46.985)	(29.805)	(0.124)	(0.478)	(0.717)
Number of parcels	907	604	604	604	555	555
Panel B: Male-headed households						
Parcel is outside the village (η)	0.184	-42.440***	-7.425	-0.047	0.328**	-0.047
	(0.283)	(13.300)	(13.753)	(0.036)	(0.158)	(0.095)
HH lives in treated village (β)	0.206	0.412	-1.507	0.003	0.000	0.084
	(0.380)	(7.420)	(7.509)	(0.021)	(0.067)	(0.058)
$\times$ *parcel is outside the village* (ν)	-0.333	8.883	17.183	0.070	-0.125	-0.105
	(0.602)	(20.290)	(21.937)	(0.046)	(0.136)	(0.127)
Number of parcels	5,187	3,390	3,390	3,390	3,122	3,122
Panel C: All households						
Parcel is outside the village (η)	0.096	-38.963***	-3.130	-0.061	0.283*	-0.092
	(0.256)	(9.656)	(13.330)	(0.037)	(0.155)	(0.090)
HH lives in treated village (β)	0.061	3.793	-4.129	0.009	-0.037	0.019
	(0.315)	(7.203)	(6.802)	(0.021)	(0.063)	(0.054)
$\times$ *parcel is outside the village* (ν)	-0.153	11.762	14.092	0.090**	-0.074	0.016
	(0.530)	(16.434)	(19.129)	(0.045)	(0.136)	(0.131)
Number of parcels	6,094	3,994	3,994	3,994	3,677	3,677

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.

Figure 1: PFR implementation and data collection timeline



Source: Information collected by authors.

Appendix

A-1 Proof of Proposition 1

Proof. Lets us denote $\alpha = 1 - F(\Omega)$.

Because $\frac{\partial \alpha}{\partial R} = -f(Z).\frac{\partial Z}{\partial R}$, it is easy to see that $\frac{\partial \alpha}{\partial R} > 0$ if and only if $\frac{\partial Z}{\partial R} < 0$ (i.e. when the ratio of probabilities σ_C/σ_U decreases with R). Observe that $\frac{\partial Z}{\partial R} = \frac{Q(\bar{l})}{\sigma_U^2(\bar{l},R)}.A$ with $A = \sigma_U(\bar{l},R).\frac{\partial}{\partial R}\sigma_C(\bar{l},R) - \sigma_C(\bar{l},R).\frac{\partial}{\partial R}\sigma_U(\bar{l},R)$. Because a plot is more secure when cultivated than when left fallow under the same labor investment and property right, we know that $\frac{\sigma_C(\bar{l},R)}{\sigma_U(\bar{l},R)} > 1$. If property rights and cultivation are substitutes with respect to tenure security, an improvement in the property right increases the tenure security of a plot more when the plot is left fallow than when it is cultivated, implying $\frac{\frac{\partial}{\partial R}\sigma_C(\bar{l},R)}{\frac{\partial}{\partial R}\sigma_U(\bar{l},R)} < 1$. Combining the two previous inequalities yields $\frac{\sigma_C(\bar{l},R)}{\sigma_U(\bar{l},R)} > \frac{\frac{\partial}{\partial R}\sigma_C(\bar{l},R)}{\frac{\partial}{\partial R}\sigma_U(\bar{l},R)}$, which can be rearranged into $A < 0$, and thus proves that $\frac{\partial \alpha}{\partial R} > 0$. □

A-2 Proof of Proposition 2

Proof. We focus on interior solutions to the program (3).

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

$$\begin{aligned}\Phi(l_L,R) \equiv & -\frac{\partial \sigma_S(\bar{l}-l_L,R)}{\partial l}.Q_S(\bar{l}-l_l) - \sigma_S(\bar{l}-l_L,R).Q_S'(\bar{l}-l_L) \\ & + \frac{\partial \sigma_L(l_L,R)}{\partial l}.P.Q_L(l_L) + \sigma_L(l_L,R).P.Q_L'(l_L) = 0 \end{aligned} \tag{8}$$

