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Abstract

This paper investigates the link between insecure property rights and land disputes using farm-household panel data from Ethiopia. We offer two main contributions. First, we develop a novel theoretical framework of land disputes. Our model predicts that in difficult times (i.e. when water is scarce), bargaining is more likely to breakdown—and dispute to arise— if property rights are ill-defined. Second, guided by our theoretical framework, we empirically assess the causal relationship between land tenure security and clashes. Our identification strategy relies on the gradual rollout of a land certification program at the village level and on the exogenous variation in water availability, a trigger of land disputes. We find that having tenure security reduces the likelihood for a farm-household to experience land disputes by about 40%. We also show that

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secure property rights are more likely to reduce land disputes when households face adverse weather shocks, hence by reducing the vulnerability to water scarcity. We further document that water scarcity has a stronger impact on land disputes when the marginal value of land is larger.

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1 Introduction

Insecure property rights over land are an important factor behind social conflicts and violence in the developing world. Case studies linking ill-defined property rights and land disputes abound in the literature: the fact that many individuals may have claims to the same piece of land is alleged to exacerbate tensions and generate mistrust, especially in times of scarcity.[1] Furthermore, it is documented that in periods of insecurity land related disputes can turn increasingly violent and are linked to broader security, livelihood, political and identity issues.[2] The key challenge lies in identifying the causal effect of tenure security on land disputes.

While there exists a growing body of literature studying the causal channel linking insecure property rights to various economic outcomes—such as education, access to credit or migration[3]—little attention has been paid to the mechanisms linking tenure insecurity and land disputes. This is surprising because in many developing countries, informal institutions—socially shared, unwritten rules—are the main way communities manage land rights (Blattman et al., 2014). It is often pointed out that the lack of central enforcement of these informal institutions is a reason for deadlocks, disagreements and even violence (Fearon, 1998). Furthermore, it is usually purported that these bargaining failures are more likely to occur when agents face adverse shocks: it may be more difficult to sustain cooperation in times of scarcity (Ostrom, 2005).

In this paper, we offer two main contributions. *First*, we develop a novel theoretical framework of land disputes. Our simple framework predicts that in

[1] A typical illustration is the Kenyan case where, in the aftermath of the early 2008 post-election violence, the "Kenya National Dialogue and Reconciliation" process identified land reform as key to peace and reconciliation.

[2] See for example the report on "Land and Conflict" produced by the "Disaster and conflict" program of the UNEP: United Nations Environment Programme (2011).

[3] See for recent examples Besley (1995), Goldstein and Udry (2008), Besley et al. (2012), Acemoglu et al. (2014), or de Janvry et al. (2015).

difficult times (i.e. when water is scarce), bargaining is more likely to break down—and dispute to arise— if property rights are ill-defined. *Second*, guided by our theoretical framework, we empirically assess the *causal* relationship between tenure security and land disputes. We provide new evidence showing that households with tenure security are less prone to land disputes.

Following the theoretical framework, we also detail a mechanism linking property rights and tenure security. In particular, we show that secure property rights are (i) more likely to reduce land disputes when households face adverse weather shocks and (ii) that water scarcity has a stronger impact on land disputes when the marginal value of land is larger. Identifying a clear mechanism linking tenure security, water scarcity and land disputes is new in the literature and is of importance to effectively reduce the occurrence of land disputes in developing countries.

Our theoretical framework is a simple bargaining model with private information. We assume that agents bargain over a piece of land. One agent can illegally use the land, albeit at a (privately known) cost.[4] This cost reflects the strength of property rights in the region: the cost is substantive if tenure security is strong, and low if property rights are ill-defined. When facing water scarcity, the temptation to encroach on the land of the tenant rises along with the marginal value of land. This setup gives rise to a simple perfect Bayesian equilibrium in which we observe (i) fewer costly disagreements when property rights are more secure and (ii) higher probability of disagreement in dire times. The framework highlights that the marginal value of land is central in explaining the role of tenure security and water scarcity on land disputes.

We empirically test the theoretical framework by using data on the gradual

[4]Most rational models of conflicts (see Blattman and Miguel, 2010 for a recent review) are based on a contest mechanism: agents invest in a fighting technology determining a probability of winning the fight. We are interested in a different type of events, encroachment and illegal use of land, in which physical violence is almost never used directly. The cost of disputes is not linked directly to the investment in a conflict technology but rather reflects the legal and reputation costs of encroaching.

rollout at the village level of a large land certification program implemented by the World Bank in the Highlands of Ethiopia. In particular, we use a large farm-household panel survey conducted in the region in years 2005 and 2007. Our identification strategy relies on a fixed effects specification that compares reported land disputes between households in certified and non-certified villages. Because the program provided certificates to the entire village simultaneously, this process eliminates concerns about selection at the individual level. Any time-invariant village characteristic correlated with the program rollout and land disputes is accounted for by the village fixed effects. Therefore, the identifying assumption for our first result—the effect of tenure security on land disputes—is that any time-varying village characteristic that affects land disputes is uncorrelated with the rollout of the program. We provide evidences supporting this assumption in sections 4 and 5.

Our second main result—the effect of tenure security on land dispute transits through less vulnerability to water scarcity—relies on exogenous variations of water availability. We use a drought indicator, the Standardized Precipitation-Evapotranspiration Index (SPEI), reflecting the climatic water balance at different time scales. This metric allows to investigate whether farm-households with tenure security are more resilient to weather anomalies, and less likely to experience disputes.

We first show that having tenure security reduces the likelihood for a household to experience land disputes by about 40%. We then present robust evidence that water scarcity affects disputes over land: our baseline estimates suggest that switching from a good year in which no serious droughts occur during the rainy season to a bad year in which severe droughts occur every month during the rainy season increases the likelihood of disputes over land by around 24% for farm-households without land tenure. For households with tenure security this effect is not significantly different from 0. This highlights that tenure security leads to fewer disputes by reducing the vulnerability of rural households to water scarcity. Guided by the predictions of our theoretical model, we further document that factors increasing the marginal value of land (i.e. having more labor or livestock available in the farm) magnify the impact of water scarcity on land disputes. Our findings are robust to different specifications and measures of climate shocks.

Ethiopia provides a prime set up to address our research questions. A largely rural country, historically plagued by rainfall anomalies, Ethiopia's land rights were shaped by a radical land reform in 1975 implemented by the Marxist regime (the Derg). As a result, all land was made collective property of the Ethiopian people for more than three decades. Farmers were given usufruct rights (only user-rights to land) with periodic village-level land redistributions. Land could not be sold, mortgaged, exchanged, or transferred. While the new government in 1991 partially lifted the market ban and then allowed for some land rental activities, tenure security remained a critical issue. The momentum for more market oriented land policy was indeed very weak. A combination of oral contracts and lack of judicial institutions to intervene in case of disputes created a situation of persistent land insecurity, and frequent litigations among rural households (Deininger et al., 2008). The land certification program issued non-alienable use-right certificates and used a participatory and highly decentralized process of field adjudication.

This paper is related to a vast empirical literature on how improved property rights affect economic outcomes. In reviewing the property rights literature, Besley and Ghatak (2009) detail how well-defined and secure property rights over land can impact economic outcomes. First, tenure security can increase investment incentives (Besley, 1995; Fenske, 2011) and it can also increase the use of land as collateral in accessing credit (Besley et al., 2012). Furthermore, there is evidence that political power uses land tenure as a way to control the local economy. For instance, Goldstein and Udry (2008) show that in Ghana agents who are not central to the networks of local political power through which land is allocated are very likely to have their land expropriated if it is fallowed. This creates an incentive for intensive and inefficient land use. Similarly, in a recent contribution, Acemoglu et al. (2014) show that in Sierra Leone powerful chiefs control the access to the land. As a result, a whole series of development outcomes, such as educational attainment and child health among others, are significantly lower. Finally, De Janvry et al. (2015), using the rollout of the Mexican land certification program from 1993 to 2006, show that land certification induces migration.

In this study, we document a new channel though which tenure security impacts economic outcomes: insecure property rights lead to disputes over land in dire times. Land security is crucial for many development outcomes given that localized disputes can severely affect welfare, generate tensions and potentially escalate into large-scale conflicts (Andre and Platteau, 1998).

Our results also add new micro evidence to the literature on the relationship between weather anomalies and conflicts.[5] It is generally found that rainfall anomalies are positively correlated with the occurrence of conflicts. We show here, using micro data, that tenure security is an important channel through which water scarcity translates into local clashes. It is noteworthy that this literature stresses an "opportunity cost" mechanism: water scarcity generates violence through a decrease in agricultural income, which diminishes the opportunity cost of fighting for farmers (Chassang and Padro-i-Miquel, 2009). In this study, we deal with disputes over land and encroachment: no physical fight is usually taking place. We highlight that for this kind of disputes the marginal value of land is at the roots of the mechanism linking water scarcity and land disputes (and not income). To the best of our knowledge, the clear identification

[5] See for instance, recent studies by Jia (2013); Harari and La Ferrara (2014); Couttenier and Soubeyran (2014) or Almer et al. (2015).

of the role of tenure insecurity in generating disputes over land is new in this literature.

The paper is organized as follows. Section 2 presents the theoretical framework. Section 3 describes the background and the Ethiopian land certification program. Section 4 describes the data while section 5 presents the empirical strategy and the results. Section 6 investigates the underlying mechanisms linking property rights and land disputes and section 7 provides concluding remarks.

2 Theoretical Framework

This section presents a simple theoretical framework close in spirit to Besley and Ghatak (2009). Taking stock of the fact that physical violence is almost never used directly for land disputes, we rely on a bargaining model with asymmetric information: if bargaining breaks down one agent simply encroaches on the land of the other. Our model highlights the role of the marginal value of land in generating land disputes in dire times.

The environment Two agents $N = \{1, 2\}$ share a total amount of land of size 1. Let x_1 be the land share of agent 1 and x_2 the share of agent 2, with $x_1 + x_2 = 1$. We assume that water falls uniformly over the land. We denote by w the amount of water available per unit of land. Hence, each agent has access to an amount of water $x_i w$ which we denote w_i.

Water is a substantial input in production (i.e. farming, herding) but also an essential part of agents livelihoods. We denote the payoff that each agent gets from an amount w_i of water by $b_i(w_i - \bar{w})$ where $\bar{w} > 0$ represents the minimum water requirement of an individual. We assume that $b_i(.)$ is increasing and concave in the available amount of water w_i and that $\frac{\partial b_i(.)}{\partial w_i}$ goes to infinity as $w_i - \bar{w}$ tends to 0. Let v_i be the marginal value of land for each agent, i.e. $\frac{\partial b_i}{\partial x_i} = v_i$ for $i = 1, 2$.

