BETWEEN THREE FIRES: POPULATION PRESSURE, SOIL DEGRADATION, AND LAND CONFLICTS IN SUB-SAHARAN AFRICA — EVIDENCE FROM KENYA AND UGANDA

A Dissertation

Submitted to the National Graduate Institute for Policy Studies (GRIPS)

in Partial Fulfillment of the Requirements for the Degree of

Ph.D. in Development Economics

by

Francisco M. P. Mugizi

September 2018

Abstract

This dissertation contains three analytical chapters. The central thesis in the first two analytical chapters is that population pressure on farmland can have two opposing effects on soil quality. Population pressure can negatively affect soil quality due to more frequent and intensive use of farmlands, but it can also induce transition of farming methods towards more intensive farming in which more fertilizer and improved seeds are used in order to make smaller farmlands more productive. In Sub-Saharan Africa, the net effect is likely to be negative given the region's current low fertilizer use. Recent studies, however, show evidence of agricultural intensification in regions with high population pressure. It is important to quantitatively analyze the extent and speed of soil degradation and its relationship with population pressure. Nonetheless, empirical studies on this topic are extremely scarce (almost non-existent), partly because soil quality is shaped over a long time horizon, and quality panel data on this issue are rare. This dissertation uses unique panel data for rural households, containing detailed soil quality information from Kenya and Uganda to elucidate the effect of population pressure on soil quality. The study finds that population pressure reduces soil quality in both of the countries studied, and that it induces agricultural intensification considerably in Kenya but little in Uganda. The findings for Kenya suggest that although farmers are trying to mitigate the negative effect of population pressure on soil quality, the rate of soil degradation is probably outpacing that of agricultural intensification. On the other hand, the findings for Uganda indicate that farmers have yet to change their farming practices to respond to increasing land scarcity resulting

from population growth. Furthermore, land tenure system may be one of the non-market factors that affect farmers' decision to invest in soil improvement in Uganda, as seen in the findings that individually-owned parcels have better soil than communally-owned parcels.

The third analytical chapter examines land conflicts over property rights and land demarcation between neighbors who have been absent due to displacement caused by armed conflicts in Northern Uganda. This analysis uses detailed parcel-, household-, and community-level data collected in 2015 from villages in Northern Uganda. The results are noteworthy: households that were displaced to locations far away from their homes are more likely to have new land conflicts and more likely to be concerned about land conflicts. The number of years a household spent without doing farming in its home village and weakening of informal institutions of land governance appears to be the main transmission mechanisms of the results here. Furthermore, land conflicts are found to have a negative effect on agricultural productivity because they reduce farmers' incentive to invest in the plots due to insecure property right to the lands.

Dedication

To my late father Mr. Paul Mugizi,

my mother Mrs. Agnes Mugizi,

my wife Florentina,

and

my children Lina and Nathan.

Acknowledgements

This dissertation which marks the end of my long arduous but rewarding PhD journey could not have been completed without the support of numerous individuals and institutions. I cannot pretend to mention all of them because doing so would make this piece of acknowledgements larger than it is supposed to be. I would therefore like to extend my deepest gratitude to all who contributed in one way or the other to make my dream come true. Nonetheless, I am morally obliged to mention at least some few individuals and institutions that played more direct roles towards completion of my PhD studies.

I am particularly grateful to my supervisor Prof. Tomoya Matsumoto for his advisory role. Despite his busy schedule he was always willing to provide his professional guidance at every stage of my research. During three years of our academic interactions I learnt a lot from him. I thank him for being tolerant of me especially in our first months when I had to try and abandon some research ideas in the quest of trying to come up with a novelty and interesting idea. I am confident that I have done my best to meet his stringent but important requirement for a PhD research. I thank him for being such a wonderful supervisor. His intellectual wisdom and guidance will always be remembered. In the same spirit, I am very thankful to my sub-advisors: Professors Yoko Kijima and Chikako Yamauchi, all of whose well-thought questions, comments and criticisms whenever I presented my work to them have improved the rigor of this dissertation. I am also thankful to the other two committee members−Professors Yamano Takashi and Iio Jun for their questions and comments on my defense day.

I would also like to recognize with appreciation the role played by GRIPS economics Professors who taught me various core and applied courses during my two years of intensive coursework: Alistair Munro, Chikako Yamauchi, Dainn Wie, Jonna Estudillo, Julen Esteban-Pretel, Junichi Fujimoto, Kaori Hatanaka, Keijiro Otsuka, Makoto Hasegawa, Makoto Tanaka, Minchung Hsu, Ponpoje Porapakkarm, Roberto Leon-Gonzalez, Shinsuke Ikeda, Takasi Fukushima, Tetsushi Sonobe, Tomoya Matsumoto, Yoichi Arai, and Yosuke Yasuda. It is mainly from the knowledge and skills gained from their classes that I was able to do my own research.

I also benefited from insightful comments given during my presentations at the following seminars and international conferences: the Center for Local and Regional Governance of the University of the Philippines, the Economic Policy Research Centre of Makerere University, Young Scholars' Workshop at GRIPS, Western Economic Association International (WEAI) held at the University of Newcastle-Australia, GRIPS Policy Analysis Research Workshops, World Bank Conference on Land and Poverty 2018 held in Washington D.C, WEAI Annual Conference held in Vancouver, BC. Canada, and Hitotsubashi Summer Institute at Hitotsubashi University. Special thanks to the participants for their useful comments. I am also very grateful to Prof. Tomoya, Prof. Tetsushi Sonobe, and GRIPS for the financial support without which it would have been impossible to present my work outside my comfort zones.

I would also like to thank all the households and community leaders I met during my field trip in Uganda. From them I was able to garner first-hand information on my research topic that enriched my understanding on various issues facing rural households in Uganda. Once again, I thank Professors Tomoya and Tetsushi Sonobe for generously funding the trip.

To my classmates Drs. Opoku Kwadwo, Faith Masekesa, Adu Boahen Emmanuel, Mr. Nagashima Masaru, Md Arifur Rahman, Mr. Sharif Mosharraf Hossain, and Ms. Nguyen Kim Lan, thank you very much for the wonderful moments we shared together during our academic life at GRIPS. I am also grateful to my senior programmates. Thanks especially to Drs. Zarau Wendeline Kibwe, Manang Fredrick Emiliano, Francis Mwesigye and Kefyalew Endale. Many thanks to my colleagues –Dr. Edwin Mhede, Dr. Rie Muraoka, Dr. Rayner Tabetando, Dr.Benedict Makanga and Mr.Herman Shombe.

I am also appreciative of the support I received from the wonderful administration staff at GRIPS, particularly the staff at IT department, Student Office, Academic Support Team, International Program Team, General Affairs Team, and Health Center. Their timely response whenever I was in need of their services made my stay and study in Japan a bit stress-free. Their services embedded in Japanese culture of trustworthiness, efficiency and punctuality are second to none. I will surely miss their services.

I would also like to extend my gratitude to the Government of Japan through its Ministry of Education, Culture, Sports, Science and Technology (MEXT); and GRIPS for awarding me the MEXT scholarship without which perhaps it would have been a daydream for me to study in Japan. I am also thankful to my employer Mkwawa University for granting me a five-year study leave. My sincere gratitude also goes to Prof. Longinus Rutasitara (now economic advisor to the President of Tanzania), Professors Delphin Rwegasira and Michael Ndanshau of the University of Dar es Salaam-Tanzania, who were kind enough to serve as my referees during my application for admission at GRIPS.

To my parents, I cannot find any good vocabulary to show my appreciation for the parenting roles they played. It is their good nurturing that molded and prepared me to survive in different circumstances. Truly, this was very instrumental during my PhD studies. Suffice to say THANK YOU. It is very sad that my beloved father passed on when I had just started my third year. May his soul rest in peace, Amen. I also acknowledge with appreciation the moral support from my beloved wife, brothers, sisters, relatives and all other well-wishers. To my beloved children Lina and Nathan, thank you for your presence and priceless jokes that acted as catalysts and made me accomplish this noble task. To all my friends thank you for everything. Special thanks to Dr. Pastory for everything he did on our behalf (my family and I) during our absence.

Lastly, despite the support I received from the above mentioned individuals and institutions, any shortcomings in this dissertation remains solely mine.

Glory is to the Almighty God.

Table of Contents

List of Tables

List of Figures

Tables in Appendix

Figures in Appendix

Abbreviations

FAO	Food and Agriculture Organization
IDMC	Internal Displacement Monitoring Centre
IFAD	International Fund for Agricultural Development
IFDC	International Fertilizer Development Center
KNBS	Kenya National Bureau of Statistics
NASA	National Aeronautics and Space Administration
SDGs	Sustainable Development Goals
SSA	Sub-Saharan Africa
UBOS	Uganda Bureau of Statistics

CHAPTER 1

Introduction

In many countries of Sub-Saharan African (SSA), agriculture has long been recognized as the backbone of their economies. The sector has been important not only for its contribution to GDPs, but also because it employs a larger proportion of the region's population especially those in rural areas. Despite its importance, for many years now its performance has not been impressive. In fact in the recent past, agricultural productivity has been declining in some countries of SSA, or remained stagnant at best, thus exacerbating rural poverty and hunger. That's why; scholars have widely and often linked persistent poverty in much of rural SSA to poor performance of the agricultural sector (Ehui & Pender, 2005; Minten & Barrett, 2008; World Bank, 2008; De Janvry, 2010).

Several initiatives by governments and international agencies have been and are undertaken to reverse the situation. For example, the world through Sustainable Development Goals (SDGs) is determined to end poverty and hunger by 2030 (United Nations, 2015). Specific targets include doubling of agricultural productivity and incomes of smallholder farmers by 2030. However, in Sub-Saharan Africa, population growth and soil degradation may pose a serious threat to realization of these great ambitions. With a current population of 1.02 billion people, the region's population is projected to more than double to 2.2 billion people by 2050 (Population Reference Bureau, 2017). With this surge in population, studies have suggested that food production in Sub-Saharan Africa needs to double over the next 20 years (De Janvry, 2010). At the same time, available evidence indicates that soil quality in SSA is deteriorating at a tremendous rate. Moreover, soil scientists have long cautioned that the scope of this problem is very severe particularly in East African highlands where rural densities are disproportionality high (Stoorvogel & Smaling, 1990; Sanchez, 2002). These concerns are further supported and validated by available statistical evidences. For example, within only two years from 2002 to 2004; SSA lost Nitrogen, Phosphorous, and Potassium (NPK) soil nutrients at a rate of more than 30 kg/ha per year (Henao & Baanante, 2006). Similar trend is revealed by more recent evidence which shows that the average combined depletion rate of NPK for all SSA countries in the past decade is 54kg/ha per year (Sommer et al., 2013), whereas in 2015 the average fertilizer use intensity was only 14.9kg/ha (FAO, 2015b). This suggests that there seems to be little hope if any for the situation to reverse in the near future. Indeed, if these trends continue, i.e., higher population growth rates vs. higher rate of soil quality exhaustion; one is inclined to wonder how the region will feed its growing population and what will be the welfare implications especially on smallholder farmers. Undeniably, these are important questions that need to be answered since majority of the region's population live in rural areas and greatly depend on farming for their livelihoods.

Theoretically there is a link between population pressure and soil quality dynamics. According to population pressure hypothesis, population pressure is the major underlying cause of soil degradation (Blaikie & Brookfield, 1987; Mortimore, 1993). The main argument is that when population pressure is low, agricultural land is abundant for farming households. The main method to recover soil fertility is by fallowing. As population increases, farmers react by bringing new land into cultivation (extensification). However, a further increase in population lives very little or no arable land unoccupied and extensification becomes unfeasible. To feed the growing population, farmers' option is to cultivate the same little available agricultural land. Overuse of the same land over time leads to soil exhaustion and degradation. Contrary to the population hypothesis, Boserup (1965) posits that population pressure leads to transition of farming system towards a more intensive farming in which more fertilizer and other modern inputs are used so as to make the small available farmlands more productive. The main idea behind Boserupian hypothesis is that as population density rises and farm sizes decline, traditional methods of soil fertility maintenance such as fallow become difficult. Consequently, farmers shift from long-fallow periods to multi-cropping practices. To increase land productivity and crop yield, they adopt modern farming technologies such as use of organic and chemical fertilizers. This line of intellectual wisdom runs parallel with the induced innovation theory by Hayami & Ruttan (1985) which argues that increasing scarcity of resources (land) stimulates technological change to save the scarce resource.

The two perspectives highlighted above suggest that population pressure may have two opposing effects on soil quality. However, its net effect on soil quality is not only ambiguous but also empirically less understood. Existing scholarly attempts are all based on cross-sectional positive correlation between population pressure and soil erosion

(Grepperud, 1996; Shiferaw & Holden, 1998).[1] On the other hand, however, there is a growing body of recent empirical studies that reveal a positive association between population pressure and agricultural intensification in form of use of manure, chemical fertilizers, and other inputs (Josephson, Ricker-Gilbert, & Florax, 2014; Muyanga & Jayne, 2014; Ricker-Gilbert, Jumbe, & Chamberlin, 2014).

Even though from Boserup's perspective population pressure is not a threat but rather a catalyst for farmers to change their farming behaviours by adopting farming technologies which would help to replenish the soil nutrients, in SSA this is less likely to be the case due to the region's low fertilizer use intensity compared to its rate of soil nutrient depletion. For example, compared to the world average of 124 kg/ha or that of East Asia and the Pacific which stands at 322 kg/ha, the region's fertilizer use intensity is only 14.9 kg/ha (FAO, 2015b), whereas the average combined depletion rate of NPK for all SSA is 54kg/ha per year.

One of the reasons for lower fertilizer use intensity in some countries in SSA could be insecure land rights. Scholars widely admit that secure and individualized land rights play a crucial role in promoting investment in land improvement (Feder & Feeny, 1991; Besley, 1995; Brasselle, Gaspart, & Platteau, 2002; Goldstein & Udry, 2008; Abdulai, Owusu, & Goetz, 2011; Fenske, 2011;Bellemare,2013). Three most cited pathways through which secure land rights may affect investment in land improvement are: One, with secure and individualized land rights, farmers are incentivized to invest in their land because of

[1]Moreover these studies do not use data from soil samples.

higher certainty of reaping the fruits of their investments. Moreover, farmers may relax their credit constraints by using land as collateral when applying for loans. In turn the borrowed funds can be used to invest in land improvement. Besides, secure and individualized land rights reduce transaction costs, thus make it easier to sell or rent the land. This easiness tends to incentivize land owners to invest in land improvement. Even though dozens of studies have examined the nexus between secure land rights and investment in land improvement, we know of no any scholarly attempt to explicitly explore whether secure land rights may affect soil quality.

Moreover, in the recent past, incidences of land-related conflicts have been increasing in most parts of Sub-Saharan Africa. These land conflicts are likely to further affect agricultural productivity, thus pushing rural households into abject poverty. Amongst other things, conflicts over land discourage farmers to invest in land improvement (Yamano & Deininger, 2005). Land conflicts can also affect preferences of risk-averse farmers, thereby forcing them to choose to produce low-value seasonal crops instead of high-value perennial crops because of risk of losing land in future. Moreover, land conflicts may distort the allocation of resources in the agricultural sector away from the productive use. For example, when disputes are taken to courts; time and financial resources that could have been allocated into productive activities like agriculture are wasted in resolving disputes. It is along these lines of reasoning scholarly works in SSA, albeit few, document the detrimental effects of land conflicts on agricultural productivity (Deininger & Castagnini, 2006; Muyanga & Gitau, 2013; Mwesigye & Matsumoto, 2016). In spite of these evidences found elsewhere, no any available evidence on Northern Uganda−a region which is claimed to have many incidences of land conflicts between neighbours following long absence due to displacement caused by armed conflicts.

Elsewhere, the root causes of land conflicts mostly cited in the literature include; land inequality (Andre & Platteau, 1998; Hidalgo et al., 2010), and high population density which in turn translates into increase in value and demand for land (Deininger & Castagnini, 2006; Mwesigye & Matsumoto, 2016). This in turn leads to competition for land which sometimes translates into illegal occupation, illegal land sales, land grabbing and ultimately land conflicts. Besides, in many rural areas of SSA, customary land tenure systems are no longer well-equipped to resolve land-related conflicts (Fred-Mensah, 1999; Mwesigye & Matsumoto, 2016). Yet, formal institutions to complement or substitute the weakening informal institutions are either weak or non-existent. In Northern Uganda following armed conflicts that plagued the region for two decades (1986-2006) and subsequent massive displacement of people, there have been many concerns about incidences of land conflicts in the post-war period. Among others, it is believed that duration of displacement and how far away the households were displaced from their original homes have affected social cohesion within the communities, thus leading to weakening of informal institutions of land governance, and consequently triggering land conflicts in post-displacement period.

Deducing from all the aforementioned, the broad picture of this study is that since most of the poor people in Sub-Saharan Africa live in rural areas and directly or indirectly rely on agriculture for their livelihoods, boosting the performance of the agricultural sector is indispensable in the war against hunger and poverty. However, depletion of soil as well as land conflicts may seriously curtail agricultural productivity and push rural households into abject poverty. Therefore, since population pressure on farmland is believed to be one of the major causes of soil quality depletion in SSA, it is important to empirically analyze whether and how population pressure affects soil quality. It is equally important to examine whether land conflicts affect agricultural productivity. Both analyses can serve as basis for recommending policies to boost agricultural productivity and thereby reduce poverty in rural SSA.

Against this backdrop, this dissertation has four overriding objectives. First, it seeks to examine whether and how population pressure affects soil quality in Kenya and Uganda. Both countries provide ideal case studies. Kenya's soils were very fertile especially on high-altitude areas; however, the country has not been free from soil degradation (Drechsel, et al., 2001). Similarly, Uganda used to be one of the countries with most fertile soils in the tropics (Chenery, 1960), to-date it is one of the countries in which nutrient depletion is the highest in Africa (Henao & Baanante, 2006). Another interesting thing about the two countries is that while Kenya's fertilizer use intensity of 36.5 kg/ha is relatively better compared to other countries in SSA, Uganda's current fertilizer use intensity of 1.3 kg/ha is one of the lowest in SSA (FAO, 2015b). The soil quality information from these two countries with possibly different farming practices may enable us to identify the causes of soil degradation and help us derive some sounding policy recommendations. Second, the dissertation investigates whether land rights influence the quality of soil. The dual (private vs. communal) nature of land rights in rural Uganda makes it an ideal country for this objective. Third, it examines whether and how war-induced displacement has increased incidences of land conflicts in Northern Uganda. Subsequently, it seeks to find out whether land-related conflicts have any detrimental effects on agricultural productivity.

This dissertation offers four main contributions to the literature. With regards to population pressure and soil quality nexus, to the best of my knowledge this is the first study to examine this issue by using panel data with real soil samples. The unique soil data used by this study were collected and analyzed in the laboratory. This data is more appealing than for example using self-reported measures of soil quality that are likely to be very subjective. Moreover, previous attempts use cross-sectional data. The one decade long panel data used by this study in Chapters 2 and 3 is superior to cross-sectional data. By exploiting the panel structure of the data, this study use the fixed effects model which affords control of unobservable time-invariant characteristics that could cause bias of parameter estimates. In addition, this is the first study to explicitly examine the impact of land rights on soil quality. To the best of my understanding this issue has never been empirically examined possibly due unavailability of data on soil quality. With regards to issues of land conflicts addressed in Chapter 4, this study contributes to scanty empirical studies on land conflicts and agricultural productivity nexus. Although incidences of land conflicts in SSA are increasing, rigorous empirical studies on how they affect farmers are still scarce. More importantly, this study provides the first empirical evidence on the effect of land conflicts on agricultural productivity in post-war Northern Uganda—a region which is believed to have many incidences of land conflicts after long absence of people due to displacement caused by armed conflicts. Finally, it appears to be the first study to provide empirical evidence that one of the pathways through which land conflicts can affect agricultural productivity is by disincentivizing farmers to use improved seeds.

In terms of the main findings, the study finds that soil quality decreases with increase in population pressure in both of the countries studied, and that population pressure induces agricultural intensification considerably in Kenya but not in Uganda. The findings for Kenya indicate that farmers are aware of the problem and are trying to mitigate its negative effect while that for Uganda suggest that farmers are yet to change their farming methods to respond to increasing land scarcity resulting from population growth. Furthermore, in Uganda the study finds that individually-owned parcels have better soil compared to communally-owned parcels. This provides suggestive evidence that the land tenure system may affect farmers' decisions to invest in soil improvement in Uganda. With regards to displacement and land conflicts, the study finds that households that were displaced far away from their homes are more likely to face new land conflicts and more likely to be concerned about land conflicts. The number of years a household spent without farming in its home village and weakening of informal institutions of land appear to be the key pathways of the obtained results. Lastly, it was found that land conflicts do indeed affect agricultural productivity; the value of crops from parcels with pending conflicts are substantially lower compared to those from plots without pending conflicts operated by the same household.

The rest of the dissertation is proceeds as follows. Chapter 2 examines the impact of population on soil quality in Kenya. Chapter 3 investigates the impact of population pressure on soil quality in Uganda. It also examines whether land rights affect soil quality. Chapter 4 explores the impact of war-induced displacement experiences on land conflicts in Northern Uganda. It also investigates the possible transmission vehicles through which displacement in Northern Uganda may have impacted land conflicts. Subsequently, it examines the impact of land conflicts on agricultural productivity and the possible pathways. Chapter 5 concludes the dissertation by stressing on the main research findings and their policy implications.

CHAPTER 2

Population Pressure and Soil Degradation in Sub-Saharan Africa: Panel Evidence from Kenya

2.1 Introduction

The livelihoods of many rural households in Sub-Saharan African (SSA) largely depend on agricultural activities. Estimates suggest that about two-thirds of the 974 million people in SSA live in rural areas and heavily rely on agriculture (World Bank, 2016).[2] This overreliance on agriculture suggests that land is one of the most important natural resources for the livelihoods of rural households in the region. Even though SSA is endowed with abundant land compared to other regions such as East Asia, available arable land per person has decreased and continues to decline (Jayne & Muyanga, 2012; Rakotoarisoa, Iafrate, & Paschali, 2012; Otsuka & Place, 2015). For example, between 1961 and 2011 arable land per person declined from 0.65 ha to 0.4 ha (Otsuka & Place, 2015).

Moreover, although agricultural sector remains to be one of the most important sectors in SSA; its performance has not been encouraging and it is considered as one of the worst in the world (Sanchez, 2002; Otsuka & Larson, 2016). The sector's poor performance is reflected in many areas, including decline in food production. Since 1970 food production per capita in SSA has declined by 17% (Ehui & Pender, 2005). This trend not only makes SSA one of the regions threatened by food insecurity (Ricker-Gilbert et al.,

[2] https://data.worldbank.org/indicator/SP.RUR.TOTL.ZS

2014; FAO, 2015a), but also it has implications on widespread rural poverty found in the region. Due to the sector's poor performance, it is not surprising to learn that majority of SSA countries have remained net food importers (FAO, 2009; Rakotoarisoa et al., 2012).

The decline in agricultural productivity in SSA can be attributed to many factors, one of them being declining soil fertility (Sanchez, 2002; Kirui & Mirzabaev, 2014). The contributing factors to land deterioration widely cited in the literature include; poor or inadequate land management and farming practices, deforestation, and use of marginal lands (Morris et al., 2007; Rakotoarisoa et al., 2012; Kirui & Mirzabaev, 2014). One of the major underlying causes is believed to be population pressure (Mortimore, 1993;Kirui & Mirzabaev, 2014).[3] Unfortunately, available evidences indicate that the region's fertilizer use intensity is very low. For example, the latest available data indicates that fertilizer use intensity in SSA is only 14.9 kg/ha, a figure which is very low compared to the world average of 124 kg/ha, and that of East Asia and the Pacific which stands at 322 kg/ha (FAO, 2015b).

Whilst the region has the lowest rate of fertilizer application in the world, the rate at which soil fertility depletion is taking place in the region is quite shocking (Henao & Baanante, 2006; Smaling, Nandwa, & Janssen, 1997). For example, according to Henao & Baanante (2006), from 2002 to 2004 SSA lost Nitrogen, Phosphorous and Potassium (NPK) soil nutrients at a rate of more than 30 kg/ha per year in 85% of the African farmland (185

[3]Other major underlying causes include poverty, market and institution failures.

million ha). Similarly, Sommer et al., (2013) note that the average combined depletion rate of NPK for all SSA in the past decades is 54kg/ha per year, and as of 2010 no any SSA country used 50 kg/ha per year.[4] This trend suggests that without thorough measures to address the problem, soil degradation is likely to affect rural farmers in many ways including food shortage and income poverty.

Surprisingly, although it appears that soil fertility decline is one of the critical problems impeding agricultural development in the region, there is a paucity of empirical studies that have examined the issue. By using Kenya as a case study, this study aims at filling this literature gap and sheds some light on this very crucial issue by examining how population pressure affect soil fertility. Kenya is an interesting case study for a number of reasons. First, out of her total land mass of about 587,000 square km only 16 percent is arable land. Moreover, Kenya is one of the countries in SSA which are experiencing shrinkage in arable land resulting from high population growth. For example, land to person ratio has shrunk from 0.46 in 1960-1969 to 0.23 in 1990-1999 (Jayne et al., 2003). A more recent evidence shows that arable land per person in rural Kenya has declined from 0.16 ha in 2000 to 0.13 ha in 2011 (Otsuka & Place, 2015). Moreover, like other East African countries; historically on average, Kenya’s soils were very fertile especially on high-altitude areas. The country, however, has not been free from soil degradation (Drechsel et al., 2001; Henao & Baanante, 2006). Nevertheless, compared to other SSA

[4] A target that was set in the Abuja Declaration on Fertilizer for the African Green Revolution in 2006, and required all SSA countries to use an average of 50/kg/ha per year by 2015 (IFDC, 2006)

countries, Kenya's fertilizer use intensity of 36.5 kg/ha is relatively better (FAO, 2015b). Soil quality exhaustion amidst shrinking of arable land is likely to affect this country whose 70 percent of its population is employed by the agricultural sector; and, about 27 percent of its GDP comes from agricultural sector (KNBS, 2015).

This chapter examines the drivers of soil quality with a particular focus on rural population pressure on farmlands. First, I explore the effect of population pressure on soil fertility (degradation) in Kenya. Subsequently, I investigate to what extent farmers are responding to soil degradation. To do so, I examine the impact of population pressure on agricultural intensification. With regards to data, I use geo-referenced panel data from Research on Poverty, Environment and Agricultural Technology (RePEAT). I supplement this data with agroclimatology data from National Aeronautics and Space Administration-Prediction of Worldwide Energy Resources (NASA-POWER), and population density data sourced from Kenya National Bureau of Statistics (KNBS). In econometric analysis, I use fixed effects model which helps to control for unobservable household or parcel specific time-invariant characteristics that may cause bias of parameter estimates by utilizing the panel structure of the data. The results indicate that population pressure reduces soil quality in Kenya. At the same time, however, population pressure is found to have significant positive effect on agricultural intensification. This implies that farmers are aware of the problem and are trying to reduce its severity. Nonetheless, the fact that I find strong negative impact of population pressure on soil quality suggests that the rate of soil degradation is higher than that of agricultural intensification. To the best of my knowledge, this is the first study that rigorously examines the impact of population pressure on soil quality.