This simply equates the expected marginal gains from investments in the short-term and the long-term crops. Assuming that the Second Order Condition (SOC) is satisfied, we can now explore how a marginal improvement in the property right affects the allocation of labor between the two crops. Applying the Implicit Function Theorem to the FOC, we obtain:

$$\begin{aligned} & \frac{dl_L}{dR} = -\frac{\frac{\partial \Phi(l_L,R)}{\partial R}}{\frac{\partial \Phi(l_L,R)}{\partial l_L}} = -\frac{(B+C)}{\frac{\partial \Phi(l_L,R)}{\partial l_L}} \\ & \text{with } \begin{cases} B = P.\frac{\partial^2 \sigma_L(l_L,R)}{\partial l \partial R}.Q_L(l_L) - \frac{\partial^2 \sigma_S(\bar{l}-l_L,R)}{\partial l \partial R}.Q_S(\bar{l}-l_L) \\ C = P.\frac{\partial \sigma_L(l_L,R)}{\partial R}.Q_L'(l_L) - \frac{\partial \sigma_S(\bar{l}-l_L,R)}{\partial R}.Q_S'(\bar{l}-l_L) \end{cases} \end{aligned} \tag{9}$$

Because $\frac{\partial \Phi(l_L,R)}{\partial l_L} < 0$ (this is precisely the SOC), it is easy to see that $\frac{dl_L}{dR}$ is of the same sign as $B+C$, which may be either negative or positive. Inspection of B shows that a sufficient condition for B to be positive is $\frac{\partial^2 \sigma_S(\bar{l}-l_L,R)}{\partial l \partial R} << \frac{\partial^2 \sigma_L(l_L,R)}{\partial l \partial R}$, which means that the substitutability between labor and property rights is stronger under short term crops. In this case, because an increase in R will substitute for more labor to produce the short-term crop than to produce the long-term crop, optimality will require reallocating some of the labor away from the production of the short-term crop towards the production of the long-term crop. Similarly, for C to be positive requires $\frac{\partial\sigma_S(\bar{l}-l_L,R)}{\partial R} << \frac{\partial\sigma_L(l_L,R)}{\partial R}$. This occurs when there are greater tenure security gains from a marginal improvement in the property right for the more-insecure long-term crop than for the short-term, less insecure, crop. This is a reasonable assumption which reflects complementarity between crop maturity and property rights with respect to tenure security. □

A-3 Proof of Corollary 2

Proof. The tenure security gain for long-term cultivation resulting from a marginal improvement in a property right is likely to be greater when the initial property right is weak. This means that the condition $C > 0$, and thus $\frac{dk_L}{dR} > 0$, are all the more likely to hold. □

A-4 Proof of Proposition 3

Proof. To find the interior solution of program (4), we differentiate $\tilde{\Pi}$ with respect to l_O and equate it to 0. This gives the following first order condition:

$$\Psi(l_O,R_V) \equiv -\frac{\partial\sigma\left(\bar{l}-l_O,R_V\right)}{\partial l}.Q\left(\bar{l}-l_O\right) - \sigma\left(\bar{l}-l_O,R_V\right).Q'\left(\bar{l}-l_O\right) + \frac{\partial\sigma(l_O,R_O)}{\partial l}.Q(l_O) + \sigma(l_O,R_O).Q'(l_O) = 0 \tag{10}$$

which equates the marginal gains from investment in the village and outside-of-the-village plots. Applying the Implicit Function Theorem to $\Psi\left(l_O,R_V\right)$, we have :

$$\frac{dl_O}{dR_V} = -\frac{\frac{\partial\Psi}{\partial R_V}}{\frac{\partial\Psi}{\partial l_O}} \tag{11}$$

Under the assumption that the Second Order Condition is satisfied, $\frac{\partial\Psi}{\partial l_O}$ is negative, $\frac{dl_O}{dR_V}$ is thus of the same sign as

$$\frac{\partial\Psi}{\partial R_V} = -\frac{\partial^2\sigma\left(\bar{l}-l_O,R_V\right)}{\partial l\partial R}.Q\left(\bar{l}-l_O\right) - \frac{\partial\sigma\left(\bar{l}-l_O,R_V\right)}{\partial R}.Q'\left(\bar{l}-l_O\right) \tag{12}$$