Agents also value money. The utility of agent i from consuming w_i units of water and receiving a net money transfer t_i is $u_i = b_i(w_i - \bar{w}) + t_i$. We assume that agents are expected-utility maximizers.

The game The agents bargain over a piece of land owned by agent 1 (i.e. a *part* of x_1). Bargaining occurs naturally because the marginal value of land of agent 1 ("the tenant") is lower than agent 2, i.e. $v_2 > v_1$. The game proceeds as follows: agent 1 makes an offer $\overline{p}$ to agent 2 for the piece of land. Agent 2 can either accept or refuse this offer. If agent 2 refuses the offer, he can either use the land illegally or start a (Nash) bargaining procedure.[6] An important simplifying feature is that disputing or bargaining are game ending moves (as in most of the literature, see Alesina and Spolaore, 2005 or Chassang and Padro-i-Miquel, 2010). This implies that once agent 2 starts bargaining the choice of encroaching is forgone (i.e. the bargaining happens in front of the local authority—the elder of the village in our empirical study—and the outcome is enforceable). The bargaining procedure will lead agents to agree on a price p for the land such that $v_2 > p > v_1$. At this price the gains in utility from the transfer of land will be $(p - v_1)$ for agent 1 and $(v_2 - p)$ for agent 2.[7]

If agent 2 contests the negotiation and decides to encroach on the tenant's land she has to incur a cost c.[8] This cost reflects the legal formalities associated with the illegal use of land and the social cost of potentially acquiring bad reputation for encroaching, for example. We assume that this cost is uniformly distributed[9] over $[\theta - \frac{1}{2}, \theta + \frac{1}{2}]$ and is private information of agent 2. The pa-

[6]Note that the outcome of the game is qualitatively similar in the symmetric situation where agent 2 first makes an offer, which can be accepted or refused by agent 1, in which case agent 2 can either encroach over the land or start a Nash bargaining procedure.

[7]We choose the Nash bargaining over a non-cooperative procedure for simplicity. However, it is known that the Nash bargaining solution is a good approximation of the non-cooperative outcome of a two-person bargaining game *á la* Rubinstein (1982) when time delay goes to 0 (Binmore, 1987).

[8]This cost is sunk and is the source of inefficiency in our framework.

[9]We assume a uniform distribution for the sake of transparency. However, as it will become

rameter θ summarizes the strength of property rights: a higher θ reflects that property rights are more secure in the region.

2.1 Analysis

We proceed by backward induction, first studying the outcome of the bargaining procedure.

The bargaining procedure We are looking for the Nash solution of the bargaining process, hence the price for the land p maximizing the Nash product

$$Max_p(p - v_1)^{\alpha_1}(v_2 - p)^{\alpha_2} \tag{1}$$

where $\alpha_2 = 1 - \alpha_1$ is exogenously given and summarize the bargaining power of agent 1 and agent 2 (respectively).

The first order condition leads to $\alpha_1(p - v_1)^{\alpha_1 - 1} = \alpha_2(v_2 - p)^{\alpha_2 - 1}$. Dividing both sides by $(p - v_1)^{\alpha_1 - 1}(v_2 - p)^{\alpha_2 - 1}$ and rearranging leads to

$$p^* = (1 - \alpha_1)v_1 + \alpha_1 v_2 \tag{2}$$

Note that $v_1 \leq p^* \leq v_2$.

The decision of agent 2: dispute or peaceful negotiation Agent 2 compares the benefits of the initial offer and the bargaining price with the cost of seizing the land illegally:

- If $\min\{\overline{p}, p^*, c\} = \overline{p}$ agent 2 accepts.

- If $\min\{\overline{p}, p^*, c\} = c$, agent 2 encroaches on the piece of land.

- Finally, if $\min\{\overline{p}, p^*, c\} = p^*$ agent 2 refuses the initial offer and starts bargaining.

clear while detailing the equilibrium, most of our results hold with more general distribution functions, in particular symmetric distributions with (weakly) decreasing hazard rates.

The offer of agent 1 The decision of agent 1 depends on θ and on the subsequent decisions highlighted above. Agent 1 first seeks the p maximizing her expected payoff: $(\mathbb{P}\{c \geq p\})\,(p - v_1) - (\mathbb{P}\{c < p\})\,v_1$, leading to $p = \frac{\theta}{2} + \frac{1}{4}$ with our distributional assumption. We denote this solution by $p^{\max}$:

- If $p^{\max} \leq p^*$, *agent 1 offers* $\overline{p} = p^{\max}$. Any other initial offer decreases the expected payoff of agent 1 given that $p^{\max}$ maximizes the expected payoff of agent 1.

- If $p^{\max} > p^*$, *agent 1 offers* $\overline{p} = p^*$. If $\overline{p} > p^*$, agent 2 refuses the initial offer and starts the bargaining procedure anyway which leads to p^* (if not encroaching). Any offers $\overline{p} < p^*$ lead to a lower payoff for agent 1.

2.2 Equilibrium

In a perfect Bayesian equilibrium of the game, the strategies of the agents are as follows: Agent 1's strategy is to

- propose $\overline{p} = p^{\max}$ if $p^{\max} \leq p^*$;

- propose $\overline{p} = p^*$ if $p^{\max} > p^*$.

Agent 2's strategy is to

- accept any initial offer if $\min\{\overline{p}, p^*, c\} = \overline{p}$;

- reject the initial offer and encroach if $\min\{\overline{p}, p^*, c\} = c$;

- reject the initial offer and start the bargaining process if $\min\{\overline{p}, p^*, c\} = p^*$.

Proposition 1 *In a perfect Bayesian Nash equilibrium of the game, agent 1 offers* $\overline{p} = \min\{p^{\max}, p^*\}$. *Agent 2 accepts the initial offer if* $\overline{p} \leq c$ *and encroaches if* $\overline{p} > c$.

2.3 From Theory to Evidence

This simple framework can be used to obtain comparative statics predictions resulting from household and water availability heterogeneity. We show that the probability of observing a dispute varies with the strength of the property rights and further depends on water scarcity, farm size and factors impacting the marginal value of land.

- **Prediction 1.** We should observe that more secure property rights diminish land disputes. More secure property rights are reflected as a higher θ: better property rights translate in a higher average value for c, the cost of encroaching. Disputes occur at the equilibrium when $\overline{p} = \min\{p^{\max}, p^*\} > c$. When $\overline{p} = p^*$, clashes are less likely when θ is higher, simply because $\mathbb{P}\{c \leq p^*\} \equiv p^* - \theta + \frac{1}{2}$ decreases with θ. When $\overline{p} = p^{\max}$, the probability of disputes is also decreasing with θ because $\mathbb{P}\{c \leq p^{\max}\} \equiv 1 - \frac{\theta}{2}$.

- **Prediction 2.** A decrease in the amount of water available to agents should increase the probability of land disputes through an increase of the marginal value of land. As shown above, the probability of clashes is increasing in p^* when $\overline{p} = p^*$, because $\mathbb{P}\{c \leq p^*\} \equiv p^* - \theta + \frac{1}{2}$. It is clear in equation (2) that an increase in v_1 and/or v_2 leads to an increase in p^*. Recalling that v_i is decreasing in w_i ($b_i(.)$ is concave), a decrease in the amount of water w_i toward the minimal level $\bar{w}$ will increase both v_1 and v_2, and ultimately p^*.

- **Prediction 3.** As a corollary, any factor increasing v_1 and/or v_2 will also increase the price p^* and the probability of disputes when $\overline{p} = p^*$.

- **Prediction 4.** An increase in x_1—the land share of agent 1— may increase the probability of disputes. Recall that $x_1 = 1 - x_2$, hence a higher x_1 will decrease v_1 because $\frac{\partial v_1}{\partial x_1} \leq 0$ (recall that $b_i(.)$ is concave). Symmetrically, v_2 will increase through a decrease of x_2. Hence, referring to equation (2) we can say that p^* rises after an increase in x_1 if

$$\frac{dp^*}{dx_1} = \alpha_1 \frac{dv_2}{dx_1} + (1-\alpha_1)\frac{dv_1}{dx_1} \geq 0. \tag{3}$$

Hence, if

$$\frac{dv_2}{dx_1} \geq -\frac{1-\alpha_1}{\alpha_1}\frac{dv_1}{dx_1} \tag{4}$$

Assuming $\alpha_1 = \alpha_2$, this implies that land inequality increases the probability of disputes if the marginal value of land is convex, i.e. if $\frac{\partial v_2}{\partial x_2} \leq \frac{\partial v_1}{\partial x_1} \leq 0$ when $v_1 < v_2$.[10] If agent 2 has a very high bargaining power, land inequality may actually decrease the probability of disputes (because the price will already reflect more closely the interests of agent 2).

3 Background and the Ethiopian Land Certification Program

3.1 Background on the Ethiopian Land Tenure System

The land tenure system of Ethiopia was characterized by private land holding (the gult system), communal land tenure (the rist system) or the church until year 1975. The gult system was the relevant system in the southern half of Ethiopia and was characterized by absentee owners while the rist system was the dominant system in the northern half of the country and was denoted by shared land rights and land distribution based on the principle of equality (Bezabih et al., 2011). In the rist system, first the land was divided into parcels according to quality, and then, a lottery was implemented to allocate the land. In addition, if claimants could establish a direct line of descendants from the recognized original

[10]This assumption is very standard in demand analysis (see Deaton, 1992 for an example) and is met by many standard functions such as the Cobb-Douglas, the log funtion, the CRRA and the CARA utility function.

land holder then individuals obtained usufruct rights on the land. Under this system, farmers could not transfer the land rights to others through mortgage or sale.

In 1975 the empirical regime fell and a radical land reform was implemented. Proclamation No. 31/1975 established the collective property of land (Nickola, 1988). Almost all subsistence producers received usufruct rights. However, land transfer rights through bequests, leases, mortgages or sales, as well as hiring of labor were prohibited. In year 1991 the Ethiopian Peoples Revolutionary Democratic Front replaced the Derg regime in power since 1975 and established the state ownership of all land through Article 40 of the Constitution. Pastoralists and peasants were guaranteed the rights to access the land, and to transfer, remove or claim compensation for any improvements they made on the land. In addition, the ban on land market activity was removed giving incentives to the development of a land rental market.