The remainder of the chapter is organized as follows. Section 2.2 reviews the literature and provides testable hypotheses. Section 2.3 discusses the data and descriptive statistics. Identification strategy is discussed in Section 2.4. Estimation results are discussed in Section 2.5. The conclusions and policy recommendations are provided in section 2.6.

2.2 Literature Review

2.2.1 Soils as natural capital

To farming households especially in rural SSA, soil is as important as other forms of capital. Its quality not only serves as household wealth, but also increases the value of land (Gray, 2011). Soil is normally represented by a set of biological, physical, and chemical properties: (i) primary macro-nutrients such as carbon, nitrogen, phosphorus, and potassium; (ii) secondary macro-nutrients such as calcium; (iii) chemical properties such as soil pH-acidity or alkalinity of the soil; and, (iv) texture-grain size distribution of clay, silt and sandy particles (Ekbom, 2008).

Soil is neither homogeneous across farmlands owned by different households nor constant over time (Boserup, 1965; Ekbom, 2008). It is usually affected by biophysical factors such as climate, biophysical and chemical characteristics of the soil, topography, altitude, temperature, parental material, and biodiversity (Jenny, 1994; Nkonya, Kaizzi, & Pender, 2005). These factors influence soil nutrients balances and soil quality in various ways. For example, although rainfall is important for moisture availability which is important for soil health; excessive and intensive rainfall may lead to considerable leaching and depletion of soil nutrients through soil erosion. Drought on the other hand may negatively affect nitrogen-fixation.

In addition, since soil is owned and managed by human being, over time it is also directly or indirectly molded by human activities, amongst other things. For instance, farmers' investment decisions such as conservation practices and application of fertilizers may affect its fertility. A study by Ekbom (2008) found a strong positive association between manure and inorganic fertilizer inputs and key soil nutrients (nitrogen, phosphorus, and potassium) in Kenya. Besides the use of fertilizers, other good farming practices that may improve soil quality include; fallowing, crop rotation, and crop-livestock interaction. On the other hand, slash and burning of farm field before cultivation or after harvesting tend to accelerate land degradation and soil nutrient depletion (FAO, 2005). One of the socio-economic factors that may affect soil quality is high population pressure unaccompanied by adequate and appropriate use of fertilizers to replenish the soils. In this study, although I discuss most of these factors, the main focus, however; is to examine whether and how population pressure on farmland affects soil fertility.

2.2.2 Population pressure and soil quality

Like most other countries in SSA, Kenya has high population growth rate.[5] With a population of 49.7 million as of 2017, the country's population is estimated to be 95.5 million people by 2050 (Population Reference Bureau, 2017). The rate of population growth is likely to be higher in rural areas where majority of the people live, thus increasing population pressure on land. Population pressure on farmland can be a fundamental cause of soil degradation.

The main channel through which increasing in population density may affect soil quality is shrinkage in land size and thus overuse of land. When population density is low, land for farming is abundant for every household. As population increases, demand for food also raises which in turn increases demand for farmland. One of the farmers' reactions could be extensification i.e., expansion of agricultural land by bringing new land into cultivation (Grepperud, 1996). However, as population density increases further, it becomes difficult to bring new land into cultivation since little arable land remains unoccupied. Recent empirical studies in SSA indicate that land and farm sizes per smallholder farmer have declined as a result of subdividing land across generations (Josephson et al., 2014; Muyanga & Jayne, 2014; Ricker-Gilbert et al., 2014). Consequently, fallow periods have been shortened (Drechsel et al., 2001; Headey & Jayne, 2014; Otsuka & Place, 2015), and in some places with severe shrinkage of land size, fallow is no longer feasible. At

[5]Its population growth rate is 2.6% almost equivalent to that of SSA as whole (2.7%). Compared to the world average which is 1.18, Kenya's growth rate is high (World Bank, 2016).

household-level, population pressure could also be reflected by decline in land-labor ratio or per capita owned land, implying land scarcity and overuse of land. Overuse of land unaccompanied by good farming practices could eventually lead to soil fertility decline. The effects are likely to be more harmful in areas where the rate of fertilizer application is very low such that the nutrients being returned to the soil are less than those lost. Also, as population pressure increases, soil fertility is gradually depleted through crop harvest removal, leaching and soil erosion (Ehui & Pender, 2005). A number of existing descriptive studies suggest an inverse relationship between population pressure on farmland and soil fertility (Mortimore, 1993; Mbaga-Semgalawe & Folmer, 2000; Drechsel et al., 2001; Kirui & Mirzabaev, 2014). However, with exception of the studies by Grepperud (1996) and Shiferaw & Holden (1998); we know of no any rigorous empirical study that has examined this relationship not only in SSA but also in other regions. Grepperud's study on Ethiopia highlands found a positive correlation between population density and soil erosion. Similar association was documented by Shiferaw & Holden (1998) in Ethiopia. Likewise, a descriptive study by Drechsel et al., (2001) found an inverse relationship between population density and soil nutrient balance in 37 countries in SSA, Kenya inclusive.[6] One of the common features of these studies is that none of them used data from soil samples.[7]

Even though descriptive studies suggest a negative relationship between population pressure and soil fertility, it is worth noting that population pressure on farmland may not

[6] The study's analysis was mainly by scatter plots hence providing only bivariate relationship.
[7] Grepperud (1996) used soil erosion severity index as a proxy for water erosion, whereas Shiferaw & Holden (1998) used soil erosion perception as outcome variable.

necessarily lead to soil degradation. Farmers may react to population pressure by changing their behaviors on farming practices to maintain soil quality. This line of reasoning is well supported by the intellectual wisdom of Boserup (1965) and Hayami & Ruttan (1985). Boserup (1965) posits that increase in rural population growth leads to evolution of farming systems. As population density rises and farm sizes decline, traditional practices of soil fertility management such as fallow become difficult, thus causing shifting away from long-fallow periods towards multi-cropping practices. To increase land productivity and crop yield, farmers adopt modern farming technologies such as improved seeds and use of organic and chemical fertilizers.[8] Related to Boserup's hypothesis is the induced innovation theory by Hayami & Ruttan (1985) which postulates that as land becomes scarcer due to increase in population density, land-saving technology will be developed to conserve the scarce resource (land) and increase use of more abundant resources (labor). This may lead to technological change in form of use of new farm inputs such as inorganic fertilizers that may increase soil fertility. Recent empirical studies on SSA (Josephson et al., 2014; Muyanga & Jayne, 2014; Ricker-Gilbert et al., 2014) document a positive relationship between population pressure and agricultural intensification in form of input use, suggesting that farmers are changing their farming behavior. Indeed, it is rational to believe that when the Boserupian prediction and the induced innovation hypothesis are realized, high population pressure on land may not hurt the soil, and if anything; it may improve it if

[8]In the literature on integrated soil fertility management, underscored also is importance of: intercropping with nitrogen fixing legumes, crop rotation, use of local available technologies of soil management, and use of modern inputs such as chemical fertilizer and improved seeds. These would not only increase crop yield but also maintain soil fertility. Besides, it is widely accepted that many of them are complements; none can in isolation meet the requirements of adequate soil fertility management (Marenya & Barrett, 2007; Kassie et al., 2012).

farmers respond by using modern farming technologies so as to make the small available land more productive.[9]

Deducing from the above[10], three possible impacts of population pressure on soil quality are: One, if the effects of population pressure on soil degradation dominates the effects of population pressure on intensification, then population pressure culminates into soil degradation. Two, if fertilizer use intensity is higher than the rate of soil degradation, the end result is likely to be increase in soil quality because soil nutrients that are returned to the soil outweigh those lost due to soil degradation. Third, if the rate of intensification is equal to the speed of soil nutrient depletion, then population pressure may have no impact on soil quality. However, in most countries of SSA including Kenya, fertilizer use intensity is exceedingly low partly due to market constraints such as lack of credits for agricultural inputs, high prices of fertilizer, lack of fertilizer markets, poor infrastructure, and transportation costs (Adesina, 1996; Gregory & Bumb, 2006). Also, non-market constraints such as lack of technical information on appropriate use of fertilizer, low output prices, and soil degradation tend to reduce the returns of such inputs, thus reduce farmers' incentives to use them (Morris et al., 2007; Marenya & Barrett, 2009). Consequently, for many farmers the rate of fertilizer application is very low and may not be enough to replenish the soil. Thus, whether population pressure on farmland deteriorates the quality of the soil is quite an interesting empirical question this study seeks to answer.

[9]Adoption of modern farming technologies played a significant role in the Green Revolution of Asia.
[10] Figure 2.1 provides a summary of the conceptual framework on how population pressure may affect the soil quality. Key potential pathways through which population pressure may affect soil quality are also provided.

The major contributions of this study are twofold. First, this study use unique panel data that contains actual soil data. So far no any study known to us that used actual soil data to examine the relationship between population pressure and soil quality. This actual soil data is superior to other measures such as soil erosion perception (self-reported) used by previous studies. Second, existing studies on population pressure and soil erosion/degradation nexus are all based on cross-sectional correlation. By using panel data, this study addresses possible endogeneity issues. This is made possible by using the fixed effects model which affords control of unobservable household or parcel specific time-invariant characteristics that could cause bias of parameter estimates. Indeed, as it will be shown later this study exploits a unique identification strategy hence allowing claiming a causal effect.

2.2.3 Hypotheses

From the above literature review, I derive the following two hypotheses. First, in an environment characterized by low rates of fertilizer application, population pressure on cropland reduces soil nutrients and soil quality. I use population density and inverse of household owned land per capita to examine the impact of population pressure on soil nutrients and soil quality. Both variables are regarded as proxies of population pressure on farmland. Second, I expect a positive relationship between population pressure on cropland and agricultural intensification.

2.3 Data, Soil Quality and Intensification Indices, and Descriptive Statistics

2.3.1 Data

The data used by this study mainly come from household-level panel surveys collected as part of the Research on Poverty, Environment and Agriculture Technologies (RePEAT) project. [11] The RePEAT surveys are detailed with geo-referenced household-and community-level information. The surveys were conducted jointly by the National Graduate Institute for Policy Studies in Tokyo (GRIPS), and Foundation of Advanced Studies on International Development (FASID). RePEAT questionnaires cover a wide array of information including; demographic, household income, education, farm input use, asset ownership, land ownership and land issues, amongst others. In Kenya, the first survey was conducted in 2004. Subsequently, follow-up surveys were conducted in 2007, 2009 and 2012. In this study I use data from 2004 and 2012 surveys. The 2004 survey covered 899 households randomly selected from 99 sub-locations drawn from five provinces of Kenya i.e., Rift Valley, Central, Nyanza, Western, and Eastern provinces. Of this total, only 751 households were successfully traced in 2012, leading to an attrition of 16.5%. I estimate a probit model of 2004-2012 attrition on a number of 2004 household characteristics.[12] To control for possible attrition bias, all estimations are weighted by attrition weights estimated based on the methods of inverse probability weights suggested by Fitzgerald, Gottschalk, & Moffitt (1998) and Wooldridge (2010).

[11]The project covers three East African Countries: Ethiopia, Kenya, and Uganda
[12]Table 2.A1 shows that some characteristics of the attritors are different from those of non-attritors.

Along with the first and fourth rounds of surveys, soil samples were collected from the largest maize plot or non-maize cereal plot if the household did not cultivate maize. In case the household did not cultivate maize or any other cereal crops, no soil samples were taken.[13] The samples were collected at a depth of 0-20cm at five different positions within each plot and thoroughly mixed (Yamano & Kijima, 2010). Thereafter, they were taken to the soil laboratory at the World Agroforestry Center (ICRAF) in Nairobi for analysis of their properties. The samples were tested by a new method developed by Shepherd & Walsh (2002) known as near-infrared reflectance spectroscopy (NIRS) (Matsumoto & Yamano, 2009). In testing the soil samples, NIRS method had several procedures. First, the soils were air-dried and ground to pass through a 2-mm sieve (filter), after which they were stored in paper bags at a reasonable room temperature. Thereafter, multivariate relationships among soil properties were analyzed. In addition, individual soil variables were calibrated. This was followed by an evaluation of prediction performance on predictive and actual observations using the coefficient of R^2 and root mean square error. Both tests revealed that the method has high level of prediction accuracy.

Because the soil samples were only collected from maize or non-maize cereal crops, together with the fact that some samples got spoiled before they were analyzed (Matsumoto & Yamano, 2009); I only have soil samples from 598 households in 2004. During the 2012 survey, the samples were collected from 614 out of the 751 traced households. After

[13]Only 2 % did not cultivate maize or cereal in both 2004 and 2012 waves.

cleaning, I ended up with a balanced panel data of 480 households from 77 communities. Hence the attrition related to soil sampled households is 20%.[14]

In addition to the RePEAT data, I use sublocation-level population density data sourced from the 1989, 1999 and 2009 Kenya Population and Housing Censuses (KNBS, 1994, 2001, 2010). The population census in Kenya is conducted after every ten years and it is detailed to the lowest administrative unit–the village. I also use agroclimatology data namely; rainfall, temperature, and wind from National Aeronautics and Space Administration-Prediction of Worldwide Energy Resource (NASA-POWER). NASA through its Earth science research program collects solar and agroclimatology data by using satellite systems. These satellites and modeled based products are believed to be accurate enough to provide reliable solar and meteorological resource data over regions where surface measurements are scanty or non-existence (Stackhouse et al., 2015). Among others, NASA records daily averaged air temperature (degrees C) at 2 meter above the earth surface, daily wind speed at 10 meter (m/s) above the earth surface, and average precipitation (mm/day). By specifying the Geographical Positioning System (GPS) coordinates one can easily download the data. In the RePEAT surveys sub location-level latitudes and longitudes were captured during the surveys. I used these GPS coordinates to merge NASA data with RePEAT data. Since NASA data is recorded on daily basis, before merging it with the RePEAT data, I generated annual variables for five consecutive years

[14]Table 2.A1 (column 3), I treat those households with missing values of soil samples as attritors. As the table shows, this type of attrition is also not random. For robustness check, I also weighted the regressions by attrition weights estimated from this attrition type. The results (not reported) remained the same.

(the year of survey and four years before the survey). Subsequently, I calculated five year average for each of the agroclimatology variables and use them in the analysis.

2.3.2 Soil quality index

The soil data are detailed with five soil macro-nutrient variables namely carbon, nitrogen, phosphorus, potassium, and calcium[15], and one chemical property, i.e., soil pH (henceforth, soil variables). However, none of these can in isolation provide an extensive picture of quality of the soil. Therefore, I use all the six soil variables to construct a single soil quality index. I use principal component analysis (PCA). This technique reduces a given number of variables by extracting a linear combination which best describes the variables and transform them into one index (Sena et al., 2002; Gray, 2011). PCA determines weights intrinsically and the weights are assigned to each indicator by the relative importance of that factor (Mishra, 2007). This allows interpretation of better summarized information. The first principal component is constructed in such a way that it captures the greatest variation among the set of variables. It is this first principal component that serves as the index.[16]

[15] These soil variables are measured as: percent carbon, percent nitrogen, extractable phosphorus (mg/kg), extractable potassium (cmolc /kg), and extractable calcium (cmolc /kg), respectively.

[16] PCA could result in bias towards weights of indicators which are highly correlated to each other and could give marginal representation to the poorly correlated variables (Mishra, 2007). Table 2.3 shows that this is not the case since all our soil variables are strongly correlated.

Following the literature (Filmer & Pritchett, 2001; Gray, 2011), we construct the soil quality index as follows:[17]

$$SQI_{it} = \sum_{k=1}^{6} W_k \left[\frac{y_{itk} - y_k}{s_k}\right] \qquad (2.1)$$

where SQI_{it} is the soil quality index of farmland of household i in year t, W_k is the weight of each of the soil macro-nutrient/characteristics in the PCA model, and y_{itk} is the soil variable of the farmland of household i in year t. y_k and s_k are the mean and standard deviation of variable k, respectively. For robustness check I also construct three other indices: (i) with five soil variables as continuous, and soil pH defined as a dummy equal to one if pH is within a suitable range of 6.6 to 7.3, and zero otherwise;[18] (ii) by using five soil variables (excepting soil pH); and (iii) by using only three key soil variables (nitrogen, phosphorus, and potassium).

[17] It is worth noting that soil quality index is likely to be nonlinear. It is difficult however to establish the optimal level because optimal level is not only crop specific, but also site specific (Ussiri et al., 1998; Be´langer et al., 2000; Srivastava et al., 2006; Musinguzi et al., 2013). Thus, it is not possible to come up with a single minimum or maximum threshold value of the soil quality that can be universally or regionally accepted. Nevertheless, existing literature shows that regardless of the type of crop; the desired level of soil carbon content is about 2% (Loveland & Webb, 2003; Musinguzi et al., 2013). With regards to some specific crops, the optimal phosphorous for corn was found to be 13 mg/kg (Mallarino & Blackmer, 1992), while that of soil carbon content on maize crop was found to be between 1.9% and 2.204% in Uganda (Musinguzi et al., 2016). The optimal level of soil pH on maize crop is widely believed to be 6.0 to 7.0, whereas that of beans is 6.0 to 6.5. Even though it is difficult to establish the optimal soil quality, anecdote evidences suggest that currently in SSA due to soil degradation and low fertilizer usage, soil fertility is far less than the optimal.

[18] Note that below soil pH of 6.6 is acidity and above 7.3 is alkalinity. Both are not suitable for most crops. Thus, an index in which soil pH enters as continuous variable could inaccurately reflect better soil quality.

2.3.3 Agricultural intensification index

I also use the PCA to measure farmers' degrees of agricultural intensification. I limit my attention to maize farming intensification. Maize is one of the crops grown by vast majority of the farmers in the study areas−98% of the sampled households produced maize as one of their crops both in 2004 and 2012. Moreover, it is from maize plots where the soil samples were taken. To create the agricultural intensification index, I use three intensive farming practices-related variables: adoption of improved maize seeds, the amount of chemical fertilizer applied, and the amount of manure applied per hectare of the land cultivated.[19] The index so constructed at parcel-level is as follows;

$$AI_{pist} = \sum_{z=1}^{3} W_z \left[\frac{c_{pistz} - c_z}{s_z}\right] \quad (2.2)$$

where AI_{pist} is the agricultural intensification of parcel p of household i in season s in year t. W_z is the weight of each of the three intensive farming practiced-related variables used to construct the index, and c_{pistz} is the value of the variable z of household i on parcel p in season s in year t. c_z and s_z are the mean and standard deviation of variable z, respectively.

[19] For robustness check I also use an alternative intensification index constructed by using only two variables more related to soil i.e., the amount of chemical fertilizer applied, and the amount of manure applied per hectare of the land cultivated.

2.3.4 Descriptive statistics

Table 2.1 shows the distribution of soil sampled households from five provinces. The summary statistics for some key variables are presented in (Table 2.2).[20] Carbon and nitrogen contents in the soil declined from 2.5 to 2.3; and from 0.22 to 0.18, respectively during the 9 year period. The same declining trend is observed on soil pH from 6.2 in 2004 to 6 in 2012. On the other hand, phosphorus, potassium and calcium increased from 15 to 22.8, from 1.04 to 1.9, and from 7.5 to 9.7, respectively. The overall soil quality declined from 0.10 to 0.03 during the same period, which indicates soil degradation.

During the same period, population density (persons per square kilometer) increased. It rose from 422.2 persons per square kilometer in 2004 to 543.5 persons per square kilometer in 2012, an increase of about 29 percent. Unsurprisingly, owned land per capita declined from 0.37 ha in 2004 to 0.27 in 2012 ha. Similarly, land-labor ratio (household own land divide by the number of household members of working age, i.e., age 15 to 64) declined from 0.6 to 0.5 during that period. The decrease in both land-labor ratio and owned land per capita, and the increase in population density suggest increasing population pressure on land over time. With regards to agricultural intensification variables, no significant changes are observed between the two survey periods.

[20] Note that while some of the soil nutrients improved over time, the overall soil quality depleted over time. However, it is worth pointing out that it may be difficult to compare the absolute value of soil indictors from different year samples because the values were obtained by calibration and was done year by year separately. This is why trends of some soil variables are not in line with our expectations (Table 2.2). However, this is not a threat in regression because it is controlled for by inclusion of year fixed effects. Table 2.A2 in the appendix shows the percentage of soil samples below the required threshold for each soil nutrient year by year.

Table 2.3 shows the pairwise correlations between population pressure variables and soil variables. Overall, column 1 shows a strong positive correlation between soil macro-nutrients and soil quality index. Moreover, in general the soil variables are strongly correlated to each other. With regards to population pressure and soil variables, Table 2.3 shows a strong inverse relation between population density and soil variables. The inverse of per capita owned land (another proxy for population pressure) is inversely related with soil variables although the correlation is not statistically significant. Table 2.4 shows the pairwise correlations between changes in population pressure variables, and changes in soil variables. A strong positive correlation between changes in soil macro-nutrients and change in soil quality index is revealed. Similarly, strong inverse relation between change in population density and changes in both soil quality and macro-nutrients is observed.

Table 2.5 presents factor loadings of the individual soil variables. The factor loadings are correlation between explanatory variables and the factor. As the table shows, the loadings increase with carbon, phosphorus, potassium, and calcium in 2004 and 2012, but decrease with soil pH and nitrogen in 2004 and 2012, respectively. The factor loadings for input use variables are shown in Table 2.6. The top panel of Table 2.6 shows factor loadings at household-level while the bottom panel shows the loadings at parcel-level. At both levels, all the three agricultural intensification variables are positively associated with the intensification index. The intensification index has increased from -0.21 in 2004 to 0.22 in 2012 suggesting that agricultural intensification has improved.

Overall, the descriptive statistics suggest that soil quality is declining, but at the same time agricultural intensification is improving. Such intuition provides a basis to perform a rigorous analysis in later sections to examine how population pressure on farmland affects soil quality and agricultural intensification.

2.4 Estimation Strategies

Examining the drivers of the soil quality changes is challenging because measuring changes in soil quality requires a study over a long time horizon since most soil properties are shaped or accumulated after a long period of time (Ekbom, 2008). To address this concern, fortunately I have a panel data set that span for 9 year-period. I believe this time interval is long enough to analyze some soil quality dynamics.

Building on soil formation literature in soil science (Jenny, 1994), an ideal structural equation to estimate the drivers of changes in soil quality or individual properties of the soil can be depicted as follows:

$$\boldsymbol{SQ}_{ijrt} = f(\boldsymbol{H}_{it,}\, \boldsymbol{I}_{it}, \boldsymbol{Cl}_{jt,} \boldsymbol{O}_{rt}, T_t, P_i, \boldsymbol{Pop}_{jt,} \boldsymbol{X}_{ijrt}) \qquad (2.3)$$

where $\boldsymbol{SQ}_{ijrt}$ is soil quality index or a vector of soil individual properties, $\boldsymbol{H}_{it}$ is a vector of household characteristics, $\boldsymbol{I}_{it}$ is a set of soil conservation variables including application of fertilizers, $\boldsymbol{Cl}_{jt}$ is a vector representing climate-related variables**,** $\boldsymbol{O}_{rt}$ stands for organisms (biota), T_t is time, P_i is parental material, $\boldsymbol{Pop}_{jt}$ is population pressure, $\boldsymbol{X}_{ijrt}$ is a set of other controls. Since we are using panel data, time-invariant factors such as P_i will be absorbed by household fixed effects. As pointed earlier, population pressure on farmlands can affect soil quality directly through more frequent and intensive use of farmlands hence soil degradation. Indirectly, it can also affect soil quality by inducing smallholder farmers to change their behavior and use more fertilizers to increase land productivity. I therefore estimate two reduced form equations of the above structural equation.

$$\boldsymbol{SQ}_{ijrt} = h(\boldsymbol{H}_{\boldsymbol{it}}, \boldsymbol{Pop}_{jt,} \boldsymbol{Cl}_{jt}, \boldsymbol{O}_{rt}, \boldsymbol{X}_{ijrt}) \quad (2.4)$$

$$\boldsymbol{I}_{ijrt} = g(\boldsymbol{H}_{\boldsymbol{it}}, \boldsymbol{Pop}_{jt,} \boldsymbol{Cl}_{jt}, \boldsymbol{X}_{ijrt}) \quad (2.5)$$

Equation (2.4) is the first reduced form of impact of population pressure on soil quality and soil macro-nutrients, while equation (2.5) is the second reduced form equation in which I regress the endogenous variables i.e., fertilizer use variables on population pressure.

2.4.1 The impact of population pressure on soil quality

To estimate the direct effect of population pressure on soil quality (equation (2.3)), I use fixed effects estimation strategy to control for unobservable time-invariant household or parcel specific characteristics that may bias our estimates. Although I use fixed effects, one might suspect that the coefficient of population density might be plagued by endogeneity problem arising from reverse causality. Indeed, it might be the case that it is not population density that is affecting soil quality but rather it is soil quality that is affecting population density since people may tend to settle in areas with fertile soils. To address this concern, I use long lag population density (1989 and 1999)−henceforth past population density. I argue that "current soil quality" (2004 and 2012) cannot affect past population density. Thus, the relationship found by using this identification strategy should carry a causal interpretation. The empirical model to be estimated is specified as follows.

$$SQ_{ijrt} = \beta_0 + \beta_1 Lsize_{it} + \beta_2 lnPop_{jt}^{lag14yrs} + \beta_3 H_{it} + \beta_4 V_{jt} + \gamma_{rt} + \alpha_i + \varepsilon_{ijrt} \quad (2.6)$$

where i, j, r, t denotes household, sublocation, province, and year of survey, respectively. SQ_{ijrt} is the outcome variable of interest either each of the soil variables or the soil quality index. $Lsize_{it}$ is the inverse of per capita owned land.[21] $lnPop_{jt}^{lag14yrs}$ is log of past population density. H_{it} is a vector of household specific controls namely: a dummy variable equal to 1 if female headed household, age of household head, years of schooling of head of the household, number of male adults and number of female adults (18 years and above), average years of schooling of male adults, average years of schooling of female adults, log of asset value, log of livestock value, and amount of land used other than owned land–rented in land.[22] V_{jt} controls for observable sublocation characteristics such as rainfall, temperature, wind, and travel time by car in minutes to the nearest big town. γ_{rt} is expected to capture province-year specific unobservable characteristics such as those in $\boldsymbol{O}_{rt}$ which would affect soil quality. α_i is included to remove the effects of time-invariant household or parcel characteristics such as soil type, parental material, elevation, and soil management

[21] According to the theory, $Lsize$ is the function of past population density. Thus, in this reduced-form equation there may be no need to include it separately from past population density. For robustness check, I re-estimated the respective equation without $Lsize$. The significance levels didn't change only the magnitude of the coefficients of interest changed slightly. The results are shown in Table 2.A3.