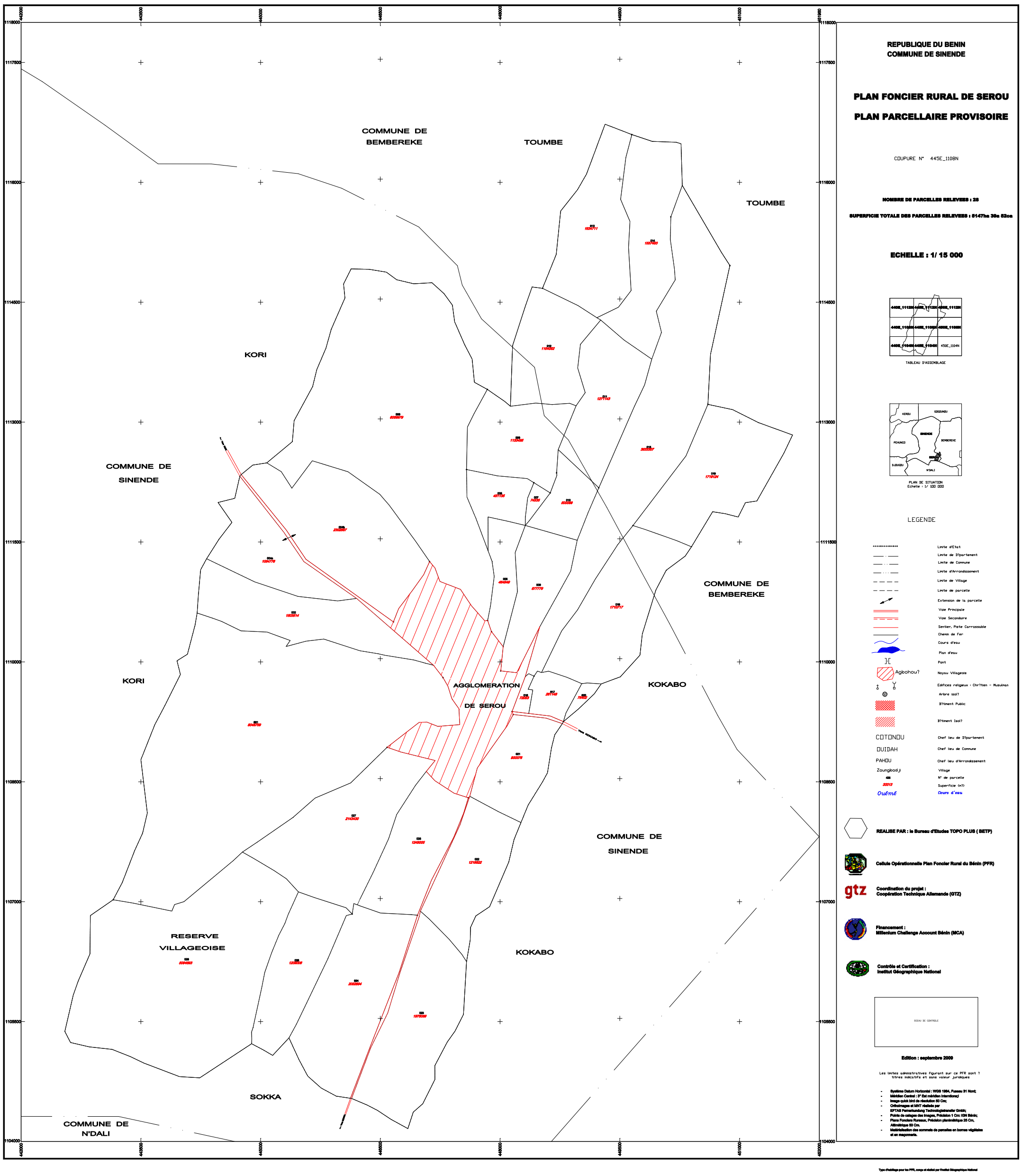
Because the first term is positive (under the assumption that labor and property rights are substitutes with respect to tenure security) and given that the second term is negative, $\frac{\partial\Psi}{\partial R_V}$ cannot be signed. When labor and property rights are strong substitutes with respect to tenure security, $-\frac{\partial^2\sigma(\bar{l}-l_O,R_V)}{\partial l\partial R_V} >> 0$ so that $\frac{\partial\Psi}{\partial R_V} > 0$. An improvement in the village property right thus frees up more labor as optimality requires to reallocate labor to cultivating the out-of-the-village plot. □