3.2 The Ethiopian Land Certification Program

The Ethiopian land certification program has delivered the largest number of non-freehold land rights per time unit in Sub-Saharan Africa and follows the 1997 Federal Rural Land Administration Proclamation, which was revised in 2005. The program has been implemented in the four most populated regions of Ethiopia: Tigray in years 1998 and 1999, Amhara in year 2003, Oromiya and the Southern Nations, Nationalities and Peoples' Region (SNNPR) in year 2004 (Deininger et al., 2008; Bezabih et al., 2011).

The focus of our analysis is the Amhara National Regional State (ANRS), which is the second largest region in Ethiopia, located in the Northwest of the country (see Figure A1 of the appendix for a map of the Amhara region).[11]

[11] The Amhara region covers 11% of Ethiopia's total area and is divided into three major agricultural climatic zones: lowland (below 1,500 meters), semi-highland (between 1,500 and 2,300 meters) and highland (above 2,300 meters), accounting for 28%, 44% and 20% of the

Following the land proclamation at a federal level, ANRS adopted a Regional Conservation Strategy (RCS) in year 1999, and a land administration and land use policy in year 2000 to stop land degradation. Afterwards, proclamation No. 46/2000 (revised in year 2006) was issued. This proclamation established state ownership of the land and the registration of farmland for lifetime entitlement and children's succession. In year 2000, ANRS established the regional Environmental Protection, Land Administration and Use Authority (EPLAUA) to implement the RCS and the land use policy (proclamation No. 47/2000).

The lowest level of the local government (kebele and sub-kebele) handled the actual implementation process. Kebele and sub-kebele land administration committees were elected by the local community and trained as land registrars. A local consultation process took place before registration. The fees were generally very low and the technology was very simple. This was a highly participatory process with most of the input for adjudication and the demarcation of land provided by the local community, including women.

The preparation and awareness campaign started with kebele and sub-kebele administration discussions with the farmers, followed by the election of the Land Administration and Use Committees (LAC) and the provision of training. This was followed by the LAC and representatives of elders from the different kebeles together with the different kebele officials of EPLAUA demarcating kebeles' boundaries, public areas and communal lands. Each potential certificate recipient was instructed to negotiate the border with their neighbours. The LAC together with the farmers first conducted the demarcation of parcel boundaries and the traditional measurement of the area, and then after entering the information into field sheets, the LAC approved the legal status of the holding. The result of the land adjudication was presented to the public for a month long ver-

land area, respectively. A large part of the population is living in highland areas with steep slope topography and about 90% (14.7 million) of the people live in rural areas (Adenew and Abdi, 2005.

ification and corrections. The LAC chairperson and the kebele EPLAUA head would then approve the field sheets, with outstanding conflicts being passed on to the courts. Information collected regarding holdings and parcels were registered in the Land Registry Book at the kebele and approved by the kebele EPLAUA head and LAC chairperson.

The actual evidence of registration was issued in two stages. First, the LAC of the kebele issued temporary certificates based on the approved field sheet information, mainly as a way of ensuring that paper evidence was given to the certificate recipients before the actual certificate. Then, the Book of Holding was issued by the kebele (Palm, 2010). Types of data collected included: name and address of the landholder; parcel boundaries of the landholder; the estimated area of parcels; the current land use and land cover (grazing, cropland, etc.); the level of fertility status (low, medium and poor) identified by subjective judgment; and the local area name for identifying the parcels' locations.

The major advantage of the certification program is a decentralized implementation process at the village level through the elected LAC that involves sufficient public awareness about the program and the election of the local land administration committee with little political interference (Palm, 2010; Deininger et al., 2011). In addition, although land remains state-owned and many restrictions on land transfers continue to exist, certification was reported to increase the chance of getting compensation in the case where land was acquired for non-agricultural uses. Deininger et al. (2011) find that the land certification program in Ethiopia increased investments related to the land, renting and resulted highly cost effective as well as improved female household heads' participation in the land rental market. Bezabih et al. (2011) analyze the effect of land certification in Ethiopia on trust and productivity of female farmers, respectively, and find significant impacts of the program in increasing trust and the productivity of land owned by female-headed households.

An important feature of the certification program is that lack of manpower led to adoption of a gradual rollout of the program across kebeles. Because the program provided certificates to the entire village simultaneously, this process eliminates concerns about selection at the individual level.[12] As per discussions with officials from the regional EPLAUA, the choice of the certification timing was based on a combination of fixed characteristics of kebeles such as the kebele's administrative capacity and the kebele's facilities.

Differences between certified and non-certified kebeles do not undermine our identification strategy as long as they are uncorrelated with land disputes. To address this concern we verify in sections 4 and 5 that the level of land disputes in year 2005—prior to the program—is not correlated with the likelihood for a household to be certified in year 2007. We also include many time-varying household characteristics as well as district-year fixed effects in our main analysis to account for the possibility that land disputes changed over time due to unobservable characteristics that were correlated with the timing of land certification.

4 Data

4.1 Land Disputes

We use the Sustainable Land Management Survey to estimate the effect of land tenure certification on land disputes. This is a farm-household panel survey conducted by the Department of Economics of Addis Ababa University in collaboration with the Ethiopian Development Research Institute, the University of Gothenburg and the World Bank in 2005 and 2007.[13] The survey was conducted in the Amhara National Regional State of Ethiopia and includes 12 villages, six

[12] This stands in contrast to many titling program where allocation is demand driven.

[13] There were actually four waves of this survey, conducted in 1999, 2002, 2005 and 2007. However, only the last two waves have explicit information on land disputes, our outcome of interest.

from the East Gojjam zone and six from the South Wello zone. These villages are part of seven districts (woredas). About 1,500 households were selected by random stratified sampling based on indicators such as population density, access to the market and agricultural potential.[14]

One of the survey instruments was specifically designed to elicit land disputes. Specific questions were included to investigate whether farmers have experienced any disputes: "Have you ever faced any conflicts or claims regarding the land you own ?" An event was defined as a conflict in the following cases: (i) the claimant pushed the borders of the farmers parcel; (ii) it was claimed that the plot was unfairly given to the farmer; (iii) it was claimed that the plot belonged to the claimant sometime ago; (iv) it was claimed that the farmer pushed the claimant's borders; (v) the claimant did not want to leave the land the farmer left for him to manage while the farmer was away; (vi) the claimant did not want to leave the farmer's land he had given out to him on sharecropping.

Our final sample includes 1,487 farm-households (1,027 with land tenure and 460 without land tenure) for a total of 2,974 observations (2,054 with land tenure and 920 without land tenure). For the villages covered by the survey, the actual provision of certificates to the farmers started in May 2005. By year 2007, four villages have received the land certification (the "certified" group) while eight villages have not received the land certification yet (the "non-certified" group).[15] The four certified villages are found in three districts (Machakel, Tenta and Debre Elias) and the eight non-certified villages are part of four other districts (Gozmin, Enemay, Tehuldere and Harbu/Kalu). It is noteworthy that the first round of the survey covered the period before the certification started (beginning of year 2005) and that all farm-households in certified villages had been certified before

[14]The rate of attrition was extremely low, less than 1% per year. It is thus highly unlikely that sample selection due to attrition drives our main results.

[15]In the original sample, six villages are certified. However, two villages were used in a pretest and were thus already certified in 2005. We excludes these two villages from our analysis.

the implementation of the second round of the survey in year 2007.

Tables A1 and A2 of the appendix present descriptive statistics on many certified and non-certified households characteristics at the village and household level, respectively. Table A1 shows that certified and non-certified villages are not statistically different in many characteristics at the baseline in year 2005 before the land certification was implemented, while Table A2 shows that at the baseline households that will receive the certification are (i) more literate, (ii) have more livestock, (iii) are more likely to use improved seed, (iv) less likely to use soil conservation measures and (v) have less access to credit on average than households that will not receive the certification.[16] We will account for the heterogeneity in these observable characteristics—potentially impacting land disputes—in our main analysis.

We also observe that at the baseline in year 2005 our key variable of interest, the indicator of reported land disputes, is not statistically different between certified and non-certified farm-households at the village and household level. We ran a set of Kolmogorov-Smirnov tests for the comparison of the distributions of land disputes in year 2005 in any possible pair of certified and non-certified villages and we never reject the null hypothesis of equality of the distributions out of 34 tests (the lowest value being 0.31): certified villages have not significantly different levels of land disputes than non-certified villages in year 2005 before the implementation of the land certification. Tables A1 and A2 show that in year 2007—after the program implementation—the proportion of land disputes is significantly higher in the non-certified group than in the certified group.

Given that households have slightly different characteristics in certified and non-certified groups, Tables A3 and A4 of the appendix report average treatment effects of a matching estimator (propensity score matching) applied to reported land disputes in years 2005 and 2007. We match households in certified and

[16]These results are all confirmed by Kolmogorov-Smirnov tests comparing the distributions of the observable characteristics, at the 10% level.

non-certified groups on observable characteristics and we observe that in year 2005 there is no significant difference in land disputes, both in the unmatched and the matched group.[17] In year 2007, the non-certified group experiences a significantly higher level of land disputes: 8.7% in the unmatched group and 10.3% in the matched sample.[18] Interestingly, this effect is in line with the result from our main analysis, where we account for different sources of heterogeneity by including various sets of fixed effects and time-varying observable characteristics.

One important concern for our analysis is whether certified and non-certified villages follow different time trends on land disputes due to unobserved heterogeneity (i.e. certified villages have a higher rate of decrease in land disputes than non-certified villages due to better administrative capacities or other unobservable characteristics). Given that we have data on land disputes only for two time periods (before and after the certification), we are unable to provide direct evidence for a common trend between certified and non-certified villages in reported land disputes long before the implementation of the program (i.e. before year 2005). However, our empirical analysis provides three sets of results supporting the absence of time-trending unobserved heterogeneity correlated with land disputes.

First, we use a proxy for reported land disputes present in past surveys on the same sample of households. As mentioned, there was four waves of the survey, conducted in years 1999, 2002, 2005 and 2007 and only the last two waves had information on land disputes. However, in the four surveys we observe the reported perception of tenure insecurity. Each household had to mention whether a change in the land holding was expected in the next five years.[19] It is likely

[17] We obtain the best balance by matching groups based on the farm size, the age and literacy level of the head of the household, the size of the household, the livestock size, if the household has access to credit and if the farm-household uses improved seeds, soil conservation measures or irrigation.