[22] Controlling for this variable is important because if land rental market is functioning and opportunities for renting-in land are there, this may reduce economic and social tension by promoting the movement of land from the land-rich to the land-poor.

ability that may bias our estimates. ε_{ijrt} is the error term that may be heteroskedastic and correlated within a sublocation. I therefore use robust standard errors clustered at the sublocation level (Angrist & Pischke, 2009 chapter 8; Cameron & Miller, 2015 p.14).

2.4.2 Impact of population pressure on agricultural intensification

Population pressure may also affect soil quality indirectly through its impact on input use. In this section I perform another reduced form analysis of equation (2.3). Following the literature review, I estimate the impact of population pressure on input use by using four variants of intensification: quantity of manure used per hectare of land cultivated; quantity of chemical fertilizer used per hectare of land cultivated; a dummy variable equal to one if used improved maize seeds; and agricultural intensification index which is constructed as a linear combination of the first three variables. Formally, I estimate the following model.

$$AI_{pijrt} = \alpha_0 + \alpha_1 Lsize_{it} + \alpha_2 lnPop_{jt} + \alpha_3 FS_{pit} + \alpha_4 H_{it} + \alpha_5 V_{jt} + \gamma_{dt} + \xi_i + \mu_{pijrt} \quad (2.7)$$

where AI_{pijrt} denotes four variants of intensification; quantity of manure, quantity of chemical fertilizer per hectare of land cultivated, a dummy variable equal to one for adoption of improved maize seeds, and the agricultural intensification index. $Lsize_{it}$ is an inverse of owned land size per capita and $lnPop_{jt}$ is log population density. FS_{pit} denotes farm size in hectare. H_{it} is a set of household characteristics defined earlier. V_{jt} controls for observable sublocation-level variables. The division-year fixed effects, $\gamma_{dt,}$ are controlled for by including a set of dummy variables for year of survey and the interactions between years and divisions,[23] which are expected to mitigate the possible estimation biases due to unobservables possibly affecting both the outcome and explanatory variables of interest. ξ_i is the fixed effects that controls for unobserved time-invariant household or parcel specific characteristics such as soil type, farm management ability, and farmer's risk preferences that may affect our estimation results. I also include a binary variable to control for season when they are in regression analysis. μ_{pijrt} is the error term. In all regressions the standard errors are clustered at the sublocation.

The identifying assumption is that unobservables that might simultaneously affect the outcome variable and our explanatory variables of interest are time-invariant and they will be successfully cancelled out by fixed effects. A concerned for omitted variable bias, however, may remain if the unobservable factors are time-variant. For example, price of inputs, institutional factors such as policies on subsidization of inputs or extension services may be correlated with both population density and adoption of inputs. Failure to control for such factors may result to biased estimates. However, in Kenya input market is well developed and prices are almost the same within the division (Matsumoto & Yamano, 2009). Thus, inclusion of division by time-trends should be able to absorb the impact of prices. Similarly, institutional factors such as policies on subsidization of inputs or extension services are to a large extent countrywide, provincewide, or divisionwide, hence division by time trends should successfully control for such factors.

[23]A division is another type of administrative unit in Kenya. In the data, there are 44 divisions, which are divided into 96 sublocations.

2.4.3 Do fertilizers improve soil quality?

So far, I have postulated that population pressure can indirectly affect soil quality by inducing farmers to use more manure and chemical fertilizers, among other inputs, so as to make small available land more productivity. Implicitly, this should help to replenish the soil nutrients and improve the quality of the soil. It is important however to examine whether intensification actually improves the soil quality. One way to do that is to estimate the structural equation and look at the correlation between fertilizer variables and soil quality.[24] Another way is to examine the relationship between the change in soil variable (quality) and change in fertilizer variables (2004-2012). If the relationship turns out to be positive and significant, it can be supportive evidence that applying fertilizers indeed improves the soil quality. To examine the later, I use the following model.

$$ChangeinSQ_{ijr} = \alpha_0 + \alpha_1 ChangeinAI_i + \alpha_2 Lsize_i + \alpha_3 \ln Pop_j + \alpha_4 H_i + \alpha_5 V_j + \gamma_r + \mu_{ijr} \quad (2.8)$$

Here, $ChangeinSQ_{ijr}$ is the change in soil quality, $ChangeinAI_i$ is the change in agricultural intensification, and γ_r is a set of province dummies. Other controls are as defined earlier except that they are now for 2012 round only.

2.4.4 Current agricultural intensification and past soil quality

It is worth pointing out that agricultural intensification can be influenced by past soil fertility. Past soil fertility can affect households' current behavior towards the use manure,

---

[24]The correlation is ambiguous. It might be positive−implying that soil fertility is higher on land where application of fertilizers is higher. The correlation can also be negative suggesting that people use more inputs on degraded soil.

chemical fertilizers, and other related inputs in two different ways. First, if past soil was very fertility, there may be no need to use fertilizer inputs in current period. Second, if past soil fertility was very low, households may find it unprofitable to use fertilizers in such very low fertile soil. To examine this relationship, I estimate the following model.

$$AI_{ijr} = \alpha_0 + \alpha_1 SQ_i^{2004} + \alpha_2 Lsize_i + \alpha_3 \ln Pop_j + \alpha_4 FS_i + \alpha_5 H_i + \alpha_6 V_j + \gamma_r + \mu_{ijr} \qquad (2.9)$$

Where, (AI_{ijr}) is agricultural intensification in 2012–hereafter current agricultural intensification, SQ_i^{2004} is soil quality in 2004–henceforth past soil quality, and γ_r is a set of province dummies. The remaining controls are as defined before; the only difference is that in this setting I only include current period variables.

2.5 Estimation Results

2.5.1 Population pressure and soil quality

Table 2.7 reports the estimation results on the determinants of individual soil macro-nutrients. The inverse of owned land per capita appears to have no significant relationship with soil variables, although it has expected signs in all but soil pH. In column 1, log of past population density significantly reduces carbon content. Similarly, log of past population density negatively affects nitrogen content of the soil (column 2). Likewise, column 3 shows that log past population density leads to reduction in phosphorous. Columns 4 and 5 also show that log past population density reduce potassium and calcium; however, the effect is not statistically significant.

Table 2.8 presents the estimation results of the impact of population pressure on soil quality. The results show that population density reduces soil quality index. Specifically, a percent increase in population density reduces the quality of soil by 0.30 standard deviations (column 3). In columns 1-3 I use soil quality index created by using all the six soil variables. As a robustness check, in column 4 I use soil quality index constructed by using five soil variables (excepting soil pH); the results remain largely unaffected−a percent increase in past population density leads to reduction of soil quality by 0.31 standard deviation. To further check the robustness of our results, in column 5 soil pH enters in the soil quality index as a dummy variable equal to one if neutral (soil pH is within the range of 6.6 to 7.3) and zero otherwise. Again the results remain unaffected. In column 6, I use soil quality index created by using only three soil variables (NPK); the effect of past population density on soil quality remains negative and statistically significant. Surprisingly, the relationship between the inverse of owned land per capita and soil quality index although bears the expected sign, it is not significant. The fact that the inverse of owned land per capita does not enter significantly while population density does, may suggest that within sublocation variation in per capita own land is very small.

2.5.2 Population pressure and agricultural intensification

Table 2.9 shows the estimation results on the determinants of agricultural intensification. The results show that log of inverse of owned land per capita is positively associated with all measures of agricultural intensification but the relationship is only significant on chemical fertilizer use (column 2) and agricultural intensification index (columns 5 and 6).

Similarly, the expected positive effect of population density on measures of intensification is found. A percent increase in population density increases the intensification by 0.33 standard deviations (column 5). In addition, population density appears to affect agricultural intensification in terms of use of chemical fertilizers (column 3), and adoption of improved maize seeds (column 4). The effect of population density on the use of manure is positive but not statistically significant (column 1).

2.5.3 Does the use of fertilizers improve soil quality?

Table 2.10 reports the correlation between change in fertilizer variables and change in soil quality. There is a significant and positive relationship between change and chemical fertilizer and change in soil quality. Likewise, the change in agricultural intensification and change in soil quality are significantly and positively related. Table 2.11 shows the relationship between soil fertility and agricultural intensification. As expected, all our agricultural intensification measures−manure use, chemical fertilizer application, and agricultural intensification index are positively associated with soil fertility. However, the relationship is not significant for the case of manure. Overall, however, the results provide supportive evidence that the use of fertilizers increase the quality of the soil.

2.5.4 Current agricultural intensification and past soil quality

Table 2.12 shows the correlation between current agricultural intensification and past soil fertility in Uganda. There is positive relationship between current application of agricultural intensification and past soil quality. This relationship is statistically significant for chemical fertilizer application and agricultural intensification index. This suggests that farmers tend to use chemical fertilizers on fertile land. The results are in line with earlier studies that showed that chemical fertilizers are less effective on degraded soil (Marenya & Barrett, 2009a, 2009b). It is also interesting to find that the square term of past soil quality is significantly and negatively correlated with current agricultural intensification. This suggests that when the soil is very fertile farmers may have no reason to use chemical fertilizers.

2.6 Conclusion and policy implications

By using a unique longitudinal data with real soil samples from rural households in Kenya, this chapter sought to examine: (i) the impact of population pressure on soil quality, and (ii) the effect of population pressure on agricultural intensification. The study finds that population density significantly reduces soil quality. The results are robust to alternative specification and alternative measures of soil quality index. However, the inverse of owned land per capita (another proxy for land constraint) does not appear to have any significant negative effect on soil quality. This result is a bit surprising, but may suggest that within sublocation variation is small. I also find significant positive effects of inverse of owned land per capita and population density on agricultural intensification. These results are interesting and indicate farmers' positive response to cope with declining soil fertility. Indeed, this suggests that the negative effect population pressure on soil quality may have been worse than what I find here if farmers were not responding to mitigate the problem as reflected by the positive effect of population pressure on agricultural intensification.

However, the fact that I find significant positive effect of population pressure on agricultural intensification on one hand, and significant negative effect of population pressure on soil fertility on the other hand, suggests that the rate at which soil degradation is taking place is higher than the speed of intensification. Overall, the results support the population hypothesis and indicate that in the areas that this study covers, the Boserupian hypothesis is yet to materialize at a desired rate. Thus, it could be interesting if future studies will look at the same issue in other regions with possibly completely different farming system.

The findings of this study have a number of policy implications. First, there is a need to promote agricultural intensification such that the effect of population density on intensification outweighs that of population density on soil degradation. One way to achieve this is through policy that stimulates investment in soil conservation and land improvement. Implementation of such policy may include provision of subsidies external inputs, encouragement of farmers to use locally available inputs such as manure and compost, and provision of technical services supporting appropriate use those inputs. Also important are policies that can eventually lead to improved markets for agricultural products; such policies are likely to induce farmers to invest in soil improvement. Without such policies, farmers are not likely to invest in soil improvement as long as what they produce from their degraded lands can meet their immediate consumption. Lastly, family planning, especially among rural households should also be encouraged.

Even though this study finds that population pressure reduces soil quality, a remaining question is its welfare impact on rural households. Even though this is beyond the scope of this study, it is worth pointing out that the welfare impact is ambiguous. It may be negative since by reducing soil quality, this may translates into lower land productivity and crop income. In addition, scarcity of land resulting from population increase could translate into more liquidity constraints and reduce households' ability to engage in off-farm activities through for example establishing small scale businesses. On the other hand, high population may create or increase demand of goods and services from non-agricultural sector which may eventually stimulate the rise of off-farm sector. The off-sector such as concentration of small scale industries may in turn create off-farm jobs and increase incomes of the rural households. Moreover, individuals from land constrained communities may have more incentive to migrate and seek jobs in urban areas and in turn send remittances to their households. Therefore, to understand the welfare impact of population pressure, one needs to examine its impact on shares of income and total income−an issue reserved for future study.

CHAPTER 3

Population Pressure and Soil Quality Dynamics in Sub-Saharan Africa: Panel Evidence from Rural Uganda

3.1 Introduction

To rural households in Sub-Saharan African, land is as important as any other form of capital and a large proportion of the rural population largely depends on it for its livelihoods. Statistically, the World Bank estimates that two-thirds out of the region's population live in rural areas and greatly depend on agriculture for their livelihoods (World Bank, 2016).[25] Unfortunately, in spite of this reality, the performance of agricultural sector in SSA is considered to be one of the poorest in the world (Sanchez, 2002;Otsuka & Larson, 2016). This raises concerns on how the region will manage to feed its population amidst its high population growth rate.[26]

The sector's poor performance can be linked to many factors. However, it is widely acknowledged that soil degradation is one of the key factors undermining the performance of the agricultural sector (Drechsel et al., 2001; Sanchez, 2002; Stocking, 2003), thereby contributing not only to food insecurity, but also to poverty in the region (De Janvry, 2010; Otsuka & Place, 2015). Existing literature seems to suggest that population pressure is the

[25] https:/data.wordbank.org/indicator/SP.RUR.TOTL.ZS

[26] Currently SSA population growth rate is 2.7% much higher than the world average which stands at 1.18 (World Bank, 2016).

main underlying cause of soil degradation[27] in the region (Grepperud, 1996; Shiferaw & Holden, 1998; Drechsel et al., 2001). Even though SSA is endowed with abundant land compared to other regions such as East Asia, because of high population growth rates arable land per person has decreased and continues to decline (Jayne, Chambelin, & Muyanga, 2012; Rakotoarisoa et al., 2012; Otsuka & Place, 2015). For example, between 1961 and 2011 arable land per person declined from 0.65 ha to 0.4 ha (Otsuka & Place, 2015). Moreover, evidence shows that the region is characterized by limited use of fertilizers compared to other regions. For example, the latest available data indicates that fertilizer use intensity in SSA is only 14.9 kg/ha, a figure which is quite unimpressive when compared to the world average of 124 kg/ha or that of East Asia and the Pacific which stands at 322 kg/ha (FAO, 2015b).

At the same time, the rate at which soil fertility depletion is taking place in the region is quite disgusting (Smaling et al., 1997; Henao & Baanante, 2006). For example, in only two years from 2002 to 2004 SSA lost Nitrogen, Phosphorous, and Potassium (NPK) soil nutrients at a rate of more than 30 kg/ha per year (Henao & Baanante, 2006). More still, a recent paper by Sommer et al., (2013) document that the average combined depletion rate of NPK for all SSA in the past decades is 54kg/ha per year and as of 2010, no any SSA country used 50 kg/ha per year.[28] This trend suggests that without thorough measures to

[27] The contributing factors to land deterioration widely cited in the literature include; poor or inadequate land management and farming practices, deforestation, and use of marginal lands (Morris et al., 2007; Rakotoarisoa et al., 2012; Kirui & Mirzabaev, 2014). Others include poverty, market and institution failures.
[28] This target was set in 2006 during the Abuja Declaration on Fertilizer for the African Green Revolution. It required all SSA countries to use an average of 50/kg/ha per year by 2015 (IFDC, 2006).

address the problem, soil degradation is likely to affect rural farmers in many ways including food shortage and income poverty.

Although it appears that soil fertility decline is one of the serious problems facing agricultural development in the region, scholarly efforts by economists to examine this issue have been remarkably scanty. By using Uganda as a case study, this study seeks to fill this literature gap and throw light on this very important issue. Uganda provides an ideal case study for a number of reasons. First, it used to be one of the countries with most fertile soils in the tropics (Chenery, 1960), but to-date it is one of the countries in which nutrient depletion is the highest in Africa (Henao & Baanante, 2006). Yet its current fertilizer use intensity of 1.3 kg/ha is one of the lowest in SSA (FAO, 2015b). This suggests that the possibility to replenish the soil nutrients that are lost is very limited. In a country such as Uganda in which over 80 percent of the population is employed in the agricultural sector (Uganda Bureau of Statistics, 2016); soil quality exhaustion is likely to have detrimental effects on the livelihoods of vast majority of people.

This chapter examines the drivers of soil quality with a more focus on the role of rural population pressure on farmland. Firstly, I explore the effect of population pressure on soil fertility (degradation) in Uganda. Secondly, I investigate the impact of land rights on soil quality. Lastly, I examine the impact of population pressure on agricultural intensification. The main source of data is Research on Poverty, Environment and Agricultural Technology (RePEAT). This data is supplemented with agroclimatology data.

In econometric analysis, I use fixed effects model which helps to control for unobservable household or parcel specific time-invariant characteristics that may cause bias of parameter estimates by utilizing the panel structure of the data. The main results show that population density reduces soil quality. Furthermore, better land rights appear to increase soil quality. Unfortunately, I find very weak evidence on the impact of population pressure on agricultural intensification in Uganda. To my best knowledge, this is the first study that rigorously examines the impact of population pressure and land rights on soil quality in Uganda.

The rest of the chapter proceeds as follows. Section 3.2 reviews the relevant literature. Section 3.3 describes the data. Section 3.4 discusses the estimation strategy. Section 3.5 discusses the estimation results. Section 3.6 concludes and provides some policy recommendations.

3.2 Literature Review

3.2.1 Population pressure and soil quality

Currently Uganda is one of the countries with highest growth rates.[29] Its population is projected to more than double from current size of 43 million to 96 million by 2050 (Population Reference Bureau, 2017). The rate of population growth is likely to be higher in rural areas where majority of the people live, thus leading to more population pressure on land. Population pressure on farmland can be a fundamental cause of soil degradation.

[29]With growth rate of 3.3%, the country is ranked the second highest in the world (World Bank, 2016).

According to population pressure hypothesis, population pressure on farmland leads to soil degradation (Grepperud, 1996). The main idea behind this line of reasoning is that at low population density, rural households have abundant land to cultivate. At this stage, land-using extensive systems such as slash and burn are practiced (Otsuka & Place, 2015). To restore soil fertility fallowing is mostly used. In other words, after cultivating the same land for say two or three consecutive seasons, soil quality deteriorates and land is left for a reasonable period without being cultivated. As population pressure increases, farmers' farmlands decrease, hence uncultivated land is brought into cultivation (extensification) since unoccupied arable land is still available. However, a further increase in population pressure leaves no or small idle arable land. Recent empirical studies in SSA document that land and farm sizes per smallholder farmer are declining as a result of subdividing land across generations (Josephson et al., 2014; Muyanga & Jayne, 2014; Ricker-Gilbert et al., 2014). This has led to reduction in fallow periods (Drechsel et al., 2001; Otsuka & Place, 2015); and in places with severe shrinkage of land size, fallow is no longer practiced. Thus, to feed the growing population amidst increasing land scarcity farmers' option is to increase frequency of cultivating the same piece of land. Overuse of land unaccompanied by good farming practices, eventually leads to soil fertility exhaustion. Indeed, such effects are likely to be more harmful in areas where the rate of fertilizer application is very low such that the nutrients being returned to the soil are less than those lost.

Although descriptive studies suggest an inverse relationship between population pressure and soil quality in SSA, no scholarly efforts to rigorously examine this relationship known to us. I only know of two attempts (Grepperud, 1996; Shiferaw & Holden, 1998). Both studies found that population pressure leads to soil erosion. More specifically, the former found a positive relationship between population density and soil erosion in Ethiopia and the latter found a negative association between land-man ratio and soil erosion. Similarly, Drechsel et al., (2001)'s study found an inverse relationship between population density and soil nutrient balances in 37 countries.[30] The major contributions of this study are twofold. First, unlike existing attempts, this is the first study to explicitly examine the effect of population pressure on soil quality.[31] Moreover, in this study I use panel data with real soil quality data−actual soil data are hardly available in household surveys. Second, existing attempts do not only look at soil quality per se; but also they use cross-section data. By using panel data that spans for a decade, this study use more superior estimation methodologies−the fixed effects model. The use of fixed effects model affords control of unobservable household or parcel specific time-invariant characteristics that could cause bias of parameter estimates.

3.2.2 Population pressure and agricultural intensification

Contrary to population pressure hypothesis, it is also believed that population pressure on natural resources induces technological changes. Credit to this line of reasoning is due to Boserup (1965) in her well-known Boserup hypothesis. The main thesis of her intellectual wisdom is that as population density increases, agricultural land gets scarcer and scarcer.

[30] The study's analysis was mainly by scatter plots hence providing only bivariate relationship.
[31]Previous attempts: Grepperud (1996) used soil erosion severity index, while Shiferaw & Holden (1998) used soil erosion perception as outcome variable.

As a result, traditional methods such as fallow that are commonly used to regain soil fertility when land is abundant will no longer be used. As a response to land constraint, farmers gradually change their farming behaviours by switching from extensification[32] to more intensive farming system in which more inputs such as manure and chemical fertilizers are used so as to increase the fertility of the soil and make the small available farm land more productive. Thus, in view of Boserupian hypothesis, agricultural intensification is a function of land scarcity which is caused by increasing population growth. A closely related intellectual reasoning is provided by Hayami & Ruttan (1985)'s induced innovation theory which postulates that as land becomes scarcer due to increase in population pressure, land-saving technology will be developed to conserve the scarce resource (land). This leads to technological change in form of use of new farm inputs such as inorganic fertilizers that may lead to improvement in land.

Empirically, existing studies in Sub-Saharan Africa confirm that farm sizes are shrinking as a result of population growth (Jayne, Chamberlin, & Muyanga, 2012; Josephson et al., 2014; Ricker-Gilbert et al., 2014). Indeed, it is no wonder other studies have found that in densely populated areas fallow periods have been reduced or abandoned altogether (Drechsel et al., 2001; Otsuka & Place, 2001; Jayne et al., 2012; Headey & Jayne, 2014). Interestingly, however, is that a bunch of recent studies document a positive relationship between population pressure (density) and agricultural intensification in form of input use, suggesting that farmers are changing their farming behavior to cope with

[32]This is when land is continuously expanded in order to increase outputs.

declining farm sizes. For example, (Josephson et al., 2014; Muyanga & Jayne, 2014; Ricker-Gilbert et al., 2014) all show a positive association between population pressure and fertilizer use per hectare. This suggests that population pressure on farmland may not necessarily hurt the soil, if anything; it may improve it if farmers respond by using modern farming technologies so as to make the small available land more productive. However, some studies have found no any relationship between population pressure and fertilizer use (Shiferaw & Holden, 1998; Headey & Jayne, 2014).

Following from 3.2.1 and 3.2.2 above, there are three possibilities. First, if the negative effect of population pressure on soil quality outweighs the positive effects of population pressure on fertilizer use intensity, then population pressure leads to soil degradation. Second, if the positive effect of population pressure on fertilizer use intensity dominates the negative effect of population pressure on soil, the end result is likely to be increase in soil quality because soil nutrients that are returned to the soil outweigh those lost due to soil degradation. Third, if the rate of intensification is equal to that of soil nutrient depletion, then population pressure may have no impact on soil quality.

However, in most countries of SSA, there is extremely limited use of fertilizers and other modern agricultural inputs such as improved seeds. This is partly due to market constraints such as lack of credits for agricultural inputs, high prices of fertilizer, lack of fertilizer markets, poor infrastructure, and transportation costs (Adesina, 1996; Gregory & Bumb, 2006). Moreover, non-market constraints such as lack of technical information on appropriate use of fertilizer, low output prices, and low soil fertility tend to reduce the returns of such inputs, thus reduce farmers' incentives to use them (Morris et al., 2007; Marenya & Barrett, 2009). Consequently, for many farmers in SSA, the rate of fertilizer application is exceedingly low and may not be enough to replenish the soil. Therefore, whether population pressure on farmland worsens the quality of the soil is an interesting empirical question that is yet to be tackled. Besides, another non-market factor that may affect farmers' reactions to invest in soil improvement is nature of land ownership rights. I discuss this in the subsequent sub-section.

3.2.3 Private (secure) land rights and soil quality

The literature underscores the role of private land rights and land tenure security on investment in land improvement and agricultural productivity. Theoretically, private land rights and secure land tenure tend to incentivize individuals to invest in land improvement (Feder & Feeny, 1991; Besley, 1995; Brasselle et al., 2002; Goldstein & Udry, 2008; Abdulai et al., 2011; Fenske, 2011; Bellemare, 2013). There are three channels through which private land rights and land tenure security may impact investment in soil improvement. First, private land rights and land tenure security reduce farmers' uncertainties about future ownership of land, thus increase their incentives to invest in land improvement. Second, with individualized or secure land rights, farmers may relax their credit constraints by using land as collateral to access credit from financial and non-financial institutions. The borrowed funds can in turn be used to invest in land improvements. Lastly, private and secure land rights reduce transaction costs and make it easier to convert land into liquid assets through selling. This tends to increase incentive to invest in land improvement because the benefits of the improvements made on it can be realized at any time.

Empirically, dozens of studies have explored the link between either land rights or land tenure security and investment in land improvement and agricultural productivity. Findings from existing studies are mixed. For example, (Goldstein & Udry, 2008; Abdulai et al., 2011; Deininger, Ali, & Alemu, 2011) found that individuals with secure land ownership rights invest more in soil conservation particularly in tree planting and organic fertilizer use. Yet, others such as Besley (1995) and Fenske (2011) document mixed results i.e., a positive relationship is found in one of the regions but not the other within the same study. Moreover, in some cases, the evidence is inconclusive (see for example Brasselle et al., 2002). Nonetheless, the documented positive association between land tenure security and investment in land improvement suggest that secure land rights may affect soil quality. Surprisingly, however, of all the existing studies, none examines whether land rights affect the quality of soil. This remains an empirical question of policy relevance. This study fills this void in the literature −the third main contribution of this chapter.

3.2.4 Hypotheses

Following from the above literature review, this chapter intends to test the following three hypotheses. First, in countries characterized by limited use of fertilizers such as Uganda, population pressure on farmland reduces soil nutrients and soil quality. Second, I hypothesize that households whose parcels are individually-owned have better soil than those with communally-owned parcels. As explained earlier, the type of land ownership rights affect incentives to invest in land improvement. Without individualized ownership rights, individuals may have less incentives to invest in land improvement especially when it comes to long-term investments such as application of manure and tree planting. Third, I expect that population pressure positively affect agricultural intensification−in the form of more use of fertilizers and improved seeds.

3.3 Data, Soil Quality and Intensification Indices, and Descriptive Statistics

3.3.1 Data

I use data from two sources. The main source is Research on Poverty, Environment and Agriculture Technologies (RePEAT) project. The RePEAT surveys are detailed with geo-referenced household-and community-level information. The surveys were conducted jointly by the National Graduate Institute for Policy Studies in Tokyo (GRIPS) in collaboration with Makerere University. RePEAT questionnaires are detailed with a wide range of information on demographic, household income, education, farm input use, asset ownership, land ownership and land issues, community population density, amongst others.