A-5 Proof of Corollary 3

Proof. The corollary is obtained by noticing that $-\frac{\partial^2\sigma(\bar{k}-k_O,R_V)}{\partial k\partial R}$ will be greater under the corollary's assumption for small values of R_V. $\frac{\partial\Psi}{\partial R_V}$ will thus more likely be positive. Because of greater substitutability when the property right is weak, a marginal improvement in the village property right will lead the household to free up more labor away from the village plot and reallocate it to the plot outside the village. □

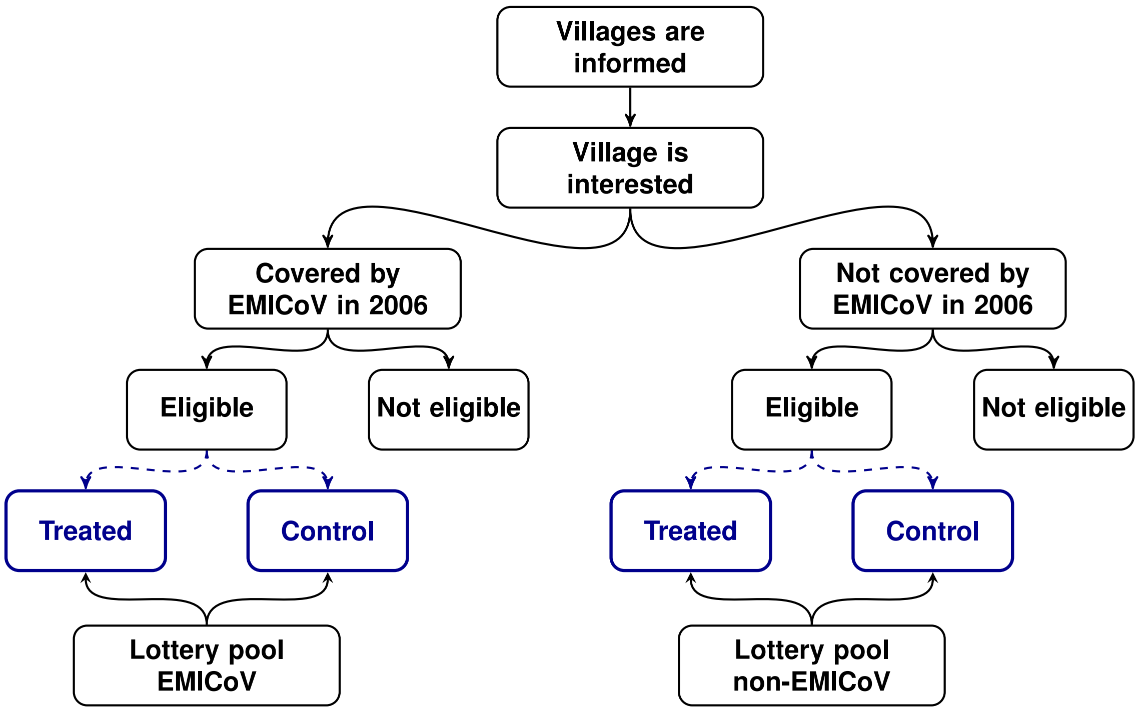
Figures and Tables

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



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

Figure A-2: Selection of treated villages within commune



Source: Information collected by authors.

Table A-1: 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
Started fallowing parcel	Binary variable equal to 1 when the parcel has newly been left fallow 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
Perennial crops	Binary variable equal to 1 when the landholding is primarily used as perennial cropland and 0 otherwise
Parcel area	Parcel size measured in hectares
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
Value of output	Total value of agricultural production (in log US $) following harvest during the main agricultural season
Yield	Agricultural yield (in log US $ per hectare) following harvest during the main agricultural season

Table A-2: 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-3: 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	0.03	(0.02)
- *lateritic*	0.32	0.47	0.30	0.46	0.01	(0.03)
- *hydromorphic*	0.18	0.38	0.16	0.36	0.01	(0.03)
- *ferralitic*	0.26	0.44	0.35	0.48	-0.04	(0.03)
- *other*	0.05	0.22	0.05	0.22	-0.01	(0.01)
Walking distance from homestead:						
- *00–05 minutes*	0.14	0.35	0.13	0.34	-0.02	(0.01)
- *06–15 minutes*	0.13	0.34	0.11	0.31	0.01	(0.01)
- *16–30 minutes*	0.16	0.36	0.16	0.37	-0.00	(0.01)
- *31–45 minutes*	0.13	0.33	0.14	0.35	-0.01	(0.01)
- *46–60 minutes*	0.11	0.32	0.12	0.32	0.01	(0.01)
- *> 1 hour*	0.33	0.47	0.34	0.47	0.00	(0.02)
Number of parcels	4,071		2,023		6,094	

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 A-4: 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.