[18] These results are robust to many different balance specifications and matching estimators. Results available upon request.

[19] We observe this variable over the four surveys only for a subset of households: respec-

that perceived tenure insecurity and land disputes are positively correlated over this period: a farmer may fear losing some land due to ongoing disputes with neighbors or, conversely, the expectation of land reallocation may create tensions among neighbors and generate disputes.

We observe in Figure A2 of the appendix that both certified and non-certified kebeles report very similar perceived tenure insecurity from 1999 to 2005. Possibly as a result of the 1997 redistribution, perceived tenure insecurity in year 1999 was very high, with 78% and 75% of households expecting a change of land holdings in certified and non-certified villages, respectively. In year 2005, before the implementation of the land certification program, this proportion decreased to 38% in certified and non-certified villages. In year 2007, plausibly because of the certification the program, the trends start to diverge, dropping to 24% in certified villages while staying around 39% in non-certified villages. If one believes that the perceived tenure insecurity in a village is correlated with land disputes over time, Figure A2 provides a convincing argument for a common trend in land disputes for certified and non-certified villages before the certification program.[20]

Another concern is whether more peaceful villages were selected for being certified first due to unobservable characteristics. Our data show that the correlation between a dummy variable indicating if a household was certified or not in 2007 and a dummy variable indicating whether a household experienced any land disputes at the baseline is statistically not significant (-0.037; s.e. 0.106). This provide additional evidence that land certification was not implemented based on the propensity of being peaceful or not. In addition, our fixed effect analysis rules out any selection bias due to time-invariant unobservable characteristics

tively 462 and 233 households for non-certified and certified kebeles in 1999, and 477 and 356 households in non-certified and certified kebeles in 2007.

[20]While establishing our main result, one of our specifications will include explicitly the change in land area between 2005 and 2007 for certified and non-certified households. This specification will show that land reallocation is not a confounding factor driving the effect of the certification program on land disputes.

such as the propensity to be confrontational.

Finally, we will show in section (5) that our main result is invariant to the inclusion of (i) village fixed effects; (ii) household fixed effects; (iii) time-varying household characteristics and (iv) district-year fixed effects. The first three robustness checks account for the possibility that land disputes changed over time due to characteristics that were (possibly) correlated with the timing of land certification. The last robustness check aims to control for the possibility that the program started earlier in certain types of districts that experienced differential changes in land disputes due to reasons other than land certification (i.e. disputes decrease faster in a district because it has better administrative capacities). Allowing for the time effects to depend on district fixed effects we further control for district characteristics that might have changed overtime and might have been correlated with the timing of the certification and the likelihood of conflicts.

4.2 Climatic Data

Our main explanatory variable of water scarcity is the Standardized Precipitation-Evapotranspiration Index (SPEI), developed by Vicente-Serrano et al. (2010). SPEI is a drought index that reflects the climatic water balance at different time scales and computes the difference between precipitation and potential evapotranspiration for each kebele over a specific time period (e.g., monthly or yearly). SPEI is a standardized variable that expresses the water balance in units of standard deviations from the long-run average of a cell. A value of zero means that the water balance is exactly at its long-run average; while a value of plus one (minus one) means that the water balance is one standard deviation above (below) the long-run average.

We used two datasets for computing the SPEI index at the kebele level (see appendix for more details). The precipitation data come from the African Rainfall Climatology Version 2 dataset (ARC2, Novella and Thiaw, 2013), which provides daily estimates at a resolution of 0.1 decimal degree, from 1983 to 2014, based on a combination of gauge and satellite data.[21] The dataset has notably been developed as a key input of the Famine Early Warning System Network (FEWSNET), one of the main tool used by international humanitarian agencies to monitor food security. The temperature data come from the Climate Prediction Center Global Land Surface Air Temperature Analysis (GHCN+CAM, Fan and Van den Dool, 2008) as monthly mean surface air temperatures at a 0.5 decimal degree resolution over the period 1948-2014. We provide more details on the construction of our main climate variables in the appendix.

5 Empirical Strategy and Results

We now turn on the empirical investigation of the theoretical predictions presented in section 2. We will first investigate whether land certification decreases the likelihood of land disputes (prediction 1) and whether farm-households with secure property rights are less likely to experience conflicts triggered by adverse weather shocks (prediction 2).

5.1 Land Certification and Land Disputes

Our empirical strategy on the effect of land certification on land disputes relies on (i) the gradual rollout of the land certification program to farm-households at the village level; and (ii) the panel nature of our dataset. In particular, we estimate a fixed effects model where the identification of the effect of tenure security on land disputes is coming from comparing reported disputes in year 2005 (before the implementation of the land certification) and in year 2007 (after the

[21] Given that we are dealing with local land disputes—and not large scale conflicts—we are not worried about the fact that rain-gauges located at the ground level may be damaged by local fighting activities, a potential concern in the climate and conflict literature.

implementation of the land certification) in certified and non-certified villages.

We estimate the following equation:

$$Y_{ijt} = \beta_0 + \beta_1 L_{jt} + \mu_j + \mu_t + \epsilon_{1,ijt} \tag{5}$$

where Y is an indicator for whether a household i in village j reported a land dispute in year t ($t = 2005, 2007$), L is a dummy variable equal to one if a household has secure property rights over land, μ_j and μ_t represent village (kebele) and time fixed effects and ϵ is an idiosyncratic error term. Standard errors are clustered at the village level. The inclusion of village fixed effects allows us to account for any time-invariant village characteristics that are correlated with the program rollout.

Table 1 presents the baseline results on the relationship between land certification and land disputes. Fixed effects estimates of equation (5) assess the first prediction of our theoretical model, that is whether tenure security reduces the likelihood of land disputes. Column 1 presents results from the baseline specification including village and year fixed effects. It shows that the probability of a household experiencing land disputes decreases by 0.08 after being certified. The average rate of land disputes during the sample period is 20.5%, indicating that land certification decreases the likelihood of land disputes by 39%, a sizable effect. This result is extremely robust to the inclusion of different set of fixed effects and clustering methods. Column 2 shows that the effect of land certification remains unaffected when household fixed effects are included in the regression, confirming that time-invariant household characteristics did not influence the program rollout differently than time-invariant village characteristics.

One main concern is the possibility of differential time trends that would be correlated with the timing of the certification and the likelihood of disputes. Column 3 shows that the result is robust to controlling for district-year fixed effects. The purpose of this robustness check is to control for the possibility that the program was initiated earlier in certain types of districts that experienced differential changes in land disputes due to reasons other than land certification. Allowing for the time effects to depend on these fixed effects further controls for district characteristics that (i) might have changed overtime and (ii) might have been correlated with the timing of the certification and the likelihood of conflicts.

Finally, we account for different clustering methods, the results are presented in Table A5 of the appendix. Given the small number of clusters ($n < 13$), the standard errors could be biased downwards. In column 1, we therefore re-estimate equation (5) by applying the finite sample correction suggested by Cameron et al. (2013). Then, in column 2 we estimate two-way cluster-robust standard errors to account for within-panel autocorrelation (clustering on farm-households) and cross-panel correlation (clustering on time) following Cameron et al. (2011). In column 3, we also re-estimate equation (5) by adjusting standard errors to account for potential spatial autocorrelation within one kilometer (Hsiang, 2010).[22] Results in Table A5 shows that the negative effect of land certification on land disputes stays significant for all the specifications (p-value < 0.065).

In addition, we re-estimate equation (5) accounting for time-varying characteristics. Table 2 reports results where we control for a set of time-variant farm-household characteristics. Column 1 addresses a potential concern of the land certification program: land certification may have induced a land reallocation impacting land disputes (through a reduction of tensions over land allocation, for example). We show that our result is only slightly lower in magnitude when introducing a variable measuring the variation in surface of the farm size between 2005 and 2007. Column 2 introduces other potential omitted variables that change overtime such as the age and the literacy level of the household

[22] We re-estimated the model with different cutoffs—5, 10, 25 and 50 kilometers—and the coefficient estimate of the land certification variable remains significant at the 10% level.

Table 1: Land Certification and Land Disputes: Baseline Results

	(1) Land disputes	(2) Land disputes	(3) Land disputes
Land certification	-0.080*	-0.080*	-0.080*
	(0.042)	(0.042)	(0.042)
Village fixed effects	yes	no	yes
Household fixed effects	no	yes	no
Year fixed effects	yes	yes	yes
District × Year fixed effects	no	no	yes
Observations	2974	2974	2974
R^2	0.027	0.008	0.027

Notes: All regressions are linear probability models. The dependent variable is equal to 1 if the farm-household has experienced any land disputes, 0 otherwise. Land certification is equal to 1 if the farm-household is certified, 0 otherwise. Standard errors clustered at the kebele level are reported in parentheses. * Significant at the 10% level.

head, the family size, the area of land cultivated, the total livestock owned by the farm-household, if the farm-household uses improved seeds or not and, finally, if soil conservation measures have been adopted on the farm. Column 3 further includes interaction terms between time effects and each of these household-level characteristics to account for specific time trends more flexibly. Once again our main result is invariant to this richer specification: the sign, the magnitude and the significance of the effect of tenure security on land disputes remain mostly unchanged. This is consistent with the fact that the certificates were distributed simultaneously to all households in a village. In summary, our analysis firmly points to land certification decreasing the probability that a household experiences land disputes.