The REPEAT data on Uganda so far consist of five surveys: 2003, 2005, 2009, 2012, and 2015. This study uses 2003 and 2012 data set covering three out four regions of Uganda.[33] During the first round ten households were randomly selected from each of 94 Local Counsel 1s (LC1)−the smallest administrative unit in Uganda,[34] making a total of 940

[33] The Northern region was not surveyed in the first four surveys due to insecurity concerns as result of war by Lord's Resistance Army.
[34] I use LC1, village, and community interchangeably.

households (Yamano et al., 2004). The fourth round of survey conducted in 2012 successfully traced 779 households of the original sampled households, leading to an attrition of 17%. I follow Fitzgerald et al., (1998) and Wooldridge (2010) to estimate a probit model of 2003-2012 attrition on a number of 2003 household characteristics.[35] To control for possible attrition bias, all estimations are weighted by attrition weights estimated based on the methods of inverse probability weights proposed by Fitzgerald et al., (1998) and Wooldridge (2010).

During the 2003 and 2012 surveys, soil samples were collected from the largest maize plot or non-maize cereal plot in case the household did not cultivate maize.[36] The soil samples were collected at a depth of 0-20cm at five different positions within each plot and were mixed thoroughly (Yamano & Kijima, 2010). Afterwards, they were taken to the soil laboratory at the World Agroforestry Center (ICRAF) in Nairobi to analyze their properties. The samples were tested by a new method developed by Shepherd & Walsh (2002) known as near-infrared reflectance spectroscopy (NIRS) (Matsumoto & Yamano, 2009). In testing the soil samples, NIRS method had several procedures. First, the soils were air-dried and ground to pass through a 2-mm sieve (filter), after which they were stored in paper bags at a reasonable room temperature. Thereafter, multivariate relationships among soil properties were analyzed. In addition, individual soil variables were calibrated. This was followed by an evaluation of prediction performance on predictive and actual observations using the

[35] Table 3.A1 presents the probit estimation results on the determinants of attrition. Indeed, some characteristics of the attritors are statistically different with those who were traced.

[36] In case the household did not cultivate maize or any other cereal crops, no soil samples were taken. Only 16% and 9% did not cultivate maize or any other cereal crop in 2003 and 2012, respectively.

coefficient of R^2 and root mean square error. Both tests revealed that the method has high level of prediction accuracy.

Since soil samples were only collected from maize or non-maize cereal crops together with the fact that some samples got spoiled before they were analyzed (Matsumoto & Yamano, 2009), in 2003 soil samples are available only for 559 households. In 2012 we were able to get the samples from 741 households.[37] The cleaning of data resulted to a balanced panel of 409 households from 77 communities. Thus, attrition related to soil sampled households is about 27%.[38]

Apart from RePEAT data, I also use agroclimatology data namely; rainfall, temperature, and wind from National Aeronautics and Space Administration-Prediction of Worldwide Energy Resources (NASA-POWER). NASA collects solar and agroclimatology data by using satellite systems. These satellites and modeled based products are believed to be accurate enough to provide reliable solar and meteorological resource data over regions where surface measurements are either rare or non-existence (Stackhouse et al., 2015). Among others, NASA's archive reports daily averaged air temperature (degrees C) at 2 meter above the earth surface, daily wind speed at 10 meter (m/s) above the earth surface, and average precipitation (mm/day). By specifying the Geographical Positioning System

[37]Responses from recall back question on soil parcel identification asked in the survey of 2012 suggest that soil samples were collected from 763 households in 2003 and 841 households in 2012. The fact that we observe few households with soil samples in the data is evidence that many soil samples got spoiled during the process.
[38]As it is shown in Table 3.A1, when I treat households with missing values of soil samples as attrite cases, the attrition is also not random. As a robustness check, I also weighted the estimations by attrition weights estimated from this type of attrition. The results (not reported) remained unaffected.

(GPS) coordinates one can download the data. In the RePEAT surveys community-level latitudes and longitudes were captured during the community-level surveys. I used these GPS coordinates to merge the NASA data with the RePEAT data. Since NASA data is recorded on daily basis, before merging it with the RePEAT data I generated annual variables for five consecutive years (the survey year and four years prior the survey). Subsequently, I calculated five year average for each of the agroclimatology variables. It is these averages that I use in the analysis.

3.3.2 Soil quality index

The soil data contain five soil macro-nutrient variables i.e., carbon, nitrogen, phosphorus, potassium, and calcium; and one chemical property−soil pH (henceforth, soil variables). Of these soil variables, none can in isolation provide a good picture of soil quality. I therefore, use all of them to create a soil quality index by using principal component analysis (PCA) technique. This technique extracts a linear combination of all the variables which best describes and transform them into one index (Sena et al., 2002; Gray, 2011). It also determines weights intrinsically and assigns the weights to each indicator by the relative importance of that factor. This allows interpretation of better summarized information. The first principal component captures the greatest variation among the set of variables. It is this first principal component that serves as the index.[39]

[39]Outliers may affect the index by pulling down (up) correlation coefficients of one of the set of variables (Mishra, 2007). Except for soil pH which is normally distributed, the rest of the variables were transformed to logarithms. It is these transformed variables that I use to construct the index.

Following Filmer & Pritchett (2001) and Gray (2011), I construct the soil quality index as follows:[40]

$$SQI_{it} = \sum_{j=1}^{6} G_j \left[\frac{x_{itj}-x_j}{sd_j}\right] \tag{3.1}$$

where SQI_{it} is the soil quality index of farmland of household i in year t, G_j is the weight of each of the soil macro nutrient/characteristics in the PCA model, and x_{itj} is the soil variable of the farm land of household i in year t. x_j and sd_j are the mean and standard deviation of variable j, respectively. To check the robustness of the results, I also construct other two indices: (i) by using only five soil variables except soil pH, (ii) by using all six soil variables but soil pH enters as a dummy variable i.e., 1 if neutral (soil pH >=6.6 & soil pH<=7.3), and 0 otherwise.[41]

3.3.3 Agricultural intensification index

I also use the PCA to measure farmers' degrees of agricultural intensification. I focus only on maize farming intensification. Maize is one of the crops grown by majority of the

[40]The soil quality index is likely to be nonlinear. However, it is difficult to know the optimal level since optimal level is not only site specific but also crop specific (Ussiri et al., 1998; Be´langer et al., 2000; Srivastava et al., 2006; Musinguzi et al., 2013). Thus it is not possible to come up with a single minimum or maximum threshold value of the soil quality that can be "a one size fits all". Nevertheless, existing literature sheds some light. For example, regardless of crop type the desired level of soil carbon content is about 2% (Loveland & Webb, 2003; Musinguzi et al., 2013). With regards to some specific crops, the optimal phosphorous amount for corn is considered to be 13 mg/kg (Mallarino & Blackmer, 1992) while that of soil carbon content for maize crop was found to between 1.9% and 2.204% in Uganda (Musinguzi et al., 2016). The optimal level for soil pH on maize crop is believed to be between 6.0-7.0 whereas for beans it is between 6.0 and 6.5. Even though it is difficult to establish the optimal soil quality level, anecdote evidences suggest given the rate of soil degradation and low fertilize usage in SSA, soil fertility is far less than the optimal.

[41] It should be pointed out that except for soil pH, for the remaining five soil variables generally more is better. Note also that soil pH below 6.6 is acidity and above 7.3 is alkalinity (both not suitable for most of crops). Therefore, an index in which pH enters as continuous could wrongly reflect better soil quality.

farmers in Uganda.[42] In addition, it is mainly from maize parcels where soil samples were collected. To create the agricultural intensification index, I use three intensive farming practices-related variables: adoption of improved maize seeds, the amount of chemical fertilizer applied, and the amount of manure applied per hectare of the land cultivated.[43] The index is constructed at parcel-level and can be depicted as follows:

$$AI_{pist} = \sum_{n=1}^{3} F_n \left[\frac{x_{pistn} - x_n}{sd_n}\right] \qquad (3.2)$$

where AI_{pist} is the agricultural intensification of parcel p of household i in season s in year t. F_n is the weight of each of the three intensive farming practiced-related variables used to construct the index, and x_{pistn} is the value of the variable n of household i on parcel p in season s in year t. x_n and sd_n are the mean and standard deviation of variable n, respectively.

3.3.4 Descriptive Statistics

Table 3.1 shows the distribution of soil sampled households. Table 3.2 reports the summary statistics of some key variables.[44] As the table shows, nitrogen and soil pH decreased

[42] 76% and 85% of the survey households produced maize in 2003 and in 2012, respectively.

[43] I also create another intensification index by using only two variables that are more linked to soil i.e. the quantity of chemical fertilizer applied, and the quantity of manure applied per hectare of the land cultivated.

[44]Note that while some of the soil nutrients improved over time, the overall soil quality depleted over time. However, it is worth noting that it may be difficult to compare the absolute value of soil indictors from different year samples because the values were obtained by calibration and was done year by year separately. That's why the trends of some soil variables as shown in Table 3.2 are contrary to our expectations. Nonetheless, in regression this is controlled for by year fixed effects. Table 3.A2 in the appendix shows the percentage of soil samples below the required threshold for each soil nutrient year by year.

significantly from 0.22 to 0.17 and 6.6 to 6.2, respectively between 2003 and 2012. On the other hand, phosphorus, potassium and calcium increased, but carbon content almost remained stable. The soil quality index decreased from 0.069 in 2003 to -0.069 in 2012. It is a bit surprising to note During the same period, population density (persons per square kilometer) increased by 11 percent from 447.4 in 2003 to 496.5 in 2012. As expected, owned land per capita decreased from 0.25 ha in 2003 to 0.16 ha in 2012. Similarly, land-labor ratio (household own land divide by the number of household members of working age, i.e., age 15 to 64) declined from 0.50 to 0.49. The increase in population density on one hand, and the decrease in owned land per capita and land-labor ratio on the other hand, suggest that population pressure on land increased during the period.

Table 3.3 presents the pairwise correlation between soil quality variables and key determinants. In column 1, all our six soil variables are strongly positively related with soil quality index. Columns 2 through 7 show that except soil pH, all other soil variables are strongly correlated to each other. As expected, population density is strongly and negatively correlated with soil quality index and with most of other soil variables. Similarly, although not statistically significant, inverse of owned land per capita is negatively related with all six soil variables. Table 3.4 shows the pairwise correlations between changes in population pressure variables, and changes in soil variables. From Table 3.4, a strong positive correlation between changes in soil macro-nutrients and change in soil quality index is observed (column 1). With regards to population pressure and soil variables, Table 3.4

depicts a weak relationship between change in population density and soil quality on one hand, and most of the soil macro-nutrients on the other hand.

Table 3.5 shows the factor loadings of the individual soil variables. The factor loadings are correlation between explanatory variables and the factor. As the table shows, the loadings increase with the levels of carbon, nitrogen, phosphorus, potassium, calcium, and soil pH in both survey periods. This implies that each of our soil variables is positively associated with soil quality index. The factor loadings for input use variables are shown in Table 3.6. The loadings increase with the quantity of chemical fertilizer, amount of manure used per hectare, and adoption of improved maize seeds, implying that these variables are positively correlated with agricultural intensification index. The intensification index has increased from -0.08 in 2003 to 0.08 in 2012 suggesting that agricultural intensification has improved. Overall, from the descriptive statistics it appears that soil quality is deteriorating, but at the same time agricultural intensification is improving. Such intuition provides a basis to perform rigorous analysis in later sections to examine the effect of population pressure on soil quality and agricultural intensification.

3.4 Estimation strategies

Examining the drivers of the soil quality changes can be empirically challenging since measuring changes in soil quality requires a study over a long time horizon. This is because most soil properties are shaped or accumulated after a long period of time (Ekbom, 2008). Fortunately, however, this study use a panel data set that span for 10 year-period. This time interval is long enough to analyze some soil quality dynamics.

Building on soil formation literature in soil science (Jenny, 1994), an ideal structural equation to estimate the drivers of changes in soil quality or individual properties of the soil can be explained by the following set of variables:

$$SQ_{ijrt} = f(\boldsymbol{H}_{it,}\, \boldsymbol{I}_{it}, \boldsymbol{Cl}_{jt,} \boldsymbol{O}_{rt}, T_t, P_i, \boldsymbol{Pop}_{jt,} \boldsymbol{X}_{ijrt}) \qquad (3.3)$$

where SQ_{ijrt} is soil quality or a vector of soil individual properties, $\boldsymbol{H}_{it}$ is a vector of household characteristics, $\boldsymbol{I}_{it}$ is a set of soil conservation variables including application of fertilizers, $\boldsymbol{Cl}_{jt}$ is a vector representing climate-related variables**,** $\boldsymbol{O}_{rt}$ stands for organisms (biota), T_t is time, P_i is parental material, $\boldsymbol{Pop}_{jt}$ is population pressure, $\boldsymbol{X}_{ijrt}$ is a set of other controls. Since we are using panel data, time-invariant factors such as P_i will be absorbed by household fixed effects. Population pressure on farmlands can affect soil quality directly through more frequent and intensive use of farmlands hence soil degradation. It can also indirectly affect soil quality by inducing smallholder farmers to change their behavior and use more fertilizers to increase land productivity. I therefore estimate the following two reduced form equations of the above structural equation.

$$SQ_{ijrt} = h(\boldsymbol{H}_{\boldsymbol{it}},\, \boldsymbol{Pop}_{jt,} \boldsymbol{Cl}_{jt}, \boldsymbol{O}_{rt}, \boldsymbol{X}_{ijrt}) \qquad (3.4)$$

$$I_{ijrt} = g(\boldsymbol{H}_{\boldsymbol{it}},\, \boldsymbol{Pop}_{jt,}\, \boldsymbol{Cl}_{jt}, \boldsymbol{X}_{ijrt}) \qquad (3.5)$$

The first reduced form equation (3.4) estimates the impact of population pressure on soil quality and soil macro-nutrients. In the second reduced form equation (3.5) I regress the endogenous variables i.e., fertilizer use variables on population pressure. In all estimations I use fixed effects model to remove the effects of unobserved time-invariant household or parcel specific characteristics that may bias our estimates.

3.4.1 The impact of population pressure on soil quality

The first reduced form of equation in (3.3) above is estimated by using the following model.

$$SQ_{ijrt} = \beta_0 + \beta_1 Lsize_{it} + \beta_2 lnPop_{jt} + \beta_3 H_{it} + \beta_4 V_{jt} + \gamma_{rt} + \alpha_i + \varepsilon_{ijrt} \qquad (3.6)$$

where i, j, r, t denotes household, community, region, and year of survey, respectively. SQ_{ijrt} is the outcome variable of interest either each of the soil macro-nutrients or the soil quality index.[45] $Lsize_{it}$ is the inverse of per capita owned land (family size divide by total land owned by the household).[46] $lnPop_{jt}$ is log of community-level population density. H_{it} is a vector of household specific controls namely: a dummy equal to 1 if female headed household, age of household head, years of schooling of head of the household, number of male adults and number of female adults (18 years and above), average years of schooling of male adults, average years of schooling of female adults, log of asset value, log of livestock value, and amount of land used other than own land−rented-in land.[47] V_{jt} is a set of observable community characteristics such as rainfall, temperature, and wind. γ_{rt} is

[45] I include all households that have soil data in both rounds regardless of whether the soil samples were taken from the same parcel or not. The results are robust to dropping the households whose soil parcels could not be matched between the two rounds.

[46] Households can adjust land-labor ratio (inverse of owned land per capita) by migration and occupation choice based on population pressure. For robustness check, I ran the regressions without the term of inverse of owned land per capita and found that the coefficient estimates of the other variables are more or less similar to those estimated with the term. To economize the space the results are not shown.

[47] Controlling for this variable is important because if land rental markets are functioning and opportunities for renting land are there, land-rich households may rent-out part of their lands to land-poor households, thus enabling the later to reduce their land constraints. In Uganda, Deininger & Mpuga (2009) found that land markets transfer land to more efficient and land-poor or landless households.

expected to capture region-year specific unobservable characteristics such as those in $\boldsymbol{O}_{rt}$ which would affect soil quality as well as population pressure. α_i is included to remove the effects of time-invariant household or parcel characteristics such as soil type, parental material, elevation, and soil management ability that may bias our estimates. ε_{ijdrt} is the error term that may be heteroskedastic and correlated within a community. To account for intracommunity correlation I use robust standard errors clustered at the community level (Angrist & Pischke, 2009 chapter 8; Cameron & Miller, 2015 p. 14). Although I use fixed effects, one might suspect that the coefficient of population density is polluted by endogeneity problem arising from reverse causality. Indeed, it might be the case that it is not population density that is affecting soil quality but rather it is soil quality that is affecting population density since people may tend to settle in areas with fertile soils. However, reverse causality is not likely to be a serious issue because the opportunity to move is already limited since areas with better soils have already been occupied.[48] Nevertheless, the results should be cautiously interpreted.

[48] During the 2012 RePEAT survey LC1s were asked to list three main reasons that attracted migrants to the LC1", and three main causes for migrating out of the LC1. Most cited reasons for the former were: land shortage in homeland, soil fertility in the destination, seeking employment in the destination, insecurity in homeland, and eradication of diseases in the destination. For the later, the cited causes were: land shortage, seeking employment in the destination, returning to homeland, soil exhaustion, insecurity, and resettlement scheme by government. Although soil quality appeared to be one of the reasons, when asked on "year when it happened"; the responses on soil quality as a factor were in the range of 1930 to 1998; while on shortage of land ranged from 1930 to 2000; and on land availability ranged from 1950 to 1995.This suggests that in Uganda soil-related factors are currently not the main drivers of rural to rural migration.

3.4.2 Land ownership rights and soil quality

To examine whether soil quality differs by land ownership rights across households with private land rights *vs*. those with communal rights, we restrict the analysis to a subsample for which we managed to match the parcels from which soils were collected.[49] We then estimate the following equation, which is a modified version of equation (3.6).

$$SQ_{pijrt} = \pi_0 + \pi_1 Lsize + \pi_2 \ln Pop_{jt} + \pi_3 \Pr_{pit} + \pi_4 H_{it} + \pi_5 V_{jt} + \gamma_{rt} + \alpha_i + \zeta_{pijrt} \quad (3.7)$$

In equation (3.7) our parameter of interest is π_3. Pr_{pit} is a time-variant private land ownership dummy equal to 1 if the parcel is individually-owned and 0 if it is communally-owned. As in Mwesigye, Matsumoto, & Otsuka (2017), I define a parcel as individually or privately-owned if the household can sell or give it away without seeking approval from extended family members, clan, or local authority.[50] Else, it is communally-owned. Other variables are as defined previously. Although I include many relevant controls and use household-parcel fixed effects to account for unobserved time-invariant household or parcel characteristics, admittedly I cannot rule out the possibility that land rights status is endogenous. For example, it may be the case that households with fertile lands have more incentive to demand private land rights so as to protect their fertile lands. To partially address this concern, in alternative specification I use a time-invariant (P_{pi}) private land

[49] During the second round of soil samples collection, a recall back question was asked to identify the parcel from which soil samples were taken during the 2003 survey. In addition, the 2012 survey identifies the parcel from which the soil samples were taken. This information allows us to match the soil sample parcels. However, there was a lot of missing information on parcel identification in 2003. Moreover, for some few households soil parcels in 2003 were different from those of 2012. In the subsample analysis, all these households are excluded.

[50] This is not private in its strict meaning but rather it is more of perception of whether the household can sell its parcel or give it away without a need to consult the above mentioned parties.

rights dummy. In other words, I exclude from the analysis households that changed their land rights status either from privately-owned to communally-owned or vice versa.[51] To estimate this time-invariant variable, I interact it with year dummies (Wooldridge, 2010 p.170). If its coefficient turns out to be significant, it is an indication that soil quality of privately-owned parcels has increased over time. It may also suggest that the gap between privately-owned land and communally-owned land has increased over time.

3.4.3 Impact of population pressure on agricultural intensification

As pointed out earlier, population pressure may also affect soil quality indirectly through its impact on input use (agricultural intensification). In this section I perform another reduced form analysis of equation (3.3). Following the literature, I estimate the impact of population pressure on input use by using four variants of intensification: quantity of manure used per hectare of land cultivated; quantity of chemical fertilizer used per hectare of land cultivated; a dummy variable equal to 1 if used improved maize seeds; and agricultural intensification index constructed as a linear combination of the first three variables. Formally, I estimate the following model.

$$AI_{pijrt} = \alpha_0 + \alpha_1 Lsize_{it} + \alpha_2 lnPop_{jt} + \alpha_3 FS_{pit} + \alpha_4 H_{it} + \alpha_5 V_{jt} + \gamma_{rt} + \xi_i + \mu_{pijrt} \quad (3.8)$$

[51] However, the omission of those households whose land ownership status changed may not fully address the possible endogeneity issue because the resulting sample is selected based on the endogenous variable. The results therefore should be cautiously interpreted.

where AI_{pijrt} denotes four variants of intensification: quantity of manure, quantity of chemical fertilizer per hectare of land cultivated, a dummy variable equal to 1 for adoption of improved maize seeds, and the agricultural intensification index. $Lsize_{it}$ and $lnPop_{jt}$ are as defined earlier. FS_{pit} denotes farm size in hectare. H_{it} is a set of household characteristics defined earlier. V_{jt} is a vector of observable community-level variables. The region-year fixed effects, $\gamma_{rt,}$ are controlled for by including a set of dummy variables for year of survey and the interactions between years and regions. These are expected to mitigate the possible estimation biases due to unobservables possibly affecting both the outcome and explanatory variables of interest. ξ_i is the fixed effects that controls for unobserved time-invariant household or parcel specific characteristics such as soil type, farm management ability, and farmer's risk preferences that may affect our estimation results. I also include a dummy variable to control for seasons when they are in regression analysis. μ_{pijrt} is the error term that may be heteroskedastic and correlated within a community, I therefore use robust standard errors clustered at the community.

The identifying assumption is that unobservables that might simultaneously affect the outcome variable and the explanatory variables of interest are time-invariant, thus will be successfully cancelled out by fixed effects. One may however worry about omitted variable bias if the unobservable factors are time-variant. Such factors include; price of inputs, institutional factors like policies on subsidization of inputs or extension services. All these may be correlated with both population density and adoption of inputs. Failure to control for such factors may lead to biased estimates. In Uganda the input market is at infant stage (Matsumoto & Yamano, 2009), thus I do not have information on the price of inputs. Nonetheless, year dummies and region by time trends are included in the regression. Indeed, region by time trends should mitigate the omitted variable bias problem since institutional factors such as policies on subsidization of agricultural inputs or extension services are to a large extent countrywide or regionwide.

3.4.4 Mechanisms: Why private land rights improve soil quality?

Earlier, I argued that private land rights may improve soil quality by incentivizing farmers to invest in land improvement and soil conservation. To understand why private ownership of land improves soil quality, it is necessary to examine the effect of individualized land rights on agricultural intensification as well. This is done by estimating the following model.

$$AI_{pijrt} = \mu_0 + \mu_1 Lsize_{it} + \mu_2 \ln Pop_{jt} + \mu_3 \Pr_{pit} + \mu_4 FS_{pit} + \mu_5 H_{it} + \mu_6 V_{jt} + \gamma_{rt} + \xi_i + \eta_{pijrt} \quad (3.9)$$

The outcome variable (AI_{pijrt}) takes three variants: quantity of manure applied (kg/ha), amount of chemical fertilizer used (kg/ha), and agricultural intensification index created by using these two variables. Our variable of interest is Pr_{pit}−a dummy which takes a value of one if a parcel is privately-owned and zero if communally-owned. In equation (3.9), I include a full set of controls as in (3.8).

3.4.5. Does application of fertilizers improve soil quality?

So far I have argued that population pressure may indirectly affect soil quality positively by inducing agricultural intensification. It is important to show whether intensification actually improves the soil quality. To do so, I examine the relationship between fertilizer variables and soil quality by estimating the structural equation.[52] I also examine the relationship between change in soil variable (quality) and change in fertilizer variables (2003-2012). If the relationship turns out to be positive and significant, it could be an indication that application of fertilizers improves the soil quality. To examine the later, I estimate the following model.

$$ChangeSQ_{ijr} = \alpha_0 + \alpha_1 ChangeAI_i + \alpha_2 Lsize_i + \alpha_3 \ln Pop_j + \alpha_4 H_i + \alpha_5 V_j + \gamma_r + \mu_{ijr} \quad (3.10)$$

Here, $ChangeSQ_{ijr}$ is the change in soil quality. $ChangeAI_i$ is the change in agricultural intensification. γ_r is a set of region dummies. Other controls are as defined earlier except that they are of 2012 wave only.

3.4.6. Current agricultural intensification and past soil quality

It is also worth noting that current agricultural intensification can be influenced by past soil fertility. Past soil fertility can affect households' current behavior towards the use manure and chemical fertilizers in two different ways. On one hand, if past soil fertility was very good, there may be no need to apply fertilizers in the present period. Conversely, if past soil

[52] The challenge with this approach is that the correlation is likely to be ambiguous. It might be positive−implying that soil fertility is higher on land where application of fertilizers is higher. The correlation is also likely to be negative−suggesting that people use more inputs on degraded soils.

fertility was very low, households may find it not profitable to use fertilizers in such very low fertile soil. To examine this relationship, I regress agricultural intensification variables of 2012−hareafter current agricultural intensification on soil quality in 2003−henceforth past soil quality. I include a full set of control variables (2012) used in equation (3.8) and region dummies.

3.5 Estimation Results

3.5.1 Population pressure and soil quality

Table 3.7 reports the estimation results on the determinants of individual soil variables. In odd-numbered columns I use full sample, whereas in even-numbered columns the sample is restricted to parcels which were exactly matched between the two rounds of survey. All the two variables of interest have the expected negative signs on soil variables. The effect of population density is only significant on phosphorus (columns 5 and 6), potassium (column 7 and 8), and calcium (column 9 and 10). The inverse of per capita owned land is negative and significant only on phosphorus (column 6), calcium (columns 9 and 10), and soil pH (columns 11 and 12).

Table 3.8 reports the estimation results on the impact of population pressure on soil quality. The results show that population density reduces soil quality index. Specifically, the table shows that a percent increase in population density lowers soil quality by 0.29 standard deviations (column 1). As a robustness check, in column 2 I use soil quality index constructed by using only five soil variables (except soil pH); the magnitude of the coefficient and its significance remains largely the same. To further check the robustness of the results and the quality of index, in column 3 I use soil quality index in which five soil variables enter as continuous, while soil pH enters as the dummy. Again, the magnitude and statistical significance of log population density remain unaffected. Surprisingly, in all specifications of the full sample the inverse of owned land per capita enters nonsignificantly. A possible explanation is that within community variation in per capita owned land across households is very small. I also check the robustness of the results by restricting the sample for which we were able to match the soil sample parcels in both surveys (columns 4-6). Two interesting results emerge: the magnitude of the coefficient on log population density increase significantly, and the inverse of owned land per capita turns out to be significant.

3.5.2 Impact of land rights on soil quality

Table 3.9 shows the relationship between private land rights and soil variables. Of the six soil variables, ownership of a private parcel is positively and significantly correlated with only potassium, and calcium. Table 3.10 presents the estimation results of the impact of land rights on soil quality. The preferred specifications are those in which a time-invariant private land rights dummy is interacted with year dummies. The coefficient of the interaction term is positive and significant suggesting that private owned parcels have higher soil quality. The results also suggest that soil quality of privately-owned parcels has increased over time.[53] Regardless of soil quality index used, the magnitude of the coefficient ranges from 0.62 to 0.68 standard deviations.