Table A-5: Correlates of parcel location

	Marginal effects	
	coeff.	s.e.
Female headed household†	0.0053	(0.006)
Age of household head (years)	-0.0002	(0.000)
Household head can read/write†	-0.0061	(0.005)
Household size	-0.0010	(0.001)
Household head is polygamous†	-0.0013	(0.004)
Landholding size (ha)	0.0028	(0.001)**
Walking distance from home to land > 1 hour†	-0.0916	(0.023)***
Mode of acquisition:		
- *bequest*	0.0229	(0.015)
- *gift*	0.0131	(0.013)
- *rental*	-0.0106	(0.008)
- *purchase*	-0.0165	(0.006)**
- *clearing*	0.0378	(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. Significance levels are reported as follows: * p<0.10, ** p<0.05, *** p<0.01.
† Indicates dummy variables.

Table A-6: 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	1.88	1.16	2.13	1.36	-0.25	(0.11)**
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)	1.57	3.33	3.13	9.50	-1.56	(0.46)***
Mode of acquisition:						
- *bequest*	0.31	0.46	0.48	0.50	-0.16	(0.04)***
- *gift*	0.24	0.42	0.20	0.40	0.04	(0.04)
- *rental*	0.14	0.35	0.09	0.28	0.05	(0.03)*
- *purchase*	0.17	0.38	0.19	0.39	-0.02	(0.03)
- *clearing*	0.01	0.08	0.03	0.18	-0.03	(0.01)***
Parcel has an official document†	0.07	0.25	0.10	0.30	-0.03	(0.03)
Fear land loss during fallow†	0.71	0.46	0.72	0.45	-0.01	(0.06)
Land conflict†	0.05	0.22	0.05	0.22	0.00	(0.02)
Parcel is delimited (trees, stones, ...)†	0.63	0.48	0.66	0.48	-0.02	(0.05)
Invested on parcel†	0.07	0.25	0.12	0.33	-0.05	(0.02)***
Started fallowing parcel†	0.00	0.06	0.01	0.10	-0.01	(0.00)**
Parcel rented out†	0.06	0.23	0.05	0.22	0.01	(0.02)
Panel C: Agricultural activities						
Landholding is cultivated†	0.64	0.48	0.65	0.48	-0.01	(0.03)
Land size cultivated (ha)	0.64	0.68	1.72	3.40	-1.08	(0.20)***
Labor input (person-day/ha)	222.06	271.32	199.72	259.35	22.34	(34.17)
Used improved inputs†	0.31	0.47	0.27	0.44	0.05	(0.07)
Used pesticide/herbicide†	0.10	0.30	0.11	0.32	-0.01	(0.04)
Crop was harvested†	0.93	0.26	0.93	0.26	0.00	(0.02)
Yield (Log USD/ha)	6.30	1.07	6.39	1.06	-0.09	(0.12)
Number of parcels	289		1,734		2,023	

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

Table A-7: Differentiated effects of household headship on reported land area (ha)

	Coeff.
Panel A: All households in control villages	
Constant	0.818
	(1.697)
Female-headed household[†]	-0.710***
	(0.267)
Number of parcels	1,770
Panel B: All households with less than 0.5 ha of land size[a]	
Constant	0.275***
	(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 households with more than 4 ha of land size[a]	
Constant	-0.614
	(5.81)
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: The dependent variable is the reported measure of land area. It is reported in hectare. The column "Coeff" reports estimates of the linear regression of the reported land area on the gender of the household head. The model also includes other household and landholding characteristics, enumerator fixed effects and lottery pool fixed effects. For concision, the coefficients of those variables are not reported. Robust standard errors are reported in parentheses. They are clustered at the village level. 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.

[†] Indicates dummy variables.