5.2 Land Certification, Water Scarcity and Land Disputes

We now turn to the mechanism linking tenure security and land disputes. The objective is to investigate theoretical prediction 2, namely that (i) droughts in-

Table 2: Land Certification and Land Disputes: Robustness Checks

	(1) Land disputes	(2) Land disputes	(3) Land disputes
Land certification	-0.059***	-0.083*	-0.084**
	(0.003)	(0.041)	(0.035)
Change in farm size (2005-2007)	0.003		
	(0.002)		
Age of household head		0.000	0.001
		(0.001)	(0.001)
Male household head		0.008	-0.047
		(0.021)	(0.026)
Literacy of household head		-0.005	0.021
		(0.017)	(0.021)
Household size		-0.003	0.012
		(0.016)	(0.021)
Farm size		-0.003	-0.008
		(0.022)	(0.022)
Livestock		0.013	0.013
		(0.017)	(0.017)
Using improved seeds		0.045**	0.030
		(0.018)	(0.040)
Adopted soil conservation measures		-0.024	0.004
		(0.028)	(0.045)
Access to credit		0.014	0.005
		(0.022)	(0.042)
Village fixed effects	yes	yes	yes
Year fixed effects	yes	yes	yes
Household characteristics × Year fixed effects	no	no	yes
Observations	1278	2799	2799
R^2	0.063	0.026	0.031

Notes: All regressions are linear probability models. The dependent variable is equal to 1 if the farm-household has experienced any land disputes, 0 otherwise. Land certification is equal to 1 if the farm-household is certified, 0 otherwise. Literacy of the household head, household size, farm size and total livestock in the household are dummy variables equal to 1 if greater than the median, 0 otherwise. The sample size is smaller in column 1 because of missing values in the reported farm size. Standard errors clustered at the kebele level are reported in parentheses. * Significant at 10% level; ** Significant at the 5% level; *** Significant at the 1% level.

crease the likelihood of land disputes (especially when they happen during the rainy seasons); and (ii) farm-households with land certification are less prone to land disputes when they face adverse weather shocks. We exploit the random nature of weather shocks for the identification of the effects and introduce climate conditions in equation (5). We compare the same household overtime subject to different water availability during the main rainy season.

In particular, we investigate whether households with land certification are less likely to experience land disputes triggered by water scarcity by estimating

$$Y_{ijt} = \beta_0 + \beta_1 L_{jt} + \beta_2 W_{ijt} + \beta_5 W_{ijt} \times L_{jt} + \mu_j + \mu_t + \epsilon_{2,ijt} \tag{6}$$

where Y is the aforementioned land dispute dummy variable, L is the land certification dummy variable, W is a variable measuring water availability at the farm-household location and $W \times L$ denotes the interaction of the water availability variable with the land certification dummy variable L. We report results of equation (6) with different measures of W, accounting for the effect of water scarcity during the two main rainy seasons in the region and for the effect of past droughts on the reported level of land disputes (land disputes are reported in t in the survey, but may have occurred in the past years).

We first provide estimates of equation (6) with different measures of water scarcity, based on our computation of the drought index SPEI for each household. The SPEI index considers the combined effect of rainfall, potential evapotranspiration and temperature—a lower value of the index means less water availability in the village. We also account for temporal lags of the index. Table 3, column 1 shows that the signs of the parameter estimates for SPEI is negative, as expected.[23] Hence a negative water balance in the last year is asso-

[23]Note that the negative sign of the SPEI index coefficient indicates that less water during the rainy season increases the likelihood of disputes, and the positive sign in front of the interaction term between SPEI and land certification means that tenure security reduces this effect.

ciated with a higher probability of land disputes. Furthermore we observe that farm-households with land certification are far less prone to land disputes: the positive coefficient in front of the interaction term counterbalance the previous effect. Column 2 suggests that the effect of a negative water balance on land conflicts is slightly stronger when focusing on the SPEI index of the last main rainy season. As we can see from column 3, this effect increases again when considering both rainy seasons (summer and spring). However, the tempering effect of tenure security is less clear in columns 2 and 3 than in column 1.

Following the recent literature on water scarcity and conflicts[24] we adopt a finer instrument to measure water availability. Our benchmark indicator of water scarcity, denoted as *Strong Shock* is defined as the fraction of the rainy seasons (spring and summer) during which the SPEI index was below its mean by one standard deviation (and between half a standard deviation and one standard deviation for *Mild Shock*). Table 4 confirms previous results: (i) droughts during both rainy seasons increase the likelihood of conflicts; and (ii) farm-households with land certification are less prone to land disputes in difficult times. Columns 1-2 present results for shocks happening during the spring and the summer seasons, column 3 presents results for both seasons separately and column 4 for the seven consecutive months of both seasons. Column 4 shows that for mild shocks, switching from the best possible year in terms of our climate variable to the worst possible year (no month with a drought to every month of both rainy seasons with a drought) increases the likelihood of observing land disputes by 24% for households without land certification[25]. Interestingly, the effect of Mild Spei on land disputes is not significantly different from zero if farm-households have been certified. Hence, tenure security dampens disputes by reducing the vulnerability

[24] See for recent examples, Couttenier and Soubeyran (2014) or Harari and La Ferrara (2014).

[25] The average farm-household without land certification faces a "Mild Spei" value equal to 0.12 while the average rate of land disputes is equal to 0.22. This implies that for the average farm-household without certification the probability of experiencing land disputes increases by $\frac{0.44}{0.22} * 0.12 = 24\%$ after switching from the best possible year to the worst possible year.

Table 3: Land Certification, Water Scarcity and Land Disputes

	(1) Land disputes	(2) Land disputes	(3) Land disputes
Land certification	0.094	-0.031	-0.062*
	(0.061)	(0.034)	(0.034)
SPEI ($t-1$)	-0.036**		
	(0.012)		
SPEI ($t-1$) × Land certification	0.322***		
	(0.058)		
SPEI ($t-2$)	0.006		
	(0.010)		
SPEI ($t-2$) × Land certification	0.344***		
	(0.075)		
SPEI (summer season, $t-1$)		-0.040**	
		(0.013)	
SPEI (summer season, $t-1$) × Land certification		-0.063	
		(0.066)	
SPEI (summer season, $t-2$)		0.042	
		(0.034)	
SPEI (summer season, $t-2$) × Land certification		0.027	
		(0.057)	
SPEI (summer and spring seasons, $t-1$)			-0.045**
			(0.014)
SPEI (summer and spring seasons, $t-1$) × Land certification			-0.085
			(0.055)
SPEI (summer and spring seasons, $t-2$)			0.011
			(0.020)
SPEI (summer and spring seasons, $t-2$) × Land certification			0.040
			(0.036)
Village fixed effects	yes	yes	yes
Year fixed effects	yes	yes	yes
Observations	2734	2734	2734
R^2	0.025	0.025	0.025

Notes: All regressions are linear probability models. The dependent variable is equal to 1 if the farm-household has experienced any land disputes, 0 otherwise. Land certification is equal to 1 if the farm-household is certified, 0 otherwise. SPEI indicates water availability at the farm-household location and is defined in the appendix. Standard errors clustered at the kebele level are reported in parentheses. * Significant at 10% level; ** Significant at the 5% level; *** Significant at the 1% level.

of households to water scarcity: the effect of tenure security on disputes transits mostly through a reduction in clashes triggered by water scarcity.

Finally, we investigate whether our specifications miss important aspects of the data and we re-estimate the effect of SPEI shocks on the probability of land disputes using a quadratic regression fit. Figure A3 of the appendix shows that the relationship is monotonically decreasing: larger weather shocks are linked with a higher probability of experiencing land disputes. Interestingly, tenure security seems to reduce the probability of disputes for the whole range of SPEI shocks.

5.3 Further Sensitivity Analysis

Results shown in Tables 1, 2 and 3 are robust to many sensitivity checks. We present in the appendix additional robustness analysis. Table A6 reports results based on non-linear specifications, namely Probit and Logit models. These estimations are consistent with the results presented in the previous tables: tenure security decreases the likelihood of land disputes. As expected, the effect is stronger in quantitative terms when using non-linear specifications.

Table A7 presents results for different measures of land disputes. Column 1 shows the effect of tenure security on the onset of land disputes (a dummy variable equal to one when a household reported no dispute in year 2005 and at least one dispute in year 2007 and equal to zero otherwise). Certified households experience significantly (at the 1% level) less emergence of disputes after the program than non-certified households. Column 2 presents results on the decrease of disputes (a dummy variable equal to one when a household reported a dispute in year 2005 but none in year 2007 and equal to zero otherwise). We observe that land certification significantly (at the 1% level) increases the likelihood that a farm-household experiences a dispute in year 2005 and reported none in year 2007.

Table 4: Land Certification, Water Scarcity and Land Disputes: Robustness Checks

	(1) Land disputes	(2) Land disputes	(3) Land disputes	(4) Land disputes
Land certification	-0.047	-0.027	0.073	-0.008
	(0.071)	(0.084)	(0.052)	(0.073)
Mild SPEI Shock (spring rainy season)	0.147**		0.213***	
	(0.049)		(0.053)	
Mild SPEI Shock (spring rainy season)×Land certification	-0.289*		0.048	
	(0.141)		(0.136)	
Strong SPEI Shock (spring rainy season)	-0.032		-0.068	
	(0.065)		(0.094)	
Strong SPEI Shock (spring rainy season)×Land certification	0.006		-0.748***	
	(0.203)		(0.165)	
Mild SPEI Shock (summer rainy season)		0.021	0.132*	
		(0.087)	(0.061)	
Mild SPEI Shock (summer rainy season)×Land certification		-0.184	-0.594***	
		(0.207)	(0.067)	
Strong SPEI Shock (summer rainy season)		-0.050	0.098*	
		(0.100)	(0.053)	
Strong SPEI Shock (summer rainy season)×Land certification		0.059	-0.156	
		(0.391)	(0.132)	
Strong SPEI Shock (spring and summer rainy seasons)				-0.099
				(0.193)
Strong SPEI Shock (spring and summer rainy seasons) ×Land certification				-0.456
				(0.533)
Mild SPEI Shock (spring and summer rainy seasons)				0.444***
				(0.138)
Mild SPEI Shock (spring and summer rainy seasons) ×Land certification				-0.423**
				(0.180)
Village fixed effects	yes	yes	yes	yes
Year fixed effects	yes	yes	yes	yes
Observations	2734	2734	2734	2734
R^2	0.024	0.022	0.026	0.024

Notes: All regressions are linear probability models. The dependent variable is equal to 1 if the farm-household has experienced any land disputes, 0 otherwise. Land certification is equal to 1 if the farm-household is certified, 0 otherwise. Strong SPEI Shock is defined as the fraction of the rainy seasons (spring and summer) during which the SPEI index was below its mean by one standard deviation (and between half a standard deviation and one standard deviation for Mild SPEI Shock). More details on the SPEI index are provided in the appendix. Standard errors clustered at the kebele level are reported in parentheses. * Significant at 10% level; ** Significant at the 5% level; *** Significant at the 1% level.

The baseline results are again confirmed when we estimate equation (6) with rainfall anomalies as climate variables instead of a drought measure (Table A8). Column 1 shows that (i) less rainfall than the long term average over the spring season is associated with more disputes and (ii) that land certification reduces significantly this effect on disputes. Column 2 shows that the effect of temperature is less clear. While a deviation in temperature two periods ago increases reported disputes, land certification does not seem to have any tempering effect. Finally, column 3 reports the results of a placebo test: a negative water balance out of the main rainy seasons (December, January and February) has no effect on land disputes, as expected.