3.5.3 Population pressure and agricultural intensification

Table 3.11 presents the estimation results on the determinants of agricultural intensification. Neither inverse of owned land per capita nor log of population density appears to have a significant impact on manure use and adoption of improved maize seeds (columns 1 and 3). The log of community population density is positively related with all four measures of agricultural intensification. This relationship, however, is significant on chemical fertilizer and intensification index (column 2 and column 5). Overall, the impact of population on agricultural intensification is very weak. The fact that we find that population pressure decreases soil quality but does not increase agricultural intensification in Uganda is a bit puzzling. Plausible explanations for these results could be: One, may be the decrease in soil quality is yet to become very serious to force people to respond. Two, perhaps there is a certain level of population density beyond which people will start to react. Three, probably it is because markets for agricultural inputs in Uganda are still at infant stage such that even if people in densely populated areas may want to use such inputs, they are unable to do so. It is also possible that people are responding to population pressure by using other means to replenish the soil nutrients such as the use of compost−which this study cannot examine due to data limitation.

[53] The results may also suggest that the gap in soil quality between households with privately-owned lands and those with communally-owned lands has increased during the period this study covers. However, since our "private owned" definition is more of perception of the household rather than the actual private ownership in its strict meaning, and since perception can change, this line of reasoning should be cautiously used.

3.5.4 Mechanisms: Why private ownership of land improves soil quality?

In section 3.5.2, I have shown that parcels that are privately-owned have better soil than the communally-owned ones. To understand why private ownership improves soil quality, I examine the effect of individual ownership on agricultural intensification and report the results in Table 3.12. Surprisingly, there is no significant difference on manure use between parcels that are privately-owned and their counterparts−communally-owned parcels. Theoretically, individualized ownership (secure land rights) is expected to incentivize farmers to invest in land improvement, and more so for long-term investment such as use of manure.[54] A plausible explanation for the insignificance relationship between the nature of land ownership and use of manure is that in our sample very few people used manure−only 3% and 5%, in 2003 and 2012, respectively. Therefore, regardless of the nature of land rights the use of manure is very limited in Uganda. It is interesting however to find that privately-owned parcels are associated with more use of chemical fertilizers than communally-owned ones (column 2). Overall, the intensification is higher on privately-owned parcels compared to communally-owned ones (column 3). Even though the effect of land ownership status on agricultural intensification is not very strong, the fact that we find strong positive association between private land rights and soil quality may suggest that the latter is affecting the former through other soil conservation means such as use of compost and planting of trees. However due to data limitations, I cannot examine these pathways.

[54]Organic fertilizers are considered as long-term investment because they remain effective in the soil for a long period of time.

3.5.5 Does application of fertilizers improve soil quality?

Table 3.13 shows the correlation between fertilizer use and soil quality. Both the use of manure and chemical fertilizer are positively associated with soil quality. However, it is only the later that is statistically significant. Similarly, Table 3.14 reports the correlation between change in fertilizer variables and change in soil quality. There is a positive and significant relationship between change in manure and change in soil quality. Likewise, the change in chemical fertilizer application is positively and significantly correlated with the change in soil quality. These results provide supportive evidence that the use of fertilizers may indeed increase the quality of the soil.

3.5.6 Current agricultural intensification and past soil quality

As pointed earlier agricultural intensification is definitely determined by the past soil fertility since if soil fertility is good, there is no need to invest in land. It is also possible that if past soil fertility is very low, households may find it unprofitable to use fertilizers in such very low fertile soils. Table 3.15 shows the correlation between current agricultural intensification and past soil fertility in Uganda. There is no significant relationship between current application of manure and past soil quality in Uganda (column 1). Interestingly, however, there is a positive and significant correlation between chemical fertilizer application and past soil fertility. This suggests that farmers tend to use chemical fertilizers on fertile land. The relationship is nonlinear since the square term of past soil quality is negatively and significantly associated with chemical fertilizer application. The negative relationship between the square term of past soil quality and application of chemical fertilizers suggests that when the soil is very fertile farmers have no reason to use chemical fertilizers. This is in line with earlier studies that showed that chemical fertilizers are less effective on soil with low soil fertility (Marenya & Barrett, 2009a, 2009b).

3.6 Conclusion and policy implications

By using panel data from rural households in Uganda, this study sought to examine: (i) the impact of population pressure on soil quality; (ii) the impact of land rights on soil quality; and, (iii) the effect of population pressure on agricultural intensification. I find that population density significantly reduces soil quality. The results are robust to alternative specification. However, the impact of inverse of owned land per capita on soil quality is significant only when I use the sub sample. I also find that households whose parcels are privately owned are positively associated with better soil. This suggests that such households have more incentives to invest in soil conservation than their counterparts. I further find very weak evidence regarding the effect of population pressure on agricultural intensification. This suggests that farmers are yet to response towards land scarcity.

The key policy implication of the findings of this study is the need to promote agricultural intensification such that the effect of population pressure on land use intensification outweighs that of population pressure on soil degradation. One way to achieve this is through policy that stimulates investment in soil conservation and land improvement. Implementation of such policy may include provision of subsidies on external inputs such as chemical fertilizers; encouragement of farmers to use locally available inputs such as manure and compost; and provision of technical services supporting appropriate of those inputs. Also important are policies that can eventually improve markets for agricultural products. Such policies are likely to induce farmers to invest in soil improvement. Without such policies, poor farmers are unlikely to invest in soil improvement as long as what they produce from degraded lands can meet their immediate consumption. It is also important to encourage family planning especially among rural households–this will help to control population growth, and in turn reduce population pressure. Lastly, land rights security and individual ownership of land should be promoted because they tend to induce farmers to invest in land improvement.

Although I find that population pressure reduces soil quality, a remaining question is its welfare impact on rural households in Uganda. This an interesting question for future research. It is worth noting though that the welfare impact is ambiguous. It can be negative because if high population pressure reduces soil quality this may translates into low land productivity and crop income. In addition, scarcity of land resulting from population could translate into more liquidity constraints and reduce households' ability to engage in off-farm activities through for example establishing small scale businesses. Conversely, high population may stimulate the rise of opportunities in the off-farm sector. For example, high population can increase demand for goods and services from non-agricultural sector, thereby lead to concentration of industries such as small scale industries. These may in turn create off-farm jobs and increase incomes of the rural households. Moreover, individuals from land starving communities may have more incentive to migrate and seek jobs in urban areas and in turn send remittances to their households.

CHAPTER 4

From Conflict to Conflicts: War-Induced Displacement, Land Conflicts, and Agricultural Productivity in Post-War Northern Uganda

4.1 Introduction

Over the past half century, internal armed conflicts have been among serious problems facing many developing countries (Blattman & Miguel, 2010). In Sub-Saharan African (SSA), many countries including Uganda have been affected by these tragedies. The list of the negative effects of armed conflicts is endless. However, the effects can be summed up in three words: wars devastate life. Massive loss of life due to internal conflicts affects the economy through loss of human capital. Also, during wars physical infrastructures are destructed. Because of their destructive consequences, wars could intensify economic inequality as well as poverty. Indeed, some scholars argue that one of the factors for growing income gap between the richest and poorest countries could be prevalent of the internal wars in many developing countries (Collier et al., 2003). Undeniably, the destructive consequences of wars are enormous and many sectors of the economy are affected. In addition, wars normally result into widespread internally displaced people (IDP).[55] Globally, the number of war-related IDPs has been on an upward trend in the recent past. For example, it increased from 17 million in 1997 to 24.5 million in 2006 to

[55] Internally displaced persons (IDPs) are individuals who have been forced to free their homes because their lives were in danger, but unlike refugees they have not crossed an international border (IDMC, 2007).

40.8 million at the end of 2015 (IDMC, 2007, 2016). Of the 2006 figure, 11.8 million were in Africa; Uganda had the third largest population of IDP during that period as a result of Northern Uganda war (IDMC, 2007). The socio-economic effects associated with war-inducement displacement are many.[56] In Northern Uganda, qualitative studies suggest that land conflicts could be one of such effects (Rugadya, Nsamba-Gayiiya, & Kamusiime, 2008; Mabikke, 2011; Kandel, 2016). Land conflicts are likely to have negative implications on agricultural productivity in the region.

In Uganda and, indeed, in many other countries of SSA, agricultural sector contributes a huge share of the Gross Domestic Product (GDP). In Uganda, it contributes about 26% of GDP and employs almost 80% of the population (Uganda Bureau of Statistics, 2016). Thus, access, ownership and use of land are crucial survival means for many poor Ugandans in rural areas. Despite its importance, land conflicts are among the challenges facing the sector's development in many SSA countries. In many cases, land conflicts are between: neighboring households due to boundary related conflicts; siblings especially after the death of parents; and, pastoralists and agriculturalists. Recently, competition for land between indigenous people and investors both from within and outside the country is also becoming a source of land conflicts. Generally, the root causes of land conflicts vary from one country to another and even within the same country. However, the most cited include; land inequality (Andre & Platteau, 1998; Hidalgo et al., 2010), and high population density

[56] They include disruption of pre-existing social networks (Adelman, 2013), poor labor market participation of formerly displaced individuals (Kondylis, 2010; Lehrer, 2013), disruption of children health (Adelman et al., 2010), and welfare loss (Ibáñez & Vélez, 2008; O'Reilly, 2015).

which in turn translate into increase in value and demand for land (Deininger & Castagnini, 2006; Mwesigye & Matsumoto, 2016). This in turn, leads to competition for land which sometimes translates into illegal occupation, illegal land sales, land grabbing, and eventually land conflicts. Besides, in many rural areas in SSA, customary land tenure systems are no longer well-equipped to resolve land-related conflicts (Fred-Mensah, 1999; Mwesigye & Matsumoto, 2016). Even though in some rural areas formal institutions have been established, many of them are still weak to prevent or timely handle the land conflicts once they occur (Sekeris, 2010). For example, in Kenya it takes about five to ten years once land conflicts are taken to courts before they get resolved (Muyanga & Gitau, 2013).

Land conflicts may have several deleterious effects. As it will be explained later, conflicts over land may affect agricultural productivity in several ways. Moreover, land conflicts may reduce trust and create hatred among the parties involved in the conflicts; thus weakening social cohesion. Indeed, if at large scale, land conflicts may cause violence and civil wars (Andre & Platteau, 1998).

This chapter examines the impact of war-induced displacement on land conflicts in Northern Uganda. Subsequently, it explores the effect of land conflicts on agricultural productivity. I use household survey data from Research on Poverty, Environment and Agricultural Technology (RePEAT). The results indicate that households that were displaced to locations farther away from their residences are more likely to have new land conflicts and more likely to be concerned about land conflicts on their land. Such households also have higher proportion of parcels with new land conflicts and with concerns about land conflicts in the post-displacement period than their counterparts. I also find that land conflicts affect agricultural productivity.

The rest of the chapter is structured as follows. Section 4.2 gives the background of the war. Section 4.3 develops a conceptual framework, testable hypotheses, and discusses the data. Empirical strategy is discussed in section 4.4. Estimation results are discussed in section 4.5. Section 4.6 concludes and provides some policy implications.

4.2 The Northern Uganda War

Over five decades since independence in 1962, Uganda has experienced a number of conflicts and political instabilities. One of the worst internal conflicts it encountered is the war between a rebel group known as Lord's Resistance Army (LRA) and the government of Uganda. The war whose origin is linked to Uganda's history was fought in Northern Uganda and persisted for 20 years (1986-2006).[57] Historically, Uganda's economic power concentrated in the south while political and military power came from the north (Nabudere, 2003). When Mr. Yoweri Museveni became president in 1986, Northerners were marginalized. Joseph Kony mobilized the remnants of several failed rebel groups from Northern Uganda into LRA (Blattman, 2009). Although it is said that the LRA had no clear and negotiable political objective, the group claimed to represent Northerners' grievances (Lehrer, 2013). Moreover, its immediate objective seemed to be the overthrow of Museveni government (Blattman & Annan, 2010; Adelman, 2013; Adelman & Peterman, 2014;

[57] See Figure 4.A1, a map of Uganda showing areas which were affected.

O'Reilly, 2015). In the beginning the rebels thought they could get support from Northerners in order to fight the government, but they didn't. Therefore, the rebels decided to attack their fellow Northerners for supplies of food and forced recruits through abduction. Moreover, actions of murder, rape, mutilation, and theft which aimed at terrorizing the local population were rampant during the war. Surprisingly enough, with all its barbaric actions; the rebel group was believed to have a spiritual component; and Kony, a self-proclaimed prophet claimed to receive instructions for his army directly from God (Global IDP, 2005).[58]

Even though the war started in 1986, prior to mid-1990s violence was at a low scale. For the first time violence escalated between the end of 1995 and early 1996 in the Acholi sub-region (Human Rights Focus, 2002). This was after re-entry of the new LRA units from Sudan into Uganda, partly linked to: LRA's support from Sudanese government in terms of weapons and territory on which to build bases following Uganda's support to Sudanese rebels (Blattman & Annan, 2010); and, presidential election in early 1996 which was won by Museveni. Both energized the rebels and attacks, abductions, and killings escalated dramatically in 1996 (Figure 4.1). As a result, in 1996 a policy of relocating civilians forcefully from their homes in most affected areas to "protected villages" (IDP camps) was announced (Figure 4.A2). The government believed that the strategy was essential not only

[58] "According to explanation from escaped abductees, Kony's military orders seem to be external to him. The orders are given while he is entranced and possessed by spirits from different places. He is reported to speak different tongues: German, Italian, Arabic, Chinese, etc. depending on the nationality of the particular spirit possessing him. His "Holy Spirit" enters him at night during his sleep. In the morning he dictates his prophecy, which secretary writes down, in which he gives military orders including directions, giving accurate maps of the actual locations of the enemy to be attacked as well as future strategies" (Nabudere, 2003 p.53).

to protect civilians from LRA attacks but also clearing the battlefields so as to easily fight the rebels. As a result of this military tactic, many Northerners were displaced.

The region became relatively calm in the late 1990s as the rebels retreated to South Sudan. In March 2002 the government of Uganda was allowed by Sudanese government to undertake military operations in Sudan in order to destroy the LRA camps and rescue the abducted children. However, the operation famously known as operation iron fist was counterproductive since LRA in full swing reacted by moving back into Uganda and began to target the population from inside the country (Nabudere, 2003). Consequently, attacks and mass killings increased abruptly (Figure 4.1). Because of that, the second wave of massive displacement occurred in 2002 through 2003, whereby almost the entire rural population of Acholi sub region (Gulu, Kitgum, and Pader districts) was forced to move into camps (Boas & Hatloy, 2005; Human Rights Watch, 2003). By 2004, there were almost no households to attack in those districts; the rebels decided to move to south in Lira districts and into eastern districts. By the end of 2005, about 1.8 million people were displaced (Bozzoli, Brück, & Muhumuza, 2011), an estimated 500,000 innocent civilians were killed (Armed Conflicts Report, 2009), and many others became victims of rapes, mutilations, and assaults. In 2005 the government of Uganda started to seek peaceful solution to end the war through peace talks. Fortunately, an agreement between the government and the rebels for cessation of the war was reached in 2006. Subsequently, security began to normalize and IDPs started to move back to their original homes.

4.3 Conceptual Framework[59]

4.3.1 Displacement and land conflicts

Like many other rural areas in SSA, most land in Northern Uganda is not surveyed. Popular traditional land demarcation markers include live plants, stones, and other natural borders that can be easily identified by owners of neighbouring fields. Moreover, land use and governance in Northern Uganda have been and continue to be under customary tenure system.[60] Under this system, even though land is owned by individual families, clan, or community, it is administered by customary chiefs who are considered to be the custodians of land. The rules governing land are agreed by the group and land governance power is vested to elders or clan leaders in the community who are chosen basing on age and experiences. Among other roles, the elders are responsible to prevent and settle land conflicts when they occur. Local rules governing land are not written anywhere but are transferred from one generation to another. In most cases owners of land have no official documents proving their ownership. Given this backdrop, incidences of land conflicts in post-war Northern Uganda may be attributed to at least two plausible displacement-related factors namely; duration of displacement and distance displaced. A detailed discussion of each is provided below.

The Northern Uganda war led to massive displacement of people who stayed away from their original homes up to ten years. Due to lengthy of absence following displacement many of land demarcation makers might have disappeared, changed due to

[59] Figure 4.2 provides a summary of the conceptual framework.
[60] In our sample more than 90% of the land is under customary land tenure system.

change in landscape or people just lost memory during resettlement (Adelman & Peterman, 2014). Thus, during resettlement it might have been difficult for some people to trace the boundaries of their land. Other households might have found whole or part of their parcels being occupied by others−extended family members, relatives or neighbours. The length of absence could also make it difficult to monitor the land, thus increase the likelihood of land conflicts. Moreover, land being a key resource for the livelihoods in the region; during resettlement it became very precious and every household needed it for recovery and survival. More still, resettlement was not a one-time process; some households resettled earlier than their neighbours. This variation in timing of resettlement may itself be a source of land conflicts. Indeed, households that returned earlier than their immediate neighbours might have incentives to temper with land boundaries by repositioning demarcation markers to increase their land size.

Regarding distance displaced, it is worth noting that during the war households were displaced to different camps. Others went to camps near their homes, while others were displaced to locations far away from their homes. Specifically, some households were displaced within their Local Council 1s (LC1s), others outside their LC1s but within their sub-counties, and others outside their sub-counties.[61] Distance displaced could increase the likelihood of land conflicts in post-displacement period. One likely transmission mechanism is that distance might have not only reduced households' frequencies of

[61]LC1 and sub-county are respectively, 1stand 2nd smallest administrative unit in Uganda. I use LC1, village, and community interchangeably. On average, a sub-county is made up of 5 LC1s. In our data the average size of the LC1 is 5 kilometer square.

accessing their land during displacement period through regular visiting, but also might have made it difficult to farm the land while living in camps. Indeed, this would attract other people to illegally use or occupy the land, hence causing land conflicts when the rightful owner comes.

Moreover, distance displaced and length of displacement may cause land conflicts through weakening of informal institutions of land governance. Although historically customary tenure system of land governance in Northern Uganda has been well suited to prevent and resolve land conflicts; displacement might have weakened it (Rugadya et al., 2008; Kandel, 2016; Kobusingye, Van Leeuwen, & Van Dijk, 2016). For example, long duration of absence due to displacement might have led to decline in people's understanding of customary law of land governance, especially among the current generation some of whom grew up in the camps. In addition, owing to hardship and change of lifestyle in camps during displacement, elders might have been unable to impart land governance knowledge to the then youth. Relatedly, during displacement clan leaders lived in the same IDP camps with their subjects and struggled to for basic necessities like their subjects. This reduced the respect they used to command. As a result their decisions on various issues including land claims are no longer respected as it was before the war (Kobusingye et al., 2016). Moreover, some elders in the community who were knowledgeable with traditional land governance might have passed away during the long time of absence without transferring the land governance knowledge to the young generation (Rugadya et al., 2008).[62] Besides, in camps clans and families from different backgrounds were mixed together.[63] This might have affected social cohesion and unity of the community, thus leading to weakening of the informal institutions of land governance.

Even though concerns of land conflicts in the post-war are many, lacking are rigorous empirical evidences to validity the claims. The only exception is Adelman & Peterman (2014) who examined the impact of displacement on some land outcomes, including land conflicts. They found a significant impact of distance displaced on the likelihood of land conflicts in the post-war period. By using a completely different data set, the contributions of this study are: i) unlike their sample which was limited to displaced households, mine has displaced and non-displaced households, hence allows also to examine the impact between those that were displaced and those that were not; ii) their paper covered only Pader and Lira districts; I cover a wider geographical area of ten districts;[64] iii) beyond examining the impact of displacement on real land conflicts, I also examine whether displacement experiences have impact on concerns about land conflicts; iv) I explore some transmission mechanisms; v) I investigate whether land conflicts affect agricultural productivity; and, vi) some pathways through which land conflicts may affect productivity.

[62]Indeed, this would also make it harder to solve boundary related-conflicts during resettlement if most elders who knew the land boundaries died over the period without passing on the information.
[63]In Lira and Pader districts for example, on average camps hosted 55 to 100 villages and camp population ranged from 3,600 to 40,000, while the average area of the camp was 1.9 km^2 (Adelman, 2013).
[64]Agago, Apac, Pader, Gulu, Kitgum, Kole, Lamwo, Lira, Nwoya, and Oyam. Agago, Kole, Lamwo, and Oyam were respectively established in 2010, 2010, 2009, and 2006. They were sub-divided from Pader, Apac, Kitgum, and Apac, respectively.

4.3.2 Land conflicts and agricultural productivity

The literature on land rights and agricultural productivity nexus underscore the vital role of land tenure security on investment in land. Land rights affect investment in land improvement through three pathways (Besley, 1995; Brasselle et al., 2002; Abdulai et al., 2011). First, secure land rights incentivize landowners to invest due to greater assurance to reap fruits of their investments as nobody can easily seize their lands. Second, well-defined land rights reduce transaction costs and make it easier to convert land into liquid assets through selling or renting. Granted, this easiness increases owner's incentives to invest in land improvement because the benefits of the improvements made on it can be realized at any time (Besley, 1995; Brasselle et al., 2002). Third, with better land rights farmers may use land as collateral to access credit from lenders and use the borrowed funds to invest in land improvement. Empirically, dozens of studies have documented a positive relationship between secure land rights and investment in land improvement on one hand (Besley, 1995; Deininger & Jin, 2006; Deininger, Ali, & Yamano, 2008; Goldstein & Udry, 2008; Abdulai et al., 2011; Deininger et al., 2011), and a positive association between better land rights and agricultural productivity (Goldstein & Udry, 2008; Abdulai et al., 2011; Melesse & Bulte, 2015).[65] However, so far few studies have explicitly examined the impact of land conflicts on agricultural productivity.

In addition to the above three pathways, land conflicts can affect crop production through other ways. For example, when land conflicts are accompanied with physical insecurity, intimidations, and actions of uprooting crops; farmers may be discouraged to

[65] See (Fenske, 2011) for a detailed survey of literature on many other studies on Africa.

supply effort in cultivating and taking care of crops on conflicted plots. Moreover, land use may be prohibited when land conflicts are heard in court. Land conflicts may also affect farmers' portfolio choice of crops. Risk-averse farmers facing land conflicts are more likely to produce low-value seasonal crops instead of high-value perennial crops because of the possibility of losing land in future (Orellano et al., 2015). Land conflicts may also disincentivise farmers to buy and use modern agricultural inputs such as high yield variety (improved) seeds. More still, land conflicts may distort the allocation of resources in the agricultural sector away from the productive use (Hidalgo et al., 2010; De Luca & Sekeris, 2012). For example, when land conflicts are taken to courts, time and financial resources that could have been allocated into productive use in agriculture are wasted in handling cases in courts.

Existing empirical studies, albeit few, seem to provide a scholarly consensus regarding harmful effects of land conflicts on agricultural productivity. For example, the productivity of plots with land conflicts was found to be between 5 and 11 percent lower than that of their counterparts in Uganda (Deininger & Castagnini, 2006). A recent paper by Mwesigye & Matsumoto (2016) that covered all regions of Uganda except the North, found yield to be lower by 22 percent on parcels with land conflicts than their counterparts owned by the same household. In Kenya, Muyanga & Gitau (2013) found that active land disputes reduced land productivity by 13 percent while concerns about future disputes reduced land productivity by about 9 percent. Notwithstanding these evidences, we know of no any empirical study on Northern Uganda, particularly in the post-war period when incidences of land conflicts are reported to be many.

4.3.3 Hypotheses

Deducing from the conceptual framework, I hypothesize that households that were displaced, households that were displaced to locations far away from their homes, and those that spent longer time displaced are more likely to be concerned about land conflicts and more likely to have new land conflicts. I also conjecture that land conflicts have harmful effect on agricultural productivity.

4.3.4 Data and Descriptive statistics

4.3.4.1 Data Source

The main source of data used by this study is agricultural household based survey conducted in Uganda as part of the Research on Poverty, Environment, and Agricultural Technology (RePEAT) project. The RePEAT surveys are detailed with geo-referenced household-and community-level information. The surveys were conducted by the National Graduate Institute for Policy Studies (GRIPS). So far we have five waves since 2003. Due to insecurity reasons Northern Uganda was not covered in the first four waves. It was covered in the fifth wave conducted in 2015, whereby 15 households were randomly selected from 23 LC1s to make a total of 345 households. Like earlier surveys, the 2015 survey covers a wide array of information at household-and community-level. Key information includes; demographic, crop production, asset ownership, and land issues, among others. On Northern Uganda, the survey also has displacement-related information. I also use rainfall and temperature data sourced from National Aeronautics and Space Administration (NASA).

4.3.4.2 Descriptive Statistics

Table 4.1 shows the distribution of sampled households used in this study. As it depicts, 60 percent of sampled households was displaced. However, there is substantial variation across districts. For example, in Agago and Kole all sampled households were displaced, whereas in Apac only 1.7 percent was displaced. Overall and consistent with our story in section 4.2, Acholi sub region suffered more relative to Lango sub region. Columns 2-5 and columns 6-9 of Table 4.2 show parcel characteristics by concern about land conflicts and by new land conflicts, respectively. The average length of parcel ownership is 18 years for parcels with concern about conflicts and 14 years for those without. 88 percent of parcels with concern about land conflicts were acquired as gift or inherited (column 2), while 67 percent of parcels without concern about land conflicts were acquired through the same means (column 1). On average, 84 percent of parcels with concerns about land conflicts have had land conflicts. With regards to new land conflicts status, on average parcels that have new land conflicts are larger than those without−with an average size of 2.1 hectares and 1 hectare, respectively. 88 percent of the parcels with new land conflicts were acquired through inheritance, while for never disputed parcels, 66 percent of them were obtained by inheriting. Lastly, households have concerns about land conflicts on 95 percent of the parcels which have had land conflicts compared to the never disputed parcels; the difference is statistically significant.

Table 4.3 shows household characteristics. Of the 344 households, 25 percent are female headed. The average age of household head is 45 years while average years of schooling are 6. On average each household has 6 members and the average landholding is 3 hectares. Of all the households that were displaced; 46 percent remained within their LC1s, 36 percent were displaced outside their LC1s but within their sub-counties, and 18 percent were displaced outside their sub-counties. On average households were displaced in 2002− the second wave of mass displacement as explained in section 4.2. Average duration of displacement is 5 years, and on overage people returned back to their original homes in 2007; few months after cessation of war in 2006.

Table 4.4 presents household-and community-level summary statistics by displacement status. As it shows, years of schooling of heads, and years of schooling of adult members are significantly lower in the displaced than non-displaced households. Of the 205 households that were displaced, 88 percent returned to their pre-displacement homes after LRA insurgency.[66] Surprisingly, the difference in land conflicts between

[66]A descriptive analysis of parcel characteristics owned by new settlers' (results not shown) suggest that their parcels in their post-displacement homes were acquired before 2006−on average length of parcel ownership is 15 years, well-above total post-displacement years. Similarly, Adelman & Peterman (2014) found that majority of households that resettled to new locations either moved to land inherited from a parent or grandparent, or to land owned by a new spouse. Moreover, the summary statistics (Table 4.A1 in the appendix) show that original settlers do not differ with new settlers either in terms of old land conflicts experiences nor current land conflicts experiences. This suggests that the two groups are unlikely to have different pre- or post-displacement land conflicts experiences. In terms of displacement experiences, original settlers are more likely to be displaced outside their sub-counties.

households that were displaced and those that were not is not statistically significant. Interestingly, communities that used to have land conflicts before displacement were less affected by displacement and vice-versa. Table 4.5 shows the correlation between land conflicts and displacement variables. Being displaced outside the sub-counties is positive and statistically significantly correlated with land conflicts. Duration of displacement does not appear to be significantly correlated with land conflicts. Overall, the descriptive statistics suggest that distance displaced is likely to be influencing land conflicts in the region. To confirm this, a rigorous analysis is performed in the subsequent section.

4.4 Estimation Strategy

In this section, I estimate three main equations: the impact of displacement on land conflicts, the transmission mechanisms, and the effect of land conflicts on agricultural productivity.

4.4.1 The impact of displacement on land conflicts

Our main question is whether households that were displaced, displaced to locations far away from their homes, or those that spent longer time in displacement are more likely to have land conflicts in the post-war period. In its basic form this is answered by estimating the following empirical model. [67]

$$LD_{ij} = \alpha + \beta Disp_{ij} + \delta H_{ij} + \varphi V_j + \mathcal{E}_{ij} \tag{4.1}$$

[67] I also perform parcel-level analysis in which I include a bunch of parcel characteristics as covariates.

$i,$ and j stands for household, and village, respectively. LD_{ij} takes four variants: a dummy indicating whether the household is concerned about land conflicts over its land, a dummy denoting whether has faced new land conflicts since 2006, proportion of parcels with concerns about land conflicts, and proportion of parcels with new land conflicts.[68] This year is used as a cut-off year in defining new land conflicts because it is the year when resettlement began−people started to go back to their original homes.[69] Any land conflicts that started prior 2006 is regarded as old conflict.[70] $Disp_{ij}$ is a vector of three variables: whether the household was displaced due to LRA war; distance displaced (proxied by displacement location dummies i.e., whether displaced within the LC1−our reference group, whether displaced outside the LC1 but within the sub-county, or whether displaced outside the sub-county); and, time spent displaced. H_{ij} is a set of observable household-level variables such as gender, age, and years of schooling of household head. Others are: family size, log of value of assets, log of owned land, number of parcels, average walking distance in minutes from the household's residence to parcels, and dummy indicating whether the household is a new settler after LRA insurgency. V_j is a set of village characteristics such as population density, log of distance to the nearest district town, whether the road to the nearest district town is tarmac or the road is all season dirt road, evaluated against seasonal

[68]Proportion of parcels with new (concerns about) land conflicts is a ratio of number of parcels that have been contested since 2006 (number of parcels with concerns about land conflicts) to total parcels owned by the household.

[69]It is worth noting that for land conflict to occur there should be two parties claiming ownership of the same piece of land. This was likely to happen in 2006 onward between those who were displaced and those who were not, or those who came earlier and those who came later, or those who were displaced far away and those who were not.

[70]Because during displacement some households could come to visit their homes (land) or even to farm, it is possible that land conflicts that started between 1996 and 2005 were caused by displacement due to LRA war. For robustness check, I redefine the variable to capture this possibility.

dirt road as a base group. In addition, V_j contains altitude, rainfall in mm (10-year average), temperature °c (10-year average), log of number of households who moved out of the village permanently during the past ten years, log of average land size, and whether the village had experienced land conflicts prior 2006. All controls in V_j are likely to influence the demand for land thereby trigger land conflicts especially if institutions for land governance are weak. $\mathcal{E}_{ij}$ is an error term that may be heteroskedastic and correlated within the village, therefore, I use robust standard errors clustered at village-level.

By using equation (4.1), I first estimate the impact of being displaced on land conflicts, and then examine the impact of distance displaced and duration of displacement on land conflicts among the subsample that was displaced. I use Linear Probability Model (LPM) for binary dependent variables. I choose LPM over other models such as probit because of its easiness to estimate and interpret the estimated marginal effects. Moreover, there is no need for strict assumptions on the distribution form of the error term when using LPM. However, the limitation of LPM is that the fitted value of dependent variable may not necessarily be in the interval [0, 1]. I examine whether this is affecting our estimates by using probit model (the results are similar, but not reported to economize space). For the two continuous outcome variables,[71] I use linear models. For comparison purpose, I run regressions with and without village fixed effects. The former allows isolating the variation

[71]They are observed only for households that have faced new (have concerns about) land conflicts, thus are censored at zero. Tobit model is normally used for such dependent variables. However, I do not use it due to its strict assumption (normality of the error term). Moreover, the output from nonlinear models such as Tobit must be converted into marginal effects in order to have meaningful interpretation of the results. It has been shown that linear model estimates and marginal effects of nonlinear models like Tobit are quite similar (Angrist & Pischke, 2009 p.103-107). I therefore report and discuss the estimation results from linear models.

in displacement experiences across neighbours within the same village, while the latter shows across village variation.

4.4.1.1 Endogeneity concerns

The identifying assumption is that displacement status and distance displaced are random conditional on observable characteristics. If displacement indicators are not orthogonal to the error term, the estimated coefficients will be biased. For example, if households whose heads were more risk-averse were more likely to be displaced or were displaced far away from their original homes, or spent longer duration of displacement; OLS estimates will be downwardly biased if such households are less likely to face land conflicts. However, in Northern Uganda, this was unlikely. Households were (are) strongly tied to their land because they depend much on it for their livelihoods. Thus, they didn't leave their homes until attacks became local or the government forced them into camps (Adelman, Gilligan, & Lehner, 2010). Therefore, differences in displacement status, timing of displacement, and distance displaced were not caused by differences in risk aversion.

Furthermore, suppose households with less political influence were more likely to be displaced, were displaced to locations far away from their homes, and spent longer time displaced. Then, if such households are more likely to face land conflicts, the coefficients of interest will be upwardly biased due to omitted variable problem. However, as discussed in section 4.2, unlike in other places in which displacement depend on economic or geographical factors; empirical and anecdotes evidences suggest that displacement in Northern Uganda was random (Nabudere, 2003; Lehrer, 2009; Adelman et al., 2010;

Adelman, 2013; Adelman & Peterman, 2014; O'Reilly, 2015). It was caused by two things−attacks and decree by the government. Both were exogenous to households. Regarding the randomness of attacks, in addition to what has been explained in section 4.2, the rebels moved throughout the region in units randomly, attacking, abducting, destroying, stealing, and terrorizing (Lehrer, 2009). When attacks became local and war intensity increased, the government came up with a strategy that forced the people into IDP camps. This was meant to protect civilians and successfully fight the rebels by isolating them from the general population. Whenever this happened, households were given less than 48 hours to leave their homes and relocate into camps; else they would be considered rebel allies and shot or arrested. Thus, there was no self-selection either on whether or when to displace.[72]

With regards to distance displaced, although in principle households could choose the IDP camps and thus had some control over the distance they were displaced, the nature of the war did not give room for that (Adelman & Peterman, 2014). Displacement was rapid and unexpected and thought to be a short-term solution to the LRA war. For that reason, other than proximity of the camp to their homes, no any other camp characteristics were considered. Thus, in most cases people went to the nearest camps (Adelman, 2013; Adelman et al., 2010; Adelman & Peterman, 2014).[73] The descriptive analysis presented in

[72] During interviews by Boas & Hatloy (2005) to IDPs in camps, many interviewees reported that camps were established by order and at times by force. Some of them moved voluntarily when the order was given because they were afraid of the LRA and wanted to be protected. Others refused to go and were moved less voluntarily. Similarly, in the survey we asked the LC1 chairpersons as to whether displacement was an individual choice rather than choice of government forces. Their responses confirmed that it was not an individual choice. Furthermore, they confirmed that once the order to leave was given by government forces, there were no any household that did not follow it.

[73] A concern may still remain−if every household went to a nearest camp, is it possible that they had to go out of the sub-county? The answer is yes. Where to go partly depended on the geographical location of the household within the village, and the availability of nearest camps. If for example there was no any camp within the village, it is possible that the nearest camp was outside the sub-county.

Table 4.A2 in the appendix supports this line of reasoning. There is no significant variation neither in displacement status nor in distance displaced within each of the 23 villages. As the table shows, in most villages either all households in the village were displaced or none was displaced. In few cases, however, majority of the households in the village were displaced and few were not, and vice versa.[74] Regarding distance displaced, at best all displaced households from a particular village were either displaced within the village, or all were displaced outside the village but within the sub-county, or all were displaced outside the sub-county. In other villages some households were displaced within the village and others outside the village but within the sub-county. In some villages some households were displaced outside the village but within the sub-county, or outside the village but within the sub-county and outside the sub-county.[75] In general, there is no any case of overlap. As another suggestive evidence of exogeneity of displacement status and distance displaced, I estimate the model with LC1 fixed effects to examine the correlation between either displacement dummy or displacement to different destinations (distance displaced) and pre-displacement or pre-return household characteristics. I also include post-return

[74]However, in the later scenario the small variation observed within villages is likely to be explained by geographical location of the household in the village rather than self-selection into displacement. In some villages in Northern Uganda households are very scattered such that it is very possible that one part of the village was declared insecure and hence became affected by the government policy of forced displacement while other parts remained relatively habitable hence not affected by the policy. Another plausible explanation for the observed small variation in displacement status is that some camps were established in people's residence. Thus, for the households that happened to live in those areas, their residences became part of the IDP camp. Such households were not displaced in the strict meaning of being displaced because they were already in "protected zones".

[75]As explained in the above subscript, the small variation observed within the village is possibly due to location of the household within the village rather than self-selection. However, even though displacement and distance displaced are arguably random, I admit that where to live i.e. displacement to different locations can be endogenous. For example, some households that had social network outside of sub-county might have left IDP camps when displacement period became longer. Unfortunately, the data do not allow us to examine this possibility.

household characteristics that are unlikely to have changed. The results are reported in Table 4.6. Except for household heads' years of schooling which is found to be negatively related with displacement status,[76] there is no significant correlation between either displacement status or displacement to different locations and other pre-displacement or pre-return household characteristics. Therefore significant variation in households' displacement experiences was not self-determined but rather exogenous.

The only displacement variable that is obviously endogenous is duration of displacement. Although displacement was purely exogenous shock, decision to return back after cessation of the war was voluntary. Admittedly, households that might have perceived to face land conflicts or lost their lands might have hesitated to return early because of perceived difficulty of resettling without land. This is plausible because by the end of 2009 (three years after cessation of the war), only 75 percent of the displaced people had already returned to their original homes; even at the end of 2011 about 30,000 IDPs were still in camps (IDMC, 2014). The opposite is also possible−households that might have foreseen the possibility of their land to be stolen by neighbours might have come home sooner than others. Indeed, endogeneity arising from reverse causality is a genuine concern. To address this issue, I instrument displacement duration with timing of displacement. This instrument is plausible and meets relevance condition and exclusion restriction. The former entails that timing of displacement is strongly correlated with duration of displacement. Indeed,

[76] Over 50% of heads of households are below 44 years of age. The observed negative relationship simply suggests that displacement affected their schooling rather than self-selection into displacement. That's why the significant negative relationship does not appear between years of schooling of heads of households and displacement to different locations.

because resettlement started in 2006, those displaced earlier should have spent longer time. The latter is that timing of displacement is unlikely to directly affect land conflicts except through displacement duration. As argued before, displacement and timing of displacement were triggered either by random attacks by rebels or government order. These were purely exogenous to the household. In fact, it is mainly the latter that forced people to relocate to IDP camps. Moreover, whenever the order was announced households were given few hours to vacate their homes.

4.4.2 Any difference in pre-displacement land conflicts?

In the previous analysis I attribute land conflicts in post-war Northern Uganda to displacement status, longer distance displaced, and length of displacement. In what follows I use two approaches to confirm whether the hypothesized difference in land conflicts among households is truly a result of differences in displacement experiences.

4.4.2.1 Subsample analysis

In this approach, I split the sample into two categories and re-estimate equation (4.1). The first is of households whose LC1s had no land conflicts prior 2006.[77] This category takes 13 out 23 LC1s.[78] Surprisingly, 77% of households are from Acholi sub region suggesting that this area which was more affected by displacement was a land conflicts free zone prior 2006. Therefore, if the results corroborate to those of the previous analysis, we can be more

[77] I also redefine it using prior 2002/2003 (2nd wave of massive displacement), and 1996−when displacement started. The results remain qualitatively similar.

[78] Although there used to be no land conflicts in these LC1s, 12 (92%) of these 13 LC1s have experienced land conflicts in the post-displacement period.

confident in concluding that the results carry a casual interpretation. The second subsample is of households whose LC1s had land conflicts prior 2006. This takes 10 out of 23 LC1s. 90% of the households in this subsample are from Lango sub region−the area which was less affected by displacement used to have land conflicts even before 2006.

4.4.2.2 Falsification test

To further confirm if the observed differences on land conflicts between households are really due to difference in displacement experiences, I perform a falsification test. This intends to check whether there were significant differences in land conflicts prior 2006 between households that later had unfavourable displacement experiences and those that didn't. I estimate a model which is a slight modification of equation (4.1). Outcome variables are: an indicator of whether the household has any old land conflicts (conflicts started before 2006), and proportion of old parcels (parcels acquired before 2006) with old land conflicts. Although the survey did not collect pre-2006 household and village characteristics, the data allows generating some pre-2006 controls. These include; landholding (ha) prior 2006, number of parcels owned prior 2006, average annual rainfall, and average temperature (26 year average: 2005-1979).[79] I also include controls that are unlikely to have changed after displacement such as household head's years of schooling and altitude.[80] I expect no statistically significant difference between households that later faced unfavourable displacement experiences and their counterparts. A concern might be on

[79] I redefined all pre-2006 using pre-1996, and pre-2002/2003 (before 1st, and 2nd wave of massive displacement, respectively), the results remain qualitatively unaffected.
[80]Covariates are less than those in equation (1); I checked and found that dropping equivalent controls from equation (4.1) leaves its estimates qualitatively unaffected.

ability of households to remember and report old land conflicts during the survey. This is not a threat, however for two reasons. One, respondents were encouraged to report all land conflicts they had ever faced. Two, even if they might have forgotten some old conflicts, this should be systematic across households and cannot affect the results.

4.4.3 Mechanisms

The discussion in the conceptual framework suggests that there are at least two plausible channels through which displacement may cause post-displacement land conflicts. First, distance displaced could make it difficult for the displaced households to farm and monitor their lands; thus leaving their lands unmonitored during the whole period of displacement. Therefore, longer duration of displacement and distance displaced could increase the number of years the land was left unmonitored (See Figure 4.3). Second, longer distance displaced and length of displacement could weaken the informal institutions of land governance. I empirically examine these mechanisms in the following subsections.

4.4.3.1 Displacement and years the household could not do farming in its village

To assess this mechanism, I estimate the following equation.

$$Yrsnofarm_{ij} = \gamma + \mu Disp_{ij} + \theta H_{ij} + \emptyset V_j + \epsilon_{ij} \qquad (4.2)$$

Conditional on being displaced due to LRA war, $Yrsnofarm_{ij}$ is number of years the household spent without doing farming in its home village during displacement period. $Disp_{ij}$ takes two variants: distance displaced as defined earlier, and duration of displacement. I include a full set of controls used in equation (4.1).

4.4.3.2 Displacement intensity and weakening of informal institutions of resolving land conflicts

To test the plausibility that displacement intensity might have weakened the informal institutions of land governance and land conflicts resolution, I estimate the following model.

$$IM_{ij} = 1\{\kappa + \sigma DispIntensity_j + \lambda H_{ij} + \psi V_j + \eta_{ij} > 0\} \tag{4.3}$$

Conditional on having faced new land conflicts in the post-war, IM is an indicator of whether the household resorted to informal means such as consulting clan members, elders, and neighbours to resolve the land conflict.[81] $DispIntensity$ is displacement intensity at a village-level. It takes three variants: proportion of households that were displaced, log of average duration of displacement, and proportion of households displaced outside the LC1. I use LPM to estimate equation (4.3).

4.4.4 The impact of land conflicts on agricultural productivity

In this section I examine the effects of land conflicts on productivity by estimating the following model.

$$Y_{pij} = \beta + \rho LD_{pi} + \pi X_{pi} + \omega H_{ij} + \varphi V_j + \vartheta C_c + \gamma S_s + \mu_{pij} \tag{4.4.a}$$

[81] In rural Uganda formal courts are not only costly, but also are still weak to handle land conflicts (Mwesigye & Matsumoto, 2016).

p, i, s, and j denote plot, household, season and community, respectively. Y_{pij} is value of all crops produced in (Ushs/ha).[82] LD_{pi} takes three variants: whether there has been concerned about land conflicts over the plot, whether there has been a land conflict on the plot, and a dummy indicating whether there is pending land conflicts. X_{pi} is a vector of parcel characteristics such as walking distance from household's residence to the parcel, tenancy (owner, or occupant−evaluated against tenant as a base group), rent per hectare of parcel for one cropping season (a proxy for land quality), log of farm size, and mode of acquisition (whether purchased, inherited, or just walked-in−evaluated against rented-in as a reference category). H_{ij}, and V_j are vectors of relevant household-and village-level characteristics, respectively. C_c , and S_s are respectively crop, and season dummies. In V_j I also control for village fixed effects by including village dummies. μ_{pij} is an error term.

A concern in estimating equation (4.4.a) by simple OLS is that land conflicts are potentially endogenous due to omitted variable problem. For example, if households that are more risk averse are less likely to have land conflicts and risk aversion is negatively correlated with yield; our estimates will be upwardly biased. To address this, I create a panel data using the second and first harvest season in 2014 and 2015, respectively.[83] This allows us to use household fixed effects to control for endogeneity of land conflicts arising from unobserved household characteristics that may affect the outcome variable as well as land conflicts. This technique is possible because the data has several households that own

[82] It is measured as a product of crop yield (kg) and the crop price per kg. To reduce the influence of outliers, the variable was winsorized at the 1% and 99% level at both ends of the distribution.
[83]The second crop season is September to December while the first crop season is March to July.

more than one plot and there is variation in land conflicts across plots within the household.[84] I slightly modify equation (4.4.a) and estimate the following model.

$$Y_{pis} = \beta + \rho LD_{pis} + \pi X_{pis} + \vartheta C_{cs} + \xi_{is} + \mu_{pis} \qquad (4.4.b)$$

where ξ_{is} is a vector of season fixed effects, household fixed effects, and their interactions. Other variables are as defined earlier. Since all household-and village-level controls do not change between seasons, they drop from the above specification.

4.4.5 Potential pathways: Land conflicts and household investment behavior.

As argued earlier, land conflicts may discourage farmers to invest in land improvement and in buying and using modern agricultural inputs such as improved (high yield variety) seeds. This is because of uncertainty to reap the fruits of their investments. To relate land conflicts and investment behavior (adoption of improved seeds),[85] I use similar identification strategy of household fixed effects. This allows controlling for unobserved heterogeneity across households with and without land conflicts which may bias the estimates. I estimate the following model.

$$IS_{pis} = 1\{\tau + \phi LD_{pis} + \varpi X_{pis} + \vartheta C_{cs} + \xi_{is} + \eta_{pis} > 0\} \qquad (4.5)$$

[84] Since I attribute land conflicts to displacement experiences; one would expect to find no variation in land conflicts across parcels owned by the same household. The fact that I find variation suggests that some parcels e.g., those which had houses built on were more secure and unlikely to be disputed.

[85] In the data farmers applied chemical fertilizer on less than 1% of cultivated plots; manure was not used at all. Thus, I cannot examine the relationship between land conflicts and use of these inputs. I only examine the relationship between land conflicts and adoption of improved seeds. Since improved seeds are relatively expensive compared to local seeds, farmers may have less incentive to buy and use them on conflicted plots. In Northern Uganda, improved seeds are used on a number of crops such as beans, groundnuts, soybean, maize, sorghum, cassava, sweet potatoes, cotton, tobacco, cabbage, tomato, guava, rice, and sunflower among others.

IS_{pis} is a dummy equal to one if improved seeds were adopted on plot p of household i during cropping season s. ξ_{is} is a vector of season fixed effects, household fixed effects, and their interactions, and η_{pis} is the error term clustered at village level. The remaining variables are as defined before. Although I use household fixed effects, the estimates are likely to be plagued by endogeneity problem arising from unobserved plot characteristics that could be correlated with land conflicts and adoption of improved seeds. For example, if land conflicts are likely to occur on very fertile plots, the coefficient of land conflicts would be biased positively if adoption of improved seeds is positively associated with quality of the plot. To mitigate this, I control for rent per hectare of plot for one cropping season (proxy for land quality).

4. 5 Estimation Results

4.5.1 Displacement and Land Conflicts

Table 4.7 reports the estimation results of the impact of displacement status on land conflicts. Column 1 shows that displacement status does not have any significant effect on the likelihood of concern about land conflicts. Column 2 adds village fixed effects; the magnitude of the coefficient increases and turns out to be significant, albeit weak. This suggests that within the same village, households that were displaced are likely to be concerned about land conflicts by 0.182 percentage points higher than those that were not. Columns 3-8 show that displacement status does not affect other outcome variables.

Overall, there is no significant difference in land conflicts between households that were displaced and those that were not.

Table 4.8 reports the estimation results of the subsample of households that were displaced. The explanatory variables of interest are distance displaced and duration of displacement. Because the latter is endogenous, I instrument it with timing of displacement. For brevity I present and discuss the IV results. Column 9 shows that timing of displacement is statistically significant. It has a negative effect on the endogenous variable. This is consistent with my expectation that those displaced earlier spent longer time in displacement. The instrument also passes weak instrument tests. I do not include village fixed effects in odd-numbered specifications, while even-numbered columns village fixed effects are controlled for. The preferred estimations are those without village fixed effects because there is no much variation in either distance displaced or timing of displacement within the village. Column 1 reveals that households that were displaced outside their sub-counties are likely to be concerned about land conflicts by 23 percentage points higher relative to those that were displaced within their LC1s. With regards to new land conflicts, column 3 reveals that households that were displaced outside their sub-counties have a higher likelihood of facing new land conflicts by 20 percentage points higher than those that were displaced within their LC1s. Similarly, households that were displaced outside their sub-counties have 13.7 % higher proportion of parcels with concerns about land conflicts than those that were displaced within their LC1s (column 5). Such households also have 12.7% higher proportions of parcels that have faced new land conflicts in the post-war period relative to those that were displaced within their LC1s (column 7). Log duration of displacement as instrumented by timing of displacement does not statistically affect any of the outcome variables.

So far, I have defined new land conflicts as any conflicts that started in 2006 or after; it is possible that land conflicts that started between 1996 and 2005 were caused by displacement due to LRA war. For robustness check, I redefined new land conflicts taking into account this possibility. The results reported in Table 4.A3 show that the estimation results remain largely the same. I also performed an analysis similar to that of Table 4.8 but at parcel-level and include a bunch of parcel characteristics. The results portrayed in Table 4.A4 are qualitatively similar to those of household-level analysis.

To further test the robustness of the results, Table 4.9 reports the results of the subsample of households whose LC1s didn't have land conflicts prior 2006. The results are similar to those of full sample in that, land conflicts are not statistically different between households that were displaced and their counterparts. Similarly, with regards to distance displaced; the results corroborate those of the main analysis. I find that households that were displaced outside their LC1s but within their sub-counties are more likely to be concerned about land conflicts by 47 percentage points higher than those that were displaced within their LC1s, while those that were displaced outside their sub-counties are more likely to be concerned about land conflicts by 68 percentage point higher relative to those displaced within their LC1s (column 3). Even after controlling for village fixed effects, I still find that households that were displaced outside their sub-counties are more likely to be concerned about land conflicts by 50% percentage point higher compared to those that were displaced within their LC1s (column 4). I also find that households that were displaced outside their LC1s but within their sub-counties are more likely to have new land conflicts by 48 percentage points higher than those that were displaced within their LC1s, while those that were displaced outside their sub-counties are more likely to have new land conflicts by 68 percentage point higher relative to those displaced within their LC1s (column 7). The results remain more or less the same even with inclusion of village fixed effects−households that were displaced outside their sub-counties are more likely to have new land conflicts by 48 percentage points higher compared those that were displaced within their LC1s (column 8). Furthermore, those that were displaced outside their LC1s but within the sub-counties have 19% higher proportions of parcels with concerns about land conflicts relative to those displaced within their LC1s, and those that were displaced outside their sub-counties have 32% higher proportion of parcels with land conflicts than those that were displaced within their LC1s (column 11). Similarly, households that were displaced outside their LC1s but with their sub-counties have 18% higher proportion of parcels with new land conflicts while those that were displaced outside their sub counties have 33% higher proportion of parcels than those that were displaced within their LC1s (column 15). With inclusion of village fixed effects, I still find that households that were displaced outside their sub counties have 22% higher proportion of parcels with new land conflicts compared to those that were displaced within their LC1s.

Table 4.10 reports the results of the subsample of households whose LC1s used to have land conflicts prior 2006. In this subsample, I only examine the impact of displacement on land conflicts.[86] Interestingly, as column 1 shows, households that were displaced are more likely to be concerned about land conflicts by 23 percentage points higher than those who were not. I do not find any statistically significant effect on other outcome variables.

To further confirm whether land-related conflicts in post-displacement are genuinely due to displacement experiences, Table 4.11 reports the results of falsification exercise. Overall, the results provide further suggestive evidence that no differences in land conflicts existed prior displacement between households that later had unfavourable displacement experiences and their counterparts.

4.5.2 Mechanisms: Years the household could not do farming in its village

As discussed earlier, one likely vehicle of transmission through which displacement may have caused land conflicts is by making it difficult for the households to farm or monitor their land during displacement. I explore the plausibility of this claim by examining whether distance displaced and duration of displacement are positively correlated with the number of years the household spent without doing farming in their home villages during displacement. As Table 4.12 (column 2) shows, on average households that were displaced

[86] It was not possible to examine the impact of distance displaced and duration of displacement on land conflicts due to small sample size.

outside their villages but within their sub counties and those displaced outside their sub counties spent about 1.7 and 2.4 more years, respectively without doing farming in the home villages compared to those that were displaced within their villages. The magnitude of coefficients become even larger when I exclude new settlers in column 4 such that those that were displaced outside their villages but within their sub counties, and those that were displaced outside their sub counties spent 4.4 and 5 more years, respectively without doing farming in their village relative to those displaced within their villages. Also, duration of displacement is significantly and positively associated with number of years the household spent without doing farming in its home village during displacement. A 1 percent increase in displacement duration increases the number of years the household spent without doing farming in its home village by 0.02 years (column 2). The magnitude of the coefficient remains almost the same in column 4 when I exclude the new settler households.