6 Land Certification, Water Scarcity and Land Disputes: Underlying Mechanisms

Having identified the effect of water scarcity on land disputes and the dampening effect of tenure security, we are now interested in studying possible underlying mechanisms explaining these effects. Following our theoretical predictions presented in section 2, we investigate whether water scarcity increases the propensity of land disputes through an increase in the marginal value of land (prediction 3), and when there is more inequality in land distribution (prediction 4). In addition, we explore another plausible mechanism presented in the literature, that is the role of access to credit in reducing land disputes through income smoothing.

6.1 The Marginal Value of Land

The prime objective is to shed light on the mechanisms linking water shocks, property rights and disputes. First, we investigate whether climate stress has a larger impact on land disputes when the marginal value of land is more important (prediction 3). We thus investigate whether having more labor available on the farm (i.e. proxied by household size larger than the median) or having more livestock than the median or whether the farm-household uses soil conservation measures would increase the impact of water scarcity on land disputes. We assume that having more labor or more livestock—crucial for farming and herding—increases the marginal value of land (if thought as a traditional complementary factor of production in an agricultural profit function). Conversely, using soil conservation measures is expected to decrease the marginal value of land by putting less pressure on each land unit.

Table 5 presents results when we include in equation (5) the factors affecting the marginal value of land, the climate shock variables and the interaction between them. Columns 1-2 present results when we include the interaction terms *SPEI Shocks* $\times$ *Household Size* and *SPEI Shocks* $\times$ *Livestock*, respectively. We observe a positive relationship between the interaction of actual water scarcity with household size and livestock. This is supportive of prediction 3: water scarcity increases land disputes through an increase in the marginal value of land. Column 3 includes the interaction term between *SPEI Shocks* and a dummy variable indicating whether the farm-household adopted soil conservation measures. As expected, we find that farm-households are less prone to land disputes in difficult times when adopting soil conservation measures.

In addition, in column 4 we study whether having more land available (i.e. share of land x_i in the theoretical model) decreases or increases the impact of water scarcity on land disputes (prediction 4). We use a dummy variable indicating if the farm size is larger than the median to investigate whether land inequality matters in difficult times, and we interact this dummy variable with *SPEI Shocks*. We find that a farm-household having more land than the median (our proxy for land inequality) will face more land disputes in times of water scarcity.

In summary, we consistently find that actual water availability has a stronger

Table 5: Land Certification, Water Scarcity and Land disputes: Underlying Mechanisms

	(1) Land disputes	(2) Land disputes	(3) Land disputes	(4) Land disputes	(5) Land disputes
Land certification	-0.054	-0.054	-0.057	-0.047	-0.059
	(0.062)	(0.060)	(0.057)	(0.063)	(0.061)
Strong SPEI Shock (summer rainy season)	-0.107	-0.173	0.111	-0.193	-0.064
	(0.093)	(0.104)	(0.119)	(0.126)	(0.082)
Strong SPEI Shock (spring rainy season)	-0.017	-0.001	0.086	-0.026	0.054
	(0.067)	(0.066)	(0.101)	(0.079)	(0.074)
Household size	-0.038				
	(0.037)				
Household size × Strong SPEI Shock (summer rainy season)	0.100**				
	(0.036)				
Household size × Strong SPEI Shock (spring rainy season)	0.081				
	(0.098)				
Livestock		-0.054			
		(0.031)			
Livestock × Strong SPEI Shock (summer rainy season)		0.220***			
		(0.068)			
Livestock × Strong SPEI Shock (spring rainy season)		0.062			
		(0.064)			
Adopted soil conservation			0.053		
			(0.042)		
Adopted soil conservation × Strong SPEI Shock (summer rainy season)			-0.251*		
			(0.126)		
Adopted soil conservation × Strong SPEI Shock (spring rainy season)			-0.102		
			(0.123)		
Farm size				-0.080	
				(0.037)	
Farm size × Strong SPEI Shock (summer rainy season)				0.241**	
				(0.084)	
Farm size × Strong SPEI Shock (spring rainy season)				0.090	
				(0.092)	
Access to credit					0.033
					(0.046)
Access to credit× Strong SPEI Shock (summer rainy season)					0.067
					(0.115)
Access to credit× Strong SPEI Shock (spring rainy season)					-0.142
					(0.135)
Village fixed effects	yes	yes	yes	yes	yes
Year fixed effects	yes	yes	yes	yes	yes
Observations	2734	2734	2734	2731	2731
R^2	0.023	0.025	0.026	0.024	0.024

Notes: All regressions are linear probability models. Variables are defined in Table 2 and Table 4. Standard errors clustered at the kebele level are reported in parentheses. * Significant at 10% level; ** Significant at the 5% level; *** Significant at the 1% level.

impact on the level of disputes when the marginal value of land is larger: either because there is more labor or more livestock available in the farm, less conservation measures or because there is more inequality in land distribution. These findings are supportive of the predictions developed in the theoretical model presented in section 2: water scarcity increases the marginal value of land, which in turns increases the temptation to rely on disputes instead of peaceful bargaining in difficult times.

6.2 Alternative Mechanism: Access to Credit

Our theoretical framework predicts that water scarcity increases the propensity of disputes through a rise in the marginal value of land. Property rights dampen this effect by increasing the cost of encroaching. Another plausible mechanism adduced in the literature highlights the role of income shocks in triggering disputes: agents fight over a dwindling resource because of a strong and unexpected drop in income. If well-defined property rights allow to smooth income over time, they would also limit disputes. One way through which property rights may allow to smooth income is found in the literature on the "De Soto" effect (Besley et al., 2012): well-defined property rights can facilitate access to credit because fixed assets can be used as collateral. While this would not invalidate the link between land tenure and land disputes, it refers to a completely different mechanism. In particular, it would imply that income shocks and credit constraints were the critical factors behind clashes.

We distinguish between these mechanisms by using the information available on access to credit by each household. We investigate if weather stress has a lower effect on land disputes when the household has access to credit. It is purported that access to credit allows to smooth income and may thus dampen the effect of weather shock. Column 5 of Table 5 presents the results including the interaction between *SPEI Shocks* and *Access to Credit*. We find no significant evidence supporting the idea that access to credit reduces the occurrence of land disputes through income smoothing.

7 Concluding Remarks

Recent literature presents robust evidence that well-defined property rights over land have a positive impact on many economic outcomes. In this paper, we present a novel theoretical model of land disputes and use a large panel dataset from Ethiopia to investigate the causal relationship between tenure security and land disputes, and whether land certification could lessen the effects of water scarcity on local clashes. Our identification strategy relies on the gradual rollout of the land certification program in Ethiopia at the village level, the exogeneity of climate shocks and the panel nature of our dataset that allows us to control for village and time fixed effects.

First, we find that well defined property rights decrease the likelihood of land disputes. Second, in line with the previous literature, we find that water scarcity increases the likelihood of land disputes. Then, we highlight that land certification decreases the effect of water scarcity on land disputes. Finally, we show that actual water conditions have a stronger impact on land disputes when the marginal value of land is larger: either because there is more labor or livestock available in the farm or because there is more land inequality. Our findings are robust to different specifications and measures of climate conditions.

These results suggest that land certification can be considered as an effective policy instrument to buffer against water scarcity. The policy implications of this paper are potentially very large. Policies that strengthen property rights over land besides creating a precondition for economic growth and development may also reduce the likelihood of disputes triggered by environmental shocks. Secure property rights to land can have a profound effect on incentives and on the working of markets for land and on welfare in general.

References

[1] Acemoglu, D. and I. N. Chaves and P. Osafo-Kwaako and J. A. Robinson 2014. Indirect Rule and State Weakness in Africa: Sierra Leone in Comparative Perspective. *African Economic Successes* edited by Sebastian Edwards, Simon Johnson and David Weil, University of Chicago Press, Chicago, IL..

[2] Adenew, B. and F. Abdi 2005. Research Report 3: Land Registration in Amhara Region, Ethiopia. International Institute for Environment and Development.

[3] Alesina, A. and E. Spolaore. 2005. War, Peace and the Size of Nations. *Journal of Public Economics* 89: 1333-1354.

[4] Almer C., J. Laurent-Lucchetti and M. Oechslin. 2015. Water Scarcity and Rioting: Disaggregated Evidence from Sub-Saharan Africa. *Mimeo.*

[5] Andre, C., and J. P. Platteau. 1998. Land Relations under Unbearable Stress: Rwanda Caught in the Malthusian Trap. *Journal of Economic Behavior and Organization* 34(1): 1-47.

[6] Begueria, S., and S. M. Vicente-Serrano. 2013. SPEI: Calculation of the Standardised Precipitation-Evapotranspiration Index, (R package version 1.6 edn.).

[7] Besley, T., 1995. Property Rights and Investment Incentives: Theory and Evidence from Ghana. *Journal of Political Economy* 103(5): 903-937.

[8] Besley, T. and M. Gathak. 2009. Property Rights and Economic Development. In: Rodrick, Dani and Rosenzweig, M. R., (eds.) *Handbook of Development Economics. Handbooks in Economics*, 5. Elsevier North Holland.

[9] Besley, T., K. Burchardi and M. Ghatak. 2012. Incentives and the De Soto Effect. *Quarterly Journal of Economics* 127(1): 237-282.

[10] Bezabih, M., G. Kohlin, and A. Mannberg. 2011. Trust, Tenure Insecurity, and Land Certification in Rural Ethiopia. *Journal of Socio-Economics* 40: 833-843.

[11] Binmore, K. and P. Dasgupta, eds. 1987. *The Economics of Bargaining*. Oxford: Blackwell.

[12] Blattman C, Hartman A, Blair R. 2014. How to Promote Order and Property Rights under Weak Rule of Law? An Experiment in Changing Dispute Resolution Behavior Through Community Education. *American Political Science Review* 108(1): 100-120.

[13] Blattman, C., and E. Miguel. 2010. Civil War. *Journal of Economic Literature* 48(1): 3-57.

[14] Cameron, C., J. Gelbach, and D. Miller. 2011. Robust Inference with Multiway Clustering. *Journal of Business and Economic Statistics* 29(2): 238-249.