4.5.3 Mechanisms: Weakening of informal means of land conflicts resolution

The second mechanism through which displacement may impact land conflicts in post-war Northern Uganda is by weakening the informal mechanisms of land governance. I explore the plausibility of this reasoning by examining whether households in communities which were more affected by displacement are less likely to resort to informal means of land conflicts resolution if faced land conflicts in the post-war period. The results are reported in Table 4.13. All three alternative measures of displacement intensity have the expected signs. The coefficients on the proportion of households that were displaced are negative and significant. The point estimates indicate that on average a 1 percentage point increase in the number of households that were displaced leads to a decrease in the probability of using informal means to resolve land conflicts in post-war period by 0.19 percentage points. Similarly, a farmer in a village with a high proportion of households that were displaced outside the village is less likely to use informal mechanisms of resolving land conflicts. This is also true for a household in a village whose households on average spent longer time away from their homes during displacement−a 1 percent increase in average duration of displacement reduces the likelihood of using informal mechanisms to resolve land conflicts by 0.0005. Taken together, the inverse relationship between all the three measures of displacement intensity and the probability of using informal means to resolve land conflicts constitute suggestive evidence that displacement intensity might have weakened the informal mechanisms of resolving land conflicts.[87]

4.5.4 Land Conflicts and Crop Yield

I now turn to the effects of land conflicts on agricultural productivity shown in Table 4.14. As the Table depicts land conflicts have negative effects on value of crop yield. Our preferred specifications (columns 4-6) show that plots with land conflicts have lower value of crop yield compared with those without land conflicts. In column 4, value of crop yield from plots with concern about land conflicts are lower by 175,972.6 Ushs/ha compared to

[87]As shown earlier that pre-1996 land conflicts are much higher in Lango area than Acholi area. Because of this it is possible that land institutions in Acholi and Lango region could be different prior-1996−if there were no land conflict in Acholi sub region before the war, perhaps even the informal means may not be there. However, land governance in Northern Uganda (Acholi and Lango sub regions) has historically been through traditional institutions. These informal institutions have been in the past important institutions of disputes resolutions and protectors of tenure security (Rugadya et al., 2008; Mabikke, 2011; Kobusingye, Van Leeuwen, & Van Dijk, 2016). In fact, the fact that Acholi was a land conflict free zone before displacement suggests that its informal institutions before displacement were very strong than those of Lango.

their counterparts operated by the same household. However, this effect is not statistically significant. Similarly, in column 5 plots which have had land conflicts are associated with lower value of crop yield of about 74,678 Ushs/ha compared to conflict-free plots operated by the same household, but the effect is not statistically significant. Unsurprisingly, pending land conflicts are more harmful (column 6). Value of crop yield from plots with pending conflicts are statistically significant lower by 177,532.2 Ushs/ha[88] compared to plots without pending conflicts operated by the same household.

4.5.5 Pathways: Land conflicts and adoption of improved seeds

The results on the relationship between land conflicts and adoption of improved seeds are presented in Table 4.15. The probability of adopting improved seeds is lower on plots with pending conflicts compared to none conflicted plots (column 3). Specifically, the likelihood of adopting improved seeds decreases by 11 percentage points when the plot has pending conflicts compared to when it has no any pending conflict. Neither a mere concerned about land conflicts nor if the plot has had land conflicts significantly affect the adoption of improved seeds.

4.6 Conclusion and Policy Implications

War-induced displacement can have numerous harmful effects on displaced individuals during or post-displacement. The war that plagued Northern Uganda for 20 years led to massive displacement of people. After cessation of the war in 2006, virtually all people

[88] The average exchange rate during the survey period was UGX 2,850 per USD 1(Bank of Uganda, 2015)

have now resettled to their original homes. During resettlement and post-displacement period there have been concerns of land conflicts. Such concerns have been documented by various reports and qualitative studies, but have not been backed up with rigorous empirical research. This chapter aimed at filling this gap. It examined the impact of displacement on land conflicts in Northern Uganda. Subsequently, it explored the effects of land conflicts on value of crop yield.

The study finds that households that were displaced to locations far away from their homes are more likely to have new land conflicts and more likely to be concerned about land conflicts over their lands. They also have higher proportion of parcels with new land conflicts, and with concerns about land conflicts in the post-war period. The findings with are in line with Adelman & Peterman (2014) who use a continuous distance variable. Contrary to expectation, duration of displacement is not significant in explaining the likelihood of land conflicts. Possible explanation is that households that stayed longer in IDP camps happened to be in camps closer to their original homes. Thus, they could monitor or farm their lands while still in camps. Indeed, such households might have less incentive to return immediately after cessation of war until they have prepared good environment including reconstruction of houses in case they were damaged. The first stage regression result appears to support this line of reasoning since displacement duration is found to be negatively associated with distance (Table 4.8 column 9).

Through which channel does the positive effect we find operate? The findings reveal two transmission channels. First, distance displaced reduced the possibility of the farmers to farm or visit (for monitoring purpose) their lands. This increased the number of years the lands ware left unattended which in turn might have attracted neighbours to temper with land boundaries. Moreover, it might have led to confusion of land boundaries upon return since demarcation markers used are natural markers which can change easily as land scape changes. Second, within communities; displacement intensity might have weakened the informal mechanisms of land governance and resolving land conflicts as shown that conditional on facing land conflicts, households in communities that had higher displacement intensity are less likely to use informal means to resolve land conflicts in post-displacement period. Regarding the productivity impact of land conflicts, overall the value of crop yield from plots with land conflicts are lower compared to their counterparts. This suggests that land conflicts affect crop production. Unsurprisingly, the effect is more harmful on pending conflicts. In fact, the results found may be taken as lower bound because the output of conflicts-free plots owned by the same household with some conflicted-plots may be reduced due to time and financial resources that are wasted in trying to resolve disputes−the resource which could have been allocated into agriculture and eventually increase crop productivity. Besides, I only examine the impact of conflicts on accessed plots and hence do not capture the effect on those plots lost due to conflicts.[89]

The findings of this study are of policy relevance not only to Uganda but to other SSA countries. In terms of policy implications, the results on output-reducing impact of land conflicts point out to the urgent need of efficient land conflict containment and

[89]In the data 16% of households reported to have lost land due to conflicts. The amount of land lost is 0.25 to 100 acres.

resolution mechanisms. These could include establishment of formal land governance institutions to complement the existing but slowly weakening informal institutions so as to prevent or in a timely way resolve land conflicts whenever they occur. Also, surveying and registering land in rural areas together with adoption of better land demarcation makers may play a great role in reducing land conflicts.

CHAPTER 5

Conclusions and Policy Implications

Descriptive studies suggest that population pressure on farmland is the major underlying driver of soil degradation in Sub-Saharan Africa. This assertion has theoretical basis under the population pressure hypothesis which postulates that population pressure on farmland leads to soil degradation. Among others, the main mechanism is shrinkage of farmland, which in turn makes fallowing unfeasible. Indeed, this leads to overuse of the same land; eventually translates into soil degradation. On the contrary, the Boserupian hypothesis and its sister theory of Induced innovation argue that population pressure induces farmers to change their farming practices by adopting new farming technologies such as use of manure and chemical fertilizers. Implicitly this should help to replenish the soil nutrients and possibly improve or at least maintain soil fertility. Empirically, recent studies on a number of countries in SSA show that population pressure induces agricultural intensification. More concretely, it leads to more use of manure and chemical fertilizers, amongst others.

Thus, from both theoretical and empirical points of view, population pressure on farmland can have two opposing effects on soil quality. A puzzling question however remains: What is its “net” effect on soil quality in the context of SSA? Sadly, this seemingly important question has not been empirically tackled. The first objective of this study is to fill this void. To examine this question I use Kenya and Uganda. Although the two countries represent what is likely to be the case in other countries of SSA, the choice of Kenya and Uganda is also driven by their uniqueness. Uganda used to be one of the countries with most fertile soils in the tropics but now it is one of the countries in which nutrient depletion is the highest in Africa. Yet, her current fertilizer use intensity is one of the lowest in SSA. Similarly, Kenya’s soils particularly in high-altitude areas used to be very fertile; however, since the past recent decades soil degradation has become a threat. Nevertheless, Kenya’s fertilizer use intensity is relatively better. Thus, the soil quality information from these two countries with possibly different farming practices would enable us to identify the causes of soil degradation and help us derive some sounding policy recommendations.

In addition, theoretically it is believed that secure land rights incentivize individuals to invest in land improvement. This is because with secure land rights individuals are confident that nobody can seize their lands, and thus they would enjoy the benefits of their investment. A number of studies provide empirical evidences regarding positive effect (association) of (between) secure land rights on (and) investment in land improvements be it in terms of use of fertilizers or planting of trees, amongst others. Implicitly, this implies that secure (insecure) land rights should lead to increase (decline) in soil fertility. Surprisingly, however, no any published study known so far that has explicitly examined the nexus between secure land rights and soil quality. The nature of land ownership in Uganda makes it an ideal country for this objective.

Besides concerns for soil degradation, incidences of land conflicts have been increasing in many parts of SSA. Like soil degradation, land conflicts are likely to affect agricultural productivity and rural households' welfare. Thus, the last two main objectives of this study are related to land conflict issues. Although land conflicts are prevalent in many parts of SSA, this study examines land conflicts in Northern Uganda. Specifically, I link land conflicts to Northern Uganda war−the war that plagued the region for about 20 years and led to massive displacement of people from their homes into camps. After staying in camps up to 10 years, during resettlement and post-displacement there have been concerns about land disputes. Such concerns, however, have lacked rigorous empirical evidences. To fill this gap, this study examines whether and how displacement-related experiences have affected land conflicts in post-war period. It also investigates whether and how land conflicts affect agricultural productivity.

A number of noteworthy results emerge from this study. With regards to population pressure and soil quality, I find that population pressure significantly reduces soil quality in both countries. These results are robust to a number of robustness checks. Interestingly, I also find that population pressure induces agricultural intensification in Kenya. More specifically, households that are land constrained as proxied by the inverse of per capita own land use more chemical fertilizer. Moreover, households in densely populated sublocations (another proxy of land scarcity) are likely to adopt improved maize seeds than their counterparts. The impact is more visible on agricultural intensification index (an index created by using three agricultural intensification variables). Indeed, both the inverse of per capita owned land and sublocation population density are positively and significantly associated with agricultural intensification index. The results suggest that Kenyan farmers are aware of the problem and are responding by changing their farming methods to cope with declining soil fertility. In Uganda, population density appears to induce the use of chemical fertilizer, but the inverse of per capita owned land has no impact on the intensification variables. Overall, in Uganda the evidence regarding the effect of population pressure on agricultural intensification is weak.

The results raise some important questions. First, if population pressure does induce agricultural intensification in Kenya; why at the same time it is found to affect soil quality negatively? One of the plausible answers is that the rate at which soil degradation due to population pressure is higher than the rate of agricultural intensification induced by population pressure, suggesting that the net effect is negative. Put differently, the soil nutrients that are replenished are lower than those lost due to population pressure. It is also worth noting that although the study finds positive impact of population pressure on agricultural intensification index, its effect on manure use is not statistically significant. Organic manure is very important in improving organic matter levels of the soil and thus soil fertility.

Another question is‒why farmers' response to declining soil fertility seems to be poor? This is important because any sound policy suggestion needs to take into consideration the reality on the ground. Demand and supply side factors characterizing these countries may shed light on this. Could it be that these inputs are not profitable such that farmers have no incentive to use them? Although this is beyond the scope of this study, empirical studies provide mixed evidences. For example, in Western Kenya when used appropriately (properly timed and right amount) fertilizers are very profitable, but are not when used according to the amount/dosage prescribed by the Ministry of Agriculture (Duflo, Kremer, & Robinson, 2008). This underscores the importance of right information on input usage to farmers. Similar evidences of profitability of fertilizer are documented in others parts of SSA (see for example, Michael, Travis, & Tjernström, 2015; Harou et al., 2017). Other studies like Matsumoto & Yamano (2009) and Liverpool-Tasie et al.,(2017) show that fertilizer is (may be) not profitable in Uganda and Nigeria, respectively. There are also empirical evidences showing that chemical fertilizer are less effective on soils with low carbon content (Marenya & Barrett, 2009a, 2009b). This underscores that soil quality matters for fertilizer uptake such that where soil quality is largely exhausted, fertilizer use may be unprofitable. Low fertilizer usage and profitability is also attributed to market-related factors such as availability of input markets, high prices of fertilizers and low and unpredictable prices of agricultural products. Although market conditions are not good in both countries, the situation in Kenya is relatively better compared to Uganda. In Uganda the input market is still at infant stage, while that of Kenya is a bit developed. Another factor that may discourage farmers to use modern agricultural inputs is low quality of the inputs supplied in some local markets. Bold et al., (2015) for example, found many cases of unauthentic local retail fertilizer markets in Uganda. Such fake inputs cannot be profitable and could therefore lead to low adoption.

Although I do not have sufficient data to analyse some of the aforementioned demand-and supply-related constraints, in Uganda the 2015 RePEAT survey provides some descriptive evidence on what could be the key constraints. When responding to the survey question which asked the households as to why they did not use chemical fertilizer on maize; the most cited reasons were: cannot afford, soil is fertile, not know how to use, cannot access, damage the soil, not profitable, and worry about its quality.

Basing on the study findings and the above discussion, a remaining question is how to promote agricultural intensification such that the effect of population pressure on intensification outweighs its effect on soil degradation? First, policies that can make it easier for farmers to use external inputs to replenish the soil fertility are quite important. These could include subsidies on these external inputs. It is also necessary to provide technical services to farmers on how to appropriately use such inputs. Most importantly, polices that can eventually lead to improved markets for agricultural products may induce farmers to invest in soil improvement. Without such policies, smallholder farmers are not likely to invest in soil improvement as long as what they produce from such degraded land can meet their immediate needs. Besides promoting the use of external inputs, farmers should be encouraged to use locally available inputs such as manure and compost. In addition, there is a need for continuous awareness campaign to discourage farming practices that tend to accelerate soil degradation. It is also important to make deliberate efforts to control population growth through family planning especially in densely populated rural areas.

Another key result of this study is that individualized land rights do affect soil quality. The study finds that households whose parcels are privately-owned have better soil than those with communally-owned parcels in Uganda, and the gap in soil quality between the two is widening over time. This suggests that households with individually land rights have more incentives to invest in soil conservation than their counterparts. In terms of policy implications, this finding underscores the need to promote private land rights in Uganda.

With regards to war-induced displacement and land conflicts in Northern Uganda, the study finds that households that were displaced to locations far away from their original homes during the war are more likely to have new land conflicts and more likely to be concerned about land conflicts over their lands. Moreover, they have higher proportion of parcels with new land conflicts and higher proportion of parcels with concerns about land conflicts in the post-war period. The study finds two plausible main mechanisms of the above results. First, distance displaced reduced the possibility of the farmers to farm or visit their land during the whole period of displacement. Indeed, this might have exposed the lands to many risks such as confusion of land boundaries upon return given the fact that common land demarcation markers used in the region are natural markers which do change easily as land scape changes. In addition, the longer period the land was left idle and unmonitored could increase the possibility of other people to temper with land boundaries by repositioning the demarcation markers to increase their land sizes. Two, conditional on having faced new land conflicts, the study finds that households in communities that were more affected by displacement are less likely to consult informal institutions to resolve land conflicts. This provides suggestive evidence that displacement might have weakened the informal mechanisms of land governance which used to be very strong in preventing or easily resolving land-related conflicts.

Regarding the productivity impact of land conflicts, overall this study finds that land conflicts reduce the value of crop yield. However, the findings reveal that pending conflicts are more harmful than mere concerns about land conflicts. Through which mechanisms do land conflicts affect agricultural productivity? This study finds that households are less likely to adopt high yield variety seeds on parcels with pending conflicts. This suggests that land conflicts do affect agricultural productivity by disincentivising farmers to invest on disputed lands. There are two key policy implications of these findings. First, there is an urgent need to put in place efficient land conflicts containment and resolution mechanisms. One of the possibilities is to establish formal land governance institutions to complement the existing but slowly weakening informal institutions so as to prevent or in a timely way resolve land conflicts whenever they occur. Second, surveying and registering land if done carefully may play a significant role in reducing land-related conflicts in Northern Uganda.

References

Abdulai, A., Owusu, V., & Goetz, R. (2011). Land tenure differences and investment in land improvement measures: Theoretical and empirical analyses. *Journal of Development Economics*, *96*(1), 66–78.

Adelman, S. (2013). Keep your friends close: The effect of local social networks on child human capital outcomes. *Journal of Development Economics*, *103*(1), 284–298.

Adelman, S., Gilligan, D. O., & Lehner, K. (2010). *Childhood Interrupted: How conflict-Induced Shocks Shape Human Capital Formation in Northern Uganda*.

Adelman, S., & Peterman, A. (2014). Resettlement and gender dimensions of land rights in post-conflict Northern Uganda. *World Development*, *64*, 583–596.

Adesina, A. A. (1996). Factors affecting the adoption of fertilizers by rice farmers in Cote d'Ivoire. *Nutrient Cycling in Agroecosystems*, *46*(1), 29–39.

Andre, C., & Platteau, J.-P. (1998). Land relations under unbearable stress: Rwanda caught in the Malthusian trap. *Journal of Economic Behavior and Organization*, *34*, 1–47.

Angrist, J. D., & Pischke, J.-S. (2009). *Mostly Harmless Econometrics: An Empiricist's Companion*. Princeton University Press.

Armed Conflicts Report. (2009). *Uganda:1987- first combat deaths*. Ontario, Canada.

Be´langer, G., Walsh, J. R., Richards, J. E., Milburn, P. H., & Ziadi, N. (2000). Comparison of Three Statistical Models Describing Potato Yield Response to Nitrogen Fertilizer. *Agronomy Journal*, *92*(5), 902.

Bellemare, M. F. (2013). The Productivity Impacts of Formal and Informal Land Rights : Evidence from Madagascar. *Land Economics*, *89*(2), 272–290.

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

Blaikie, P., & Brookfield, H. (1987). *Land Degradation and Society*. London: Methuen.

Blattman, C. (2009). From Violence to Voting: War and Political Participation in Uganda. *American Political Science Review*, *103*(138), 231–247.

Blattman, C., & Annan, J. (2010). The Consequences of Child Soldiering. *Review of Economics and Statistics*, *92*(4), 882–898.

Blattman, C., & Miguel, E. (2010). Civil War. *Journal of Economic Literature*, *48*(1), 3–57.

Boas, M., & Hatloy, A. (2005). *Northern Uganda IDP Profiling Volume 2 : Northern Uganda IDP Study*. Kampala. Uganda.

Bold, T., Kaizzi, K. C., Svensson, J., & Yanagizawa-Drott, D. (2015). *Adoption : Evidence from the Market for Fertilizer and Hybrid Seed in Uganda Low Quality , Low Returns , Low Adoption : Evidence from the Market for Fertilizer and Hybrid Seed in Uganda*.

Boserup, E. (1965). *The conditions of agricultural growth: The economics of agrarian change under population pressure*. London: Allen and Unwin.

Bozzoli, C., Brück, T., & Muhumuza, T. (2011). Does war influence individual expectations? *Economics Letters*, *113*(3), 288–291.

Brasselle, A. S., Gaspart, F., & Platteau, J. P. (2002). Land tenure security and investment incentives: Puzzling evidence from Burkina Faso. *Journal of Development Economics*, *67*(2), 373–418.

Cameron, A. C., & Miller, D. L. (2015). A Practitioner's Guide to Cluster- Robust Inference. *Journal of Human Resouces, 50*(2), 317–372.

Chenery, E. M. (1960). *An Introduction to the soils of the Uganda protectorate.* Ff. 80. Kampala.

Collier, P., Elliott, V. L., Hegre, H., Hoeffler, A., Reynal-Querol, M., & Sambanis, N. (2003). *Breaking the Conflict Trap: Civil War and Development Policy*. *A World Bank Policy Research Report*. Washington, DC: A co-publication of the World Bank and Oxford University Press.

De Janvry, A. (2010). Agriculture for development: New paradigm and options for success. *Agricultural Economics*, *41*, 17–36.

De Luca, G., & Sekeris, P. G. (2012). Land inequality and conflict intensity. *Public Choice*, *150*(1-2), 119–135.

Deininger, K., Ali, A. D., & Alemu, T. (2011). Impacts of Land Certification on Tenure Security, Investment, and Land Market Participation: Evidence from Ethiopia. *Land Economics*, *87*(2), 312–334.

Deininger, K., Ali, D. A., & Yamano, T. (2008). Legal Knowledge and Economic Development: The Case of Land Rights in Uganda. *Land Economics*, *84*(4), 593–619.

Deininger, K., & Castagnini, R. (2006). Incidence and impact of land conflict in Uganda. *Journal of Economic Behavior and Organization*, *60*(3), 321–345.

Deininger, K., & Jin, S. (2006). Tenure security and land-related investment: Evidence from Ethiopia. *European Economic Review*, *50*(5), 1245–1277.

Deininger, K., & Mpuga, P. (2009). The emergence of land markets in Afirca: Impacts on poverty , equity and efficiency. In S. T. Holden, K. Otsuka, & F. Place (Eds.), . Resources for the Future.

Drechsel, P., Gyiele, L., Kunze, D., & Cofie, O. (2001). Population density, soil nutrient depletion, and economic growth in sub-Saharan Africa. *Ecological Economics*, *38*, 251–258.

Duflo, E., Kremer, M., & Robinson, J. (2008). How high are rates of return to fertilizer? Evidence from field experiments in Kenya. *American Economic Review*, *98*(2), 482–488.

Ehui, S., & Pender, J. (2005). Resource degradation, low agricultural productivity, and poverty in sub-Saharan Africa: Pathways out of the spiral. *Agricultural Economics*, *32*(SUPPL. 1), 225–242.

Ekbom, A. (2008). *Determinants of Soil Capital*. *Discussion Paper Series:EfD DP 08-21*.

FAO. (2005). *The importance of soil organic matter: Key to drought-resistant soil sustained food production*. Rome, Italy.

FAO. (2009). *HighLevel Expert Forum-How to Feed the World 2050:The special challenge for sub-Saharan Africa The challenge*. Rome, Italy.

FAO. (2015a). *Regional overview of food insecurity: African food security prospects brighter than ever*. Acrcra, FAO.

FAO. (2015b). *The State of Food and Agriculture. Social protection and agriculture: Breaking the cycle of rural poverty*. Rome, Italy.

FAO, IFAD, UNICEF, WFP, & WHO. (2017). *The State of Food Security and Nutrition in the World 2017:Building resilience for peace and food security.* Rome.

Feder, G., & Feeny, D. (1991). Land Tenure and Property Rights : Theory. *The World Bank Economic Review*, 135–154.

Fenske, J. (2011). Land tenure and investment incentives: Evidence from West Africa. *Journal of Development Economics*, *95*(2), 137–156.

Filmer, D., & Pritchett, L. (2001). Estimating Wealth Effects Without Expenditure Data-- Or Tears: An Application to Educational Enrollments in States of India. *Demography*, *38*(1), 115–132.

Fitzgerald, J., Gottschalk, P., & Moffitt, R. (1998). An Analysis of Sample Attrition in Panel Data: The Michigan Panel Study of Income Dynamics. *The Journal of Human Resources*, *33*(2), 251.

Fred-Mensah, B. K. (1999). Capturing ambiguities: Communal conflict management alternative in Ghana. *World Development*, *27*(6), 951–965.

Global IDP. (2005). *Profile of Internal Displacement: Uganda*.

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

Gray, C. L. (2011). Soil quality and human migration in Kenya and Uganda. *Global Environmental Change*, *21*(2), 421–430.

Gregory, I. D., & Bumb, L. B. (2006). *Factors Affecting Supply of Fertilizer in Sub-Saharan Africa*. *Agricultural and Rural Development, World Bank*.

Grepperud, S. (1996). Population pressure and land degradation: The case of Ethiopia. *Journal of Environmental Economics and Management*, *30*(1), 18–33.

Harou, A. P., Liu, Y., Barrett, C. B., & You, L. (2017). Variable returns to fertiliser use and the geography of poverty: Experimental and simulation evidence from Malawi. *Journal of African Economies*, *26*(3), 342–371.

Hayami, Y., & Ruttan, V. W. (1985). *Agricultural Development: an International Perspective, 1880-1960.* Baltimore, MD: The Johns Hopkins University Press.

Headey, D. D., & Jayne, T. S. (2014). Adaptation to land constraints: Is Africa different? *Food Policy, 48*, 18–33.

Henao, J., & Baanante, C. A. (2006). *Agricultural production and soil nutrient mining in Africa: Implications for resource conservation and policy development.* Muscle Shoals, AL: International Fertilizer Development Center.

Hidalgo, F. D., Naidu, S., Nichter, S., & Richardson, N. (2010). Economic Determinants of Land Invasions. *Review of Economics and Statistics*, *92*(3), 505–523.

Human Rights Focus. (2002). Between Two Fires: The Plight of IDPs in Northern Uganda.

Human Rights Watch. (2003). Abducted and Abused : Renewed Conflict in Northern Uganda, *15*(12).

Ibáñez, A. M., & Vélez, C. E. (2008). Civil Conflict and Forced Migration: The Micro Determinants and Welfare Losses of Displacement in Colombia. *World Development*, *36*(4), 659–676.

IDMC. (2007). *Internal displacement: Global Overview of Trends and Developments in 2006*. Geneva, Switzerland.

IDMC. (2014). *Global Overview 2014. People internally displaced by conflict and violence*. Geneva, Switzerland.

IDMC. (2016). *Global Report on Internal Displacement*.

IFDC. (2006). *Africa Fertilizer Summit Proceedings: Abuja Declaration on Fertilizer for Green Revolution*. Abuja, Nigeria.

Jayne, T. S., Chambelin, J., & Muyanga, M. (2012). Emerginng Lad Issues in African Agriculture: Implications for food security and poverty reduction strategies. *Stanford Symposium Series on Global Food Policy and Food Security in the 21st Century, January, 12*, 1–42.

Jayne, T. S., & Muyanga, M. (2012). Land constraints in Kenya's densely populated rural areas: Implications for food policy and institutional reform. *Food Security*, *4*(3), 399–421.

Jayne, T. S., Yamano, T., Weber, M. T., Tschirley, D., Benfica, R., Chapoto, A., & Zulu, B. (2003). Smallholder income and land distribution in Africa: Implications for poverty reduction strategies. *Food Policy*, *28*(3), 253–275.

Jenny, H. (1994). *Factors of soil formation: A system of quantitative pedology*. New York: Dover Publications, Inc.

Josephson, L. A., Ricker-Gilbert, J., & Florax, R. J. G. M. (2014). How does population density influence agricultural intensification and productivity? Evidence from Ethiopia. *Food Policy*.

Kandel, M. (2016). Struggling over land in post-conflict Uganda. *African Affairs*, *115*(459), 274–295.