[15] Chassang, S. and G. Padro-i-Miquel. 2009. Economic Shocks and Civil War. *Quarterly Journal of Political Science* 4(3): 211-228.

[16] Couttenier, M., and R. Soubeyran. 2014. Drought and Civil War in Sub-Saharan Africa. *The Economic Journal* 124(575): 201-244.

[17] Daly, C. 2006. Guidelines for Assessing the Suitability of Spatial Climate Datasets. *International Journal of Climatology* 26(6): 707-721.

[18] Deaton, A. 1992. *Understanding Consumption*. Oxford University Press, Oxford.

[19] Deininger, K., D. A. Ali, and T. Alemu. 2011. Impacts of Land Certification on Tenure Security, Investment, and Land Market Participation: Evidence from Ethiopia. *Land Economics* 8(2): 312-334.

[20] Deininger, K., D. A. Ali, S. Holden, and J. Zevenbergen. 2008. Rural Land Certification in Ethiopia: Process, Initial Impact, and Implications for Other African Countries. *World Development* 36(10): 1786-1812.

[21] de Janvry A., K. Emerick, M. Gonzalez-Navarro and E. Sadoulet. 2015. Delinking Land Rights from Land Use: Certification and Migration in Mexico. *American Economic Review* 105(10): 3125-3149.

[22] Fearon, J. D. 1998. Bargaining, Enforcement, and International Cooperation. *International Organization* 52(2): 269-305.

[23] Fenske, J. 2011. Land Tenure and Investment Incentives: Evidence from West Africa. *Journal of Development Economics* 95(2): 137-156.

[24] Fan, Y. and H. Van den Dool. 2008. A Global Monthly Land Surface Air Temperature Analysis for 1948-present. *Journal of Geophysical Research: Atmospheres* 113: D01103.

[25] Goldstein, M., and C. Udry. 2008. The Profits of Power: Land Rights and Agricultural Investment in Ghana. *Journal of Political Economy* 116(6): 981-1022.

[26] Harari, M., and E. La Ferrara. 2014. Conflict, Climate and Cells: A Disaggregated Analysis. IGIER *Working Paper n. 461.*

[27] Hsiang, S.M. 2010. Temperatures and Cyclones Strongly Associated with Economic Production in the Caribbean and Central America. *Proc. Natl. Acad. Sci.* 107: 15367-15372.

[28] Jia, R. 2013. Weather Shocks, Sweet Potatoes and Peasant Revolts in Historical China. *The Economic Journal* 124(575): 92-118.

[29] Nickola, T. 1988. *The Agricultural Sector in Ethiopia: Organization, Policies and Prospects* in A. Penrose (ed.), Beyond the Famine: An Examination

of Issues behind the Famine in Ethiopia. Geneva: International Institute for Relief and Development, Food for Hungry International.

[30] Novella, N. S., and W. M. Thiaw. 2013. African Rainfall Climatology Version 2 for Famine Early Warning Systems. *Journal of Applied Meteorology and Climatology* 52(3): 588-606.

[31] Ostrom, E. 2005. *Understanding Institutional Diversity*. Princeton. Princeton University Press.

[32] Palm, L. 2000. Quick and Cheap Mass Land Registration and Computerisation in Ethiopia, Paper presented at FIG Congress 2010, "Facing the Challenges and Building the Capacity," Sydney, Australia, 11-16 April 2010.

[33] Rubinstein, A. 1982. Perfect Equilibrium in a Bargaining Model. *Econometrica* 50(1): 97-109.

[34] United Nations Environment Programme 2011. *Toolkit and Guidance for Preventing and Managing Land and Natural Resources Conflict*. Available online at http://www.un.org/en/land-natural-resources-conflict/resource-rich-economies.shtml (last accessed: March 09, 2016).

[35] Vicente-Serrano, S.M., S. Begueria, J. I. Lupez-Moreno, M. Angulo, A. El Kenawy. 2010. A Global 0.5 Gridded Dataset (1901-2006) of a Multiscalar Drought Index Considering the Joint Effects of Precipitation and Temperature. *Journal of Hydrometeorology* 11(4): 1033-1043.

[36] Wahba, G. 1990. *Spline Models for Observational Data*. Philadelphia: Society for Industrial and Applied Mathematics.

A Appendix for Online Publication

A.1 Climate Indicators

The Standardised Precipitation-Evapotranspiration Index (SPEI) We computed the Thornthwaite evapotranspiration index using the temperature data and the latitude of the centroids of each kebele following the methodology provided in Vicente-Serrano et al. (2010), and the code developed by Begueria and Vicente-Serrano (2013). Evapotranspiration is then subtracted from precipitation in order to obtain the net balance of water in each geographical unit (the centroid of each kebele). Finally, we standardized the net balance of water in order to obtain the SPEI index (see Vicente-Serrano et al., 2010 for more details).

The climatic water balance is an important factor affecting vegetation activity. According to Vicente-Serrano et al. (2010), the correlation between the water balance and vegetation activity is particularly strong and immediate under arid, semi-arid and sub-humid conditions, i.e. under conditions present in many parts of Ethiopia's agricultural regions. This, together with the strong correlation between SPEI and vegetation activity, suggests that the actual water balance matters for agricultural productivity and other types of water-dependent economic activities, like pastoralism.

Our benchmark indicator of climate shock, denoted as SPEI Shock, captures low SPEI episodes occurring during the main rainy season (the "Meher": June, July, August and September) and during the secondary rainy season (the "Belg") happening in Spring with a construction of the same variable over March, April and May. Our indication of climate shocks is defined as follows: for 2007, we consider the four months of the rainy season from the last two years (2006 and 2005) and take the number of months in which SPEI was below its mean by some magnitude. We use two thresholds: a SPEI between -0.5 and -1 and below -1. Then, divide this number by eight, the total number of months of the Meher over two years.[26] The value of our main SPEI variable thus ranges between 0 and 1, with 0 denoting a very good period in which SPEI never went below its mean over the last two years during the rainy season, and 1 denoting an exceptionally "bad" period in which the rainy season of the last two years was plagued with abnormally low values of SPEI.

We also use as a robustness check rainfall and temperature data at the household level. We impute the household specific rainfall and temperature values using longitude, latitude and elevation information of each household by adopting the *Thin Plate Spline* method of spatial interpolation, which is commonly used to generate spatial climate datasets.[27] This method has the advantage that it accounts for spatially varying elevation relationships and it is not difficult to apply. However, it does not handle easily very sharp spatial gradients, and it only simulates elevation relationship. This is a typical characteristic of coastal areas. Significant terrain features, and no climatically important coastlines characterise our study area (for more details on the properties of this method see Daly, 2006). We finally use rainfall anomalies as a measure of climate anomalies, that is the difference between the weather at time t and the 1976-2006 climatic data divided by the 1976-2006 standard deviation.

A.2 Figures

[26] Here we follow Harari and La Ferrara (2014) to construct a climate indicator including an "intensity" component and accounting for two years lags (previous weather conditions).

[27] By definition, Thin Plate Spline is a physically based two-dimensional interpolation scheme for arbitrarily spaced tabulated data. The Spline surface represents a thin metal sheet that is constrained not to move at the grid points, which ensures that the generated rainfall data at the weather stations are exactly the same as the data at the weather station sites that were used for the interpolation. In our case, the rainfall data at the weather stations are reproduced by the interpolation for those stations, which ensures the credibility of the method (see Wahba, 1990 for details).

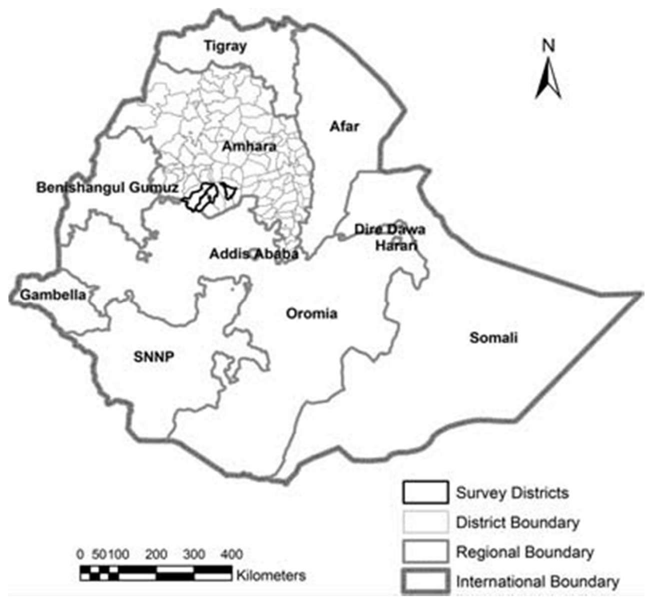

Figure A1: Map of the Amhara Region, Ethiopia (Source: Deininger et al., 2011)

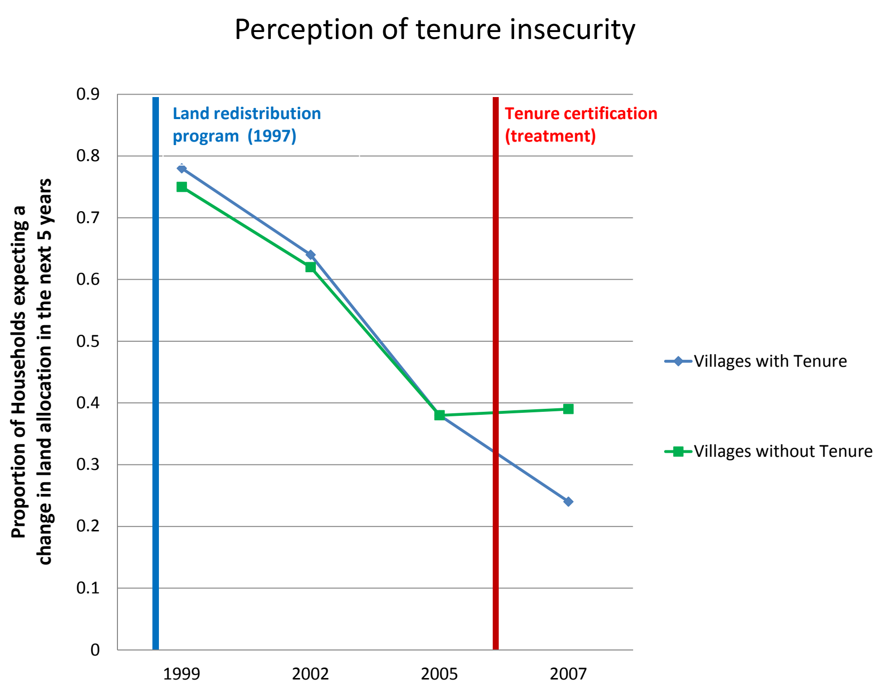

Figure A2: Expectations of Land Redistribution in the Next Five Years

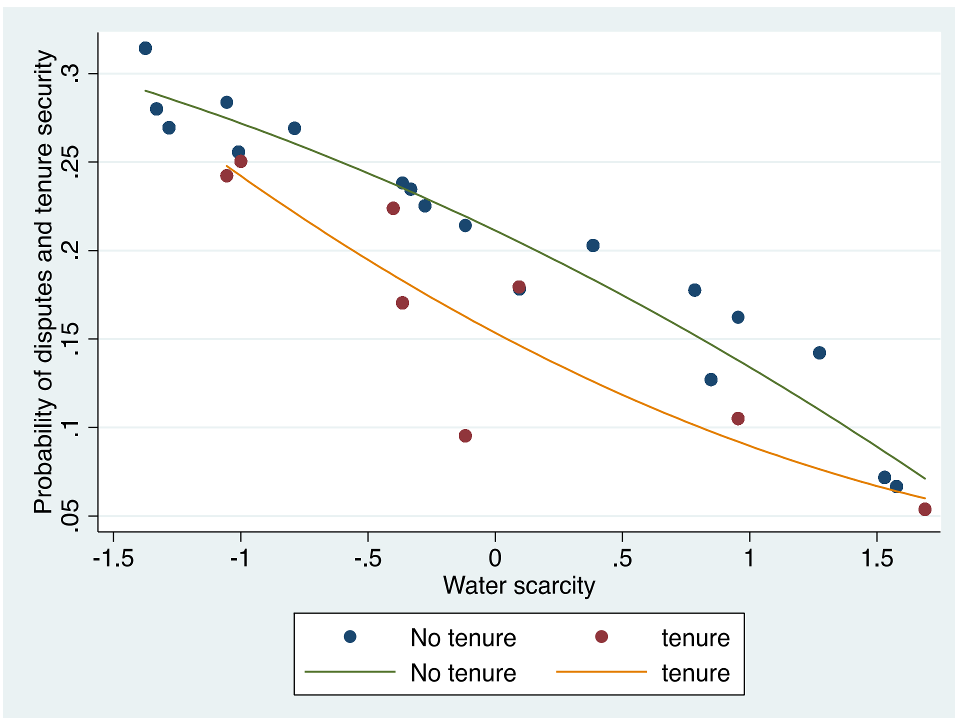

Figure A3: Water Scarcity, Probability of Disputes and Tenure Security

A.3 Descriptive Statistics at the Village and Household Level

Table A1: Descriptive Statistics at the Village Level

	Full sample		Non-certified		Certified		Non-certified
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	vs certified
Panel A: Year 2005							
Land disputes	0.189	0.037	0.192	0.03	0.183	0.055	n.s.
Male household head	0.820	0.044	0.824	0.032	0.811	0.067	n.s.
Age of household head	50.315	2.474	50.62	3.025	49.705	0.589	n.s.
Literate household head	0.475	0.078	0.446	0.075	0.534	0.047	*
Household size	6.36	0.583	6.329	0.511	6.420	0.793	n.s.
Farm size (ha)	1.821	0.576	1.766	0.355	1.932	0.947	n.s.
Total livestock	4.258	1.150	3.87	0.909	5.035	1.309	*
Access to credit	0.182	0.092	0.200	0.094	0.148	0.089	n.s.
Panel B: Year 2007							
Land disputes	0.226	0.108	0.26	0.104	0.159	0.095	n.s.
Male household head	0.817	0.051	0.823	0.039	0.804	0.075	n.s.
Age of household head	51.519	2.345	51.997	2.735	50.562	0.939	n.s.
Literate household head	0.432	0.079	0.391	0.059	0.513	0.037	***
Household size	6.667	0.642	6.604	0.551	6.793	0.877	n.s.
Farm size (ha)	2.082	0.847	1.901	0.3	2.443	1.469	n.s.
Total livestock	4.462	1.326	4.053	0.995	5.28	1.673	n.s.
Access to credit	0.240	0.075	0.225	0.074	0.269	0.079	n.s.
Observations	12		8		4		

Notes: n.s. indicates not significant difference between non-certified and certified villages. * Significant at 10% level; *** Significant at the 1% level.

Table A2: Descriptive Statistics at the Farm-household Level

	Full sample			Non-certified			Certified			Non-certified
	Obs.	Mean	Std. Dev.	Obs.	Mean	Std. Dev.	Obs.	Mean	Std. Dev.	vs certified
Panel A: Year 2005										
Land disputes	1,487	0.189	0.392	1,027	0.192	0.394	460	0.183	0.387	n.s
Male household head	1,486	0.82	0.385	1,027	0.824	0.381	459	0.81	0.392	n.s
Age of household head	1,485	50.562	15.43	1,027	50.945	15.631	458	49.703	14.95	n.s.
Literate household head	1,441	0.477	0.5	1,001	0.452	0.498	440	0.534	0.499	***
Household size	1,438	6.351	2.356	997	6.316	2.358	441	6.431	2.353	n.s.
Farm size (ha)	1,438	1.814	3.092	997	1.755	3.173	441	1.945	2.899	n.s
Total livestock	1,438	4.205	3.427	997	3.831	3.051	441	5.053	4.03	***
Access to credit	1,487	0.18	0.385	1,027	0.195	0.396	460	0.148	0.355	**
Panel B: Year 2007										
Land disputes	1,487	0.221	0.415	1,027	0.248	0.432	460	0.159	0.366	***
Male household head	1,486	0.817	0.387	1,027	0.823	0.382	459	0.804	0.397	**
Age of household head	1,485	51.684	15.009	1,027	52.186	15.31	458	50.557	14.264	**
Literate household head	1,441	0.432	0.495	1,001	0.396	0.489	440	0.514	0.5	***
Household size	1,438	6.649	2.442	997	6.58	2.409	441	6.805	2.512	n.s.
Farm size (ha)	1,438	2.057	1.869	997	1.878	1.636	441	2.463	2.26	***
Total livestock	1,438	4.398	3.615	997	3.998	3.221	441	5.303	4.245	***
Access to credit	1,487	0.235	0.424	1,027	0.22	0.414	460	0.27	0.444	***

Notes: n.s. indicates not significant difference between non-certified and certified farm-households. ** Significant at the 5% level. *** Significant at the 1% level.

A.4 Land Certification and Land Disputes: Propensity Score Matching

Table A3: Propensity Score Matching: Land Disputes in 2005

	(1) Land disputes: certified	(2) Land disputes: Non-certified	(3) Differences	(4) Standard errors
Average unmatched	0.178	0.196	-0.018	0.023
Average matched	0.178	0.147	0.031	0.032
Observations	419	956		

Table A4: Propensity Score Matching: Land Disputes in 2007

	(1) Land disputes: certified	(2) Land disputes: Non-certified	(3) Differences	(4) Standard errors
Average unmatched	0.162	0.249	-0.087***	0.024
Average matched	0.162	0.265	-0.103***	0.035
Observations	407	907		

Notes: *** Significant at the 1% level.

A.5 Additional Robustness Analysis

Table A5: Baseline Results: Different Clustering Methods

	(1) Land disputes	(2) Land disputes	(3) Land disputes
Land certification	-0.080**	-0.080**	-0.089*
	(0.042)	(0.033)	(0.048)
Village fixed effects	yes	yes	no
Year fixed effects	yes	yes	yes
Clustering	Kebele (small sample)	Kebele-Year	Spatial correlation
N	2974	2974	2974
R^2	0.027	0.037	0.123

Notes: Standard errors in parentheses. Column 1 presents standard errors with finite sample correction (Cameron et al., 2011). Column 2 presents two-way cluster-robust standard errors. Column 3 presents standard errors adjusted for spatial autocorrelation (Hsiang, 2010). * Significant at 10% level; ** Significant at the 5% level.

Table A6: Non-linear Specifications: Probit and Logit Models

	(1) Land disputes	(2) Land disputes
Land certification	-0.294*	-0.510*
	(0.159)	(0.276)
Village fixed effects	yes	yes
Year fixed effects	yes	yes
Observations	2974	2974

Notes: Standard errors clustered at the kebele level are reported in parentheses. * Significant at 10% level.

Table A7: Alternative Measures of Land Disputes

	(1) Onset of land disputes	(2) Decrease of land disputes
Land certification	-0.029***	0.034***
	(0.000)	(0.000)
Village fixed effects	yes	yes
Year fixed effects	yes	yes
Observations	1487	1487

Notes: Standard errors clustered at the kebele level are reported in parentheses. *** Significant at the 1% level.

Table A8: Alternative Measures of Water Scarcity: Rainfall and Temperature Anomalies

	(1) Land disputes	(2) Land disputes	(3) Land disputes
Land certification	-0.095	-0.075*	-0.138
	(0.056)	(0.040)	(0.096)
Deviation in rain (spring season, t-1)	-0.056*		
	(0.030)		
Deviation in rain (spring season, t-1)×Land certification	0.323**		
	(0.121)		
Deviation in rain (spring season, t-2)	-0.005		
	(0.053)		
Deviation in rain (spring season, t-2)×Land certification	-0.025		
	(0.064)		
Deviation in temperature (t-1)		-0.014	
		(0.060)	
Deviation in temperature (t-1) ×Land certification		-0.020	
		(0.196)	
Deviation in temperature (t-2)		0.012**	
		(0.005)	
Deviation in temperature (t-2) ×Land certification		-0.014	
		(0.009)	
Placebo: SPEI (off any rainy season, t-1)			0.032
			(0.025)
Placebo: SPEI (off any rainy season t-1)×Land certification			0.065
			(0.140)
Placebo: SPEI (off any rainy season t-1)			0.004
			(0.019)
Placebo: SPEI (off any rainy season t-1)×Land certification			-0.043
			(0.092)
Village fixed effects	yes	yes	yes
Year fixed effects	yes	yes	yes
Observations	2723	2974	2734
R^2	0.029	0.028	0.023

Notes: Standard errors clustered at the kebele level are reported in parentheses. * Significant at 10% level; ** Significant at the 5% level.