Kassie, M., Jaleta, M., Shiferaw, B., Mmbando, F., & Mekuria, M. (2012). Adoption of interrelated sustainable agricultural practices in smallholder systems: Evidence from rural Tanzania. *Technological Forecasting and Social Change*, *80*(3), 525–540.

Kirui, O., & Mirzabaev, A. (2014). *Economics of Land Degradation in Eastern Africa*. *ZEF*

Working Paper Series.

KNBS. (1994). *Kenya Population Census , 1989:Volume I*.

KNBS. (2001). *The 1999 Population and Housing Census: Counting Our People for Development, Volume I*.

KNBS. (2010). *The 2009 Kenya Population and Housing Census: Counting Our People for the Implementation of Vision 2030, Volume IA*.

KNBS. (2015). *Kenya Facts and Figures, 2015*.

Kobusingye, D. N., Van Leeuwen, M., & Van Dijk, H. (2016). Where do I report my land dispute? The impact of institutional proliferation on land governance in post-conflict Northern Uganda. *Journal of Legal Pluralism and Unofficial Law*, *48*(2), 238–255.

Kondylis, F. (2010). Conflict displacement and labor market outcomes in post-war Bosnia and Herzegovina. *Journal of Development Economics*, *93*(2), 235–248.

Lehrer, K. (2009). *Gender Differences in Labour Market Participation During Conflict : Evidence from Displaced People ' s Camps in Northern Uganda*. Oxford,UK.

Lehrer, K. (2013). *Returning home:Post-Conflict Livelihoods in Northern Uganda*.

Liverpool-Tasie, L. S. O., Omonona, B. T., Sanou, A., & Ogunleye, W. O. (2017). Is increasing inorganic fertilizer use for maize production in SSA a profitable proposition? Evidence from Nigeria. *Food Policy*, *67*, 41–51.

Loveland, P., & Webb, J. (2003). Is there a critical level of organic matter in the agricultural soils of temperate regions: A review. *Soil and Tillage Research*, *70*(1), 1–18.

Mabikke, B. S. B. (2011). Escalating Land Grabbing In Post-conflict Regions of Northern Uganda : A Need for Strengthening Good Land Governance in Acholi Region Global Land Grabbing. In *International Conference on Global Land Grabbing*.

Mallarino, a. P., & Blackmer, A. M. (1992). Comparison of Methods for Determining Critical Concentrations of Soil Test Phosphorus for Corn. *Agronomy Journal*, *84*(5), 850.

Marenya, P. P., & Barrett, C. B. (2007). Household-level determinants of adoption of improved natural resources management practices among smallholder farmers in western Kenya. *Food Policy*, *32*(4), 515–536.

Marenya, P. P., & Barrett, C. B. (2009a). Soil quality and fertilizer use rates among smallholder farmers in western Kenya. *Agricultural Economics*, *40*(5), 561–572.

Marenya, P. P., & Barrett, C. B. (2009b). State-conditional fertilizer yield response on Western Kenyan Farms. *American Journal of Agricultural Economics*, *91*(4), 991–1006.

Matsumoto, T., & Yamano, T. (2009). *Soil Fertility, Fertilizer, and the Maize Green Revolution in East Africa* (No. 5158). *World Bank.*

Mbaga-Semgalawe, Z., & Folmer, H. (2000). Household adoption behaviour of improved soil conservation: The case of the North Pare and West Usambara Mountains of Tanzania. *Land Use Policy*, *17*(4), 321–336.

Melesse, M. B., & Bulte, E. (2015). Does land registration and certification boost farm productivity? Evidence from Ethiopia. *Agricultural Economics*, *46*(6), 756–768.

Michael, C., Travis, L., & Tjernström, E. (2015). *The Dirt on Dirt : Soil Characteristics and Variable Fertilizer Returns in Kenyan Maize Systems*.

Minten, B., & Barrett, C. B. (2008). Agricultural Technology, Productivity, and Poverty in Madagascar. *World Development*, *36*(5), 797–822.

Mishra, S. K. (2007). *A Comparative study of various inclusive indices and the index constructed by the principal component analysis*. *MPRA Paper No.3377*.

Morris, M., Kelly, V. A., Kopicki, R. J., & Byerlee, D. (2007). *Fertilizer Use in African Agriculture Lessons Learned and Good Practice Guidelines*. *World Bank*. Washington, D.C.

Mortimore, M. (1993). Population Growth and Land Degradation. *GeoJournal*, *311*, 15–21.

Musinguzi, P., Ebanyat, P., Tenywa, J. S., Basamba, T. A., Tenywa, M. M., & Mubiru, D. N. (2016). Critical soil organic carbon range for optimal crop response to mineral Fertiliser nitrogen on a Ferralsol. *Experimental Agriculture*, *52*(4), 635–653.

Musinguzi, P., Tenywa, J. S., Ebanyat, P., Tenywa, M. M., Mubiru, D. N., Basamba, T. A., & Leip, A. (2013). Soil Organic Carbon Thresholds and Nitrogen Management in Tropical Agroecosystems: Concepts and Prospects. *Journal of Sustainable Development*, *6*(12), 31–43.

Muyanga, M., & Gitau, R. (2013). Do Land Disputes Affect Smallholder Agricultural Productivity ? Evidence from Kenya. *Journal of Economics and Sustainable*

Development, *4*(14), 112–122.

Muyanga, M., & Jayne, T. S. (2014). Effects of rising rural population density on smallholder agriculture in Kenya. *Food Policy*, *48*, 98–113.

Mwesigye, F., & Matsumoto, T. (2016). The Effect of Population Pressure and Internal Migration on Land Conflicts: Implications for Agricultural Productivity in Uganda. *World Development*, *79*, 25–39.

Mwesigye, F., Matsumoto, T., & Otsuka, K. (2017). Population pressure, rural-to-rural migration and evolution of land tenure institutions: The case of Uganda. *Land Use Policy*, *65*, 1–14.

Nabudere, D. (2003). *The hidden war, the forgotten people: War in Acholiland and its ramifications for peace and security in Uganda.*

Nkonya, E., Kaizzi, C., & Pender, J. (2005). Determinants of nutrient balances in a maize farming system in eastern Uganda. *Agricultural Systems*, *85*(2), 155–182.

Nkonya, E., Pender, J., Kaizzi, C., Edward, K., & Mugarura, S. (2005). Policy Options for Increasing Crop Productivity and Reducing Soil Nutrient. Intranational Food Policy Research Institute.

O'Reilly, C. (2015). Household Recovery from Internal Displacement in Northern Uganda. *World Development*, *76*, 203–215.

Orellano, V., Azevedo, P. F., Saes, M. S., & Nascimento, V. E. (2015). Land Invasions, Insecure Property Rights and Production Decisions. *Journal of Agricultural Economics*, *66*(3), 660–671.

Otsuka, K., & Larson, D. F. (2016). *In Pursuit of an African Green Revolution: Views from Rice and Maize Farmers' Fields*. Dordrecht, The Nrtherlands: Springer.

Otsuka, K., & Place, F. (2001). *Land Tenure and Natural Resource Management: A comparative study of Agrarian communities in Asia and Africa*. Baltimore, ML: International Food Policy Research Institute.

Otsuka, K., & Place, F. (2015). Land Tenure Agricultural Intensification in Sub-Saharan Africa. In C. Manga & Y. Lin, Justin (Eds.), *The Oxford Handbook of Africa and Economics:Volume 2: Policies and Practices* (pp. 289–309). Oxford: Oxford University Press.

Population Reference Bureau. (2017). 2017 World Population Data Sheet, 1–22. Retrieved from http://www.prb.org

Rakotoarisoa, M. A., Iafrate, M., & Paschali, M. (2012). *Why has Africa become a net food importer ? Explaining Africa agricultural and food trade deficits. Trade and Market Division, FAO*.

Ricker-Gilbert, J., Jumbe, C., & Chamberlin, J. (2014). How does population density influence agricultural intensification and productivity? Evidence from Malawi. *Food Policy*, *48*, 142–152.

Rugadya, M. A., Nsamba-Gayiiya, H., & Kamusiime, E. (2008). *Northern Uganda Land Study: Analysis of Post-Conflict Land Policy and Land Administration, A Survey of IDP Return and Resettlement Issues and Lesson, Acholi and Lango Regions.For the World Bank, to input into Northern Uganda Peace, Recovery and Development*.

Sanchez, P. A. (2002). Soil fertility and hunger in Africa. *Science*, 64–66.

Sekeris, P. (2010). Land Inequality and Conflict in Sub-Saharan Africa. *Peace Economics, Peace Science and Peace Policy*, *16*(2).

Sena, M. M., Frighetto, R. T. S., Valarini, P. J., Tokeshi, H., & Poppi, R. J. (2002). Discrimination of management effects on soil parameters by using principal component analysis: a multivariate analysis case study. *Soil and Tillage Research*, *67*(2), 171–181.

Shepherd, K. D., & Walsh, M. G. (2002). Development of Reflectance Spectral Libraries for Characterization of Soil Properties. *Soil Science Society of America Journal*, *66*(3), 988.

Shiferaw, B., & Holden, S. T. (1998). Resource degradation and adoption of land conservation technologies in the Ethiopian Highlands: A case study in Andit Tid, North Shewa. *Agricultural Economics*, *18*(3), 233–247.

Smaling, E. M. A., Nandwa, S. M., & Janssen, B. H. (1997). Soil Fertility in Africa is at Stake. In R. J. Buresh, P. A. Sanchez, & F. Calhoun (Eds.), *Replenishing Soil Fertility in Africa.* Soil Science Society of America, Madison, WI.

Sommer, R., Bossio, D., Desta, L., Dimes, J., Kihara, J., Koala, S., Winowiecki, L. (2013). *Profitable and sustainable nutrient management systems for East and Southern African smallholder farming systems: challenges and opportunities*.

Srivastava, S., Subba Rao, A., Alivelu, K., Singh, K. N., Raju, N. S., & Rathore, A. (2006). Evaluation of crop responses to applied fertilizer phosphorus and derivation of optimum recommendations using the Mitscherlich-Bray equation. *Communications in Soil Science and Plant Analysis*, *37*(5-6), 847–858.

Stackhouse, P. W., Westberg, D., Hoell, J. M., Chandler, W. S., & Zhang, T. (2015). Prediction Of Worldwide Energy Resource (POWER) - Agroclimatology Methodology - (1.0° Latitude by 1.0° Longitude Spatial Resolution), 45. Retrieved from https://power.larc.nasa.gov/documents

Stocking, M. A. (2003). Tropical Soils and Food Security: The Next 50 Years. *Science*, *302*(5649), 1356–1359.

Stoorvogel, J., & Smaling, E. (1990). *Assessment of soil nutrient depletion in Sub-Saharan:1983-2000*. Wageningen, Netherlands.

Uganda Bureau of Statistics. (2016). *National Population and Housing Census 2014-Main Report*.

United Nations. (2015). *Transforming our World: The 2030 Agenda for Sustainable Development*. Retrieved from sustainabledevelopment.un.org

Ussiri, D. A., Mnkeni, P. N. S., MacKenzie, A. F., & Seraoka, J. M. R. (1998). Soil test calibration studies for formulation of phosphorus fertilizer recommendations for maize in Morogoro district, Tanzania. II. estimation of optimum fertilizer rates. *Communications in Soil Science and Plant Analysis*, *29*(17-18), 2815–2828.

Wooldridge, J. M. (2010). *Econometric Analysis of Cross Section and Panel data*. Cambridge, MA: MIT Press.

World Bank. (2008). *Agriculture for Development-World Bank Development Report*. *The World Bank*.

Yamano, T., & Deininger, K. (2005). Land Conflicts in Kenya: Causes, Impacts, and Resolutions. *FASID Discussion Paper*, 27.

Yamano, T., & Kijima, Y. (2010). The associations of soil fertility and market access with household income: Evidence from rural Uganda. *Food Policy*, *35*(1), 51–59.

Yamano, T., Sserunkuuma, D., Otsuka, K., Omiat, G., Ainembabazi, J. H., & Shimamura, Y. (2004). The 2003 REPEAT survey in Uganda: Results. *FASID Development Database*.

List of Tables

Table 2.1: Distribution of soil sampled households

Region	District	Sub location	Households
Central	Kiambu	12	78
	Kirinyaga	6	34
	Maragua	3	19
	Muranga	8	55
Eastern	Machakos	7	51
Nyanza	Kisii	1	2
	Nyamira	3	19
	Rachnonyo	6	38
Western	Bungoma	4	18
	Kakamega	4	18
	Vihiga	4	14
Rift Valley	Nakuru	16	118
	Narok	3	16
	Total	77	480

Source: Author's computation using 2004 and 2012 RePEAT data

Table 2.2: Summary statistics and *ttest* for equality of means of key variables

	Year=2004		Year=2012			
Variable	Mean	Sd	Mean	Sd	Mean Diff	Sign
Soil quality index	0.10	1.76	0.03	1.78	0.07	
Carbon (%)	2.49	1.45	2.30	0.44	0.19	**
Nitrogen (%)	0.22	0.13	0.18	0.04	0.05	***
Extractable Phosphorus (mg/kg)	15.16	12.31	22.80	34.08	-7.64	***
Extractable Potassium (cmol$_c$ /kg)	1.04	1.86	1.13	0.54	-0.09	
Extractable Calcium (cmol$_c$ /kg	7.48	3.65	9.72	6.48	-2.24	***
Soil pH	6.18	0.59	6.02	0.63	0.16	***
Land-labor ratio	0.59	0.90	0.48	0.66	0.11	**
Land ownership (ha)	2.03	3.25	1.60	2.66	0.43	**
Owned land per capita	0.37	0.60	0.27	0.38	0.10	***
Community population density	422.16	242.29	543.49	337.75	-121.33	***
Inorganic fertilizer use (Kgs/ha)[d]	48.51	113.75	40.09	41.58	8.41	
Quantity of manure use (100Kg/ha)	18.28	38.86	30.04	167.56	-11.76	
% of households used inorganic fertilizer	0.78	0.42	0.77	0.42	0.01	
% households used manure	0.72	0.45	0.72	0.45	0.00	
% of households used fertilizer	0.93	0.26	0.93	0.25	0.00	
1 female headed household	0.22	0.42	0.31	0.46	-0.09	***
Age of household head	56.92	13.39	61.90	13.42	-4.50	***
Years of schooling of household head	6.55	4.71	6.73	4.62	-0.18	
Observations	480		480			

Notes: [d]Converted to NPK equivalent

Table 2.3: Pairwise correlations between soil variables and key determinants

	1)	2)	3)	4)	5)	6)	7)	8)	9)
1)SQ	1								
2)Carbon	0.644***	1							
3)N	0.515***	0.954***	1						
4)P	0.527***	0.138***	-0.012	1					
5)K	0.449***	0.278***	0.180***	0.227***	1				
6)Cal	0.713***	0.177***	0.059*	0.486***	0.226***	1			
7)pH	0.381***	0.251***	-0.321***	0.352***	0.314***	0.538***	1		
8)IOLpc	-0.041	-0.048	-0.049	-0.04	-0.049	-0.019	-0.022	1	
9)Pop	-0.268***	-0.083**	-0.028	-0.227***	-0.147***	-0.110***	-0.265***	0.071**	1

Notes: ***1%, **5%, and *10% significance level, respectively. 1) Soil quality index, 3) N=Nitrogen, 4) P=Phosphorus, 5) K=Potassium, 6) Cal=Calcium, 7) pH=Soil pH, 8) IOLpc=Inverse of owned land per capita, 9) Pop=Population density

Table 2.4: Pairwise correlations between changes in soil variables and key determinants

	1)	2)	3)	4)	5)	6)	7)	8)	9)
1)SQ	1								
2)Carbon	0.640***	1							
3)N	0.560***	0.969***	1						
4)P	0.354***	-0.038	-0.067	1					
5)K	0.218***	0.120***	0.101**	-0.291* **	1				
6)Cal	0.633***	0.010	-0.056	0.089**	0.445***	1			
7)pH	0.299***	-0.222***	-0.250***	0.385***	0.175***	-0.554***	1		
8)IOLpc	0.053	0.030	0.030	0.013	-0.001	0.036	0.019	1	
9)Pop	-0.199***	-0.259***	-0.220***	-0.013	-0.080*	-0.090**	0.009	-0.002	1

Notes: ***1%, **5%, and *10% significance level, respectively. All nine variables are in change form. 1) Soil quality index, 3) N=Nitrogen, 4) P=Phosphorus, 5) K=Potassium, 6) Cal=Calcium, 7) pH=Soil pH, 8) IOLpc=Inverse of owned land per capita, 9) Pop=Population density

Table 2.5: Factor loadings of soil quality index

	Year		
	2004	2012	Pooled years
	Factor loadings		
Individual elements			
Carbon (%)	0.59	0.11	0.60
Nitrogen (%)	0.58	-0.16	0.53
Extractable Phosphorus (mg/kg)	0.34	0.43	0.30
Extractable Potassium (cmolc /kg)	0.22	0.51	0.37
Extractable Calcium (cmolc /kg)	0.38	0.53	0.35
Soil pH	-0.11	0.49	0.08
Proportion of variation explained	0.42	0.49	0.36
Mean of soil quality index	0.07	-0.07	0.00
S.D of soil quality index	1.8	1.00	1.5

Table 2.6: Factor loadings of agricultural intensification

	Year		
	2004	2012	Pooled years
Household-level	Factor loadings		
Individual elements			
Quantity of chemical fertilizer (Kg/Ha)[d]	0.70	0.66	0.65
Quantity of manure (Kg/Ha)	0.21	0.36	0.32
Improved maize seeds (=1)	0.68	0.66	0.67
Proportion of variation explained	0.42	0.43	0.46
Mean of agricultural intensification index	-0.18	0.18	0.00
S.D of agricultural intensification index	1.15	1.12	1.14
Parcel-level			
Individual elements			
Quantity of chemical fertilizer (Kg/Ha)[d]	0.68	0.66	0.65
Quantity of manure (Kg/Ha)	0.29	0.33	0.33
Improved maize seeds (=1)	0.67	0.68	0.67
Proportion of variation explained	0.42	0.45	0.44
Mean of agricultural intensification index	-0.21	0.22	0.00
S.D of agricultural intensification index	1.14	1.11	1.15

Notes: [d]Converted to NPK equivalent

Table 2.7: Impact of population pressure on soil nutrients

Explanatory variables	(1) Car	(2) Nit	(3) lnph	(4) lnPot	(5) lnCa	(6) pH	(7) pH dum
Inverse of owned land per capita	-0.001	-0.0002	-0.0001	-0.001	0.0003	0.001	-0.001
	(-0.574)	(-0.454)	(-0.184)	(-1.041)	(0.064)	(0.986)	(-0.844)
Ln past population density	-0.237**	-0.019**	-0.139**	-0.044	-0.055	0.049	-0.005
	(-2.602)	(-2.306)	(-2.170)	(-0.950)	(-1.505)	(0.957)	(-0.172)
1 if female HHH	0.228	0.019	0.092	0.083	0.134**	0.101	0.046
	(1.339)	(1.165)	(1.433)	(1.462)	(2.275)	(1.336)	(1.042)
Years of education of HHH	0.012	0.001	0.014	0.009	0.009	0.007	0.000
	(0.783)	(0.668)	(1.663)	(0.962)	(1.408)	(0.926)	(0.088)
Age of HHH	0.006	0.001	-0.001	0.003	0.001	0.001	0.001
	(0.904)	(0.879)	(-0.207)	(1.600)	(0.568)	(0.540)	(0.423)
Family size	0.000	-0.000	0.027	0.022*	-0.020*	-0.019	-0.004
	(0.008)	(-0.001)	(1.567)	(1.817)	(-1.665)	(-1.416)	(-0.385)
Number of boys	0.002	0.000	-0.011	-0.005	0.036	0.030	-0.038**
	(0.075)	(0.150)	(-0.334)	(-0.235)	(1.621)	(1.128)	(-2.129)
Number of adult males	0.024	0.002	-0.042	-0.030	0.009	0.012	-0.000
	(0.528)	(0.564)	(-1.448)	(-1.583)	(0.469)	(0.544)	(-0.008)
Number of adult females	-0.016	0.000	-0.011	-0.017	0.037**	0.041**	-0.009
	(-0.356)	(0.036)	(-0.392)	(-0.917)	(2.067)	(2.150)	(-0.454)
Average yrs of schooling of male adults	-0.015	-0.002	0.000	-0.004	-0.002	0.003	0.001
	(-1.134)	(-1.200)	(0.012)	(-0.567)	(-0.349)	(0.448)	(0.175)
Average yrs of schooling of female adults	0.014	0.002	-0.009	0.012	0.003	-0.009	0.008
	(1.026)	(1.157)	(-1.049)	(1.595)	(0.590)	(-1.288)	(1.398)
Per capita value of productive assets	-0.000	-0.000	-0.000***	0.000	-0.000	0.000	-0.000
	(-0.466)	(-0.488)	(-3.596)	(0.014)	(-0.319)	(0.985)	(-0.975)
Per capita value of nonproductive assets	-0.000	-0.000	0.000	0.000	-0.000	-0.000	0.000
	(-0.592)	(-1.062)	(0.317)	(1.580)	(-0.026)	(-0.420)	(0.614)
Ln value of livestock	-0.003	-0.001	-0.011	0.021*	-0.019	-0.003	-0.013
	(-0.167)	(-0.382)	(-0.610)	(1.947)	(-1.506)	(-0.160)	(-1.242)
Ln land used other than owned land	-0.053	-0.004	-0.030	0.018	-0.028	0.036	0.055**
	(-1.128)	(-0.751)	(-0.867)	(0.791)	(-1.462)	(1.001)	(2.488)
Log travel time to nearby big town	-0.647	-0.060	-0.256	-0.478	1.212***	-0.021	0.226
	(-0.785)	(-0.718)	(-0.527)	(-0.751)	(4.230)	(-0.041)	(0.717)
Rainfall mm (5 year average)	-0.003	-0.000	0.005	0.002	0.004	0.001	0.001
	(-0.376)	(-0.265)	(0.807)	(0.457)	(1.482)	(0.280)	(0.349)
Temperature °c (5 year average)	-0.001	-0.000*	0.001**	-0.000	0.000	0.000***	0.000
	(-1.468)	(-1.836)	(2.415)	(-0.157)	(0.233)	(2.976)	(0.894)
Wind 10m (m/s) (5 year average)	-0.000	-0.000	-0.000	0.000	-0.001	-0.001	-0.001**
	(-0.230)	(-0.241)	(-0.361)	(0.538)	(-1.381)	(-0.827)	(-2.444)
Constant	13.490*	1.299*	-2.932	-0.037	-5.732*	2.791	-0.086
	(1.880)	(1.906)	(-0.531)	(-0.009)	(-1.832)	(0.613)	(-0.034)
Observations	960	960	960	960	960	960	960
R-squared	0.354	0.418	0.345	0.260	0.358	0.262	0.179
Number of households	480	480	480	480	480	480	480
HH FE	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Year FE	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Year*Region dummies	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*

Notes: Robust t-statistics in parentheses. ***Significant at 1%, **5%, and* 10%, respectively. Robust standard errors are clustered at community level. Estimates are weighted by attrition weights. Car: carbon, Nit: nitrogen, lnph: Log phosphorus, lnPot: Log potassium, lnCa: Log calcium, pH: soil pH, HH: Household, HHH: Household head.
In column 7, I use soil pH as a dummy variable equals to one if soil pH >=6.6 & soil pH<=7.3 (neutral) and zero otherwise

Table 2.8: Impact of population pressure on soil quality

Dependent variable: *Soil quality index*

Explanatory variables	(1)	(2)	(3)	(4)	(5)	(6)
Inverse of owned land per capita	-0.002		-0.002	-0.002	-0.002	-0.002
	(-0.595)		(-0.599)	(-0.650)	(-0.552)	(-1.174)
Ln past population density		-0.303**	-0.303**	-0.311**	-0.310**	-0.185**
		(-2.525)	(-2.520)	(-2.595)	(-2.591)	(-2.035)
1 if female HHH	0.402*	0.425*	0.429*	0.405*	0.393*	0.256**
	(1.822)	(1.975)	(1.987)	(1.865)	(1.799)	(2.429)
Years of education of HHH	0.024	0.028	0.028	0.025	0.025	0.021
	(1.045)	(1.264)	(1.270)	(1.159)	(1.124)	(1.248)
Age of HHH	0.011	0.010	0.010	0.010	0.010	0.007
	(1.391)	(1.256)	(1.253)	(1.206)	(1.180)	(1.655)
Family size	-0.009	-0.011	-0.012	-0.008	-0.007	0.009
	(-0.218)	(-0.280)	(-0.292)	(-0.202)	(-0.171)	(0.287)
Number of boys	0.019	0.023	0.027	0.020	0.024	0.021
	(0.374)	(0.491)	(0.553)	(0.445)	(0.548)	(0.485)
Number of adult males	0.005	0.017	0.018	0.019	0.020	-0.011
	(0.086)	(0.288)	(0.310)	(0.330)	(0.343)	(-0.295)
Number of adult females	0.029	0.027	0.028	0.017	0.017	0.001
	(0.541)	(0.503)	(0.518)	(0.319)	(0.304)	(0.013)
Average yrs of schooling of male adults	-0.015	-0.016	-0.016	-0.018	-0.018	-0.004
	(-0.773)	(-0.837)	(-0.843)	(-0.908)	(-0.919)	(-0.322)
Average yrs of schooling of female adults	0.021	0.022	0.022	0.024	0.024	0.018
	(1.011)	(1.050)	(1.083)	(1.180)	(1.155)	(1.007)
Per capita value of productive assets	-0.0003	-0.0002	-0.000	-0.000	-0.000	-0.000
	(-0.556)	(-0.313)	(-0.312)	(-0.360)	(-0.305)	(-0.158)
Per capita value of nonproductive assets	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
	(-0.595)	(-0.823)	(-0.823)	(-0.879)	(-0.981)	(-1.073)
Ln value of livestock	-0.018	-0.020	-0.021	-0.018	-0.015	0.000
	(-0.656)	(-0.690)	(-0.725)	(-0.631)	(-0.526)	(0.008)
Ln land used other than owned land	-0.028	-0.038	-0.037	-0.045	-0.052	0.032
	(-0.417)	(-0.567)	(-0.558)	(-0.682)	(-0.812)	(0.511)
Log travel time to nearby big town	0.859	0.032	0.046	-0.124	-0.216	-0.263
	(0.874)	(0.030)	(0.044)	(-0.115)	(-0.199)	(-0.429)
Rainfall mm (5 year average)	-0.001	0.008	0.008	0.006	0.006	0.012
	(-0.049)	(0.647)	(0.656)	(0.528)	(0.484)	(1.515)
Temperature °c (5 year average)	-0.000	-0.001	-0.001	-0.001	-0.001	-0.000
	(-0.703)	(-1.195)	(-1.198)	(-1.388)	(-1.459)	(-1.476)
Wind 10m (m/s) (5 year average)	-0.002	-0.000	-0.000	-0.000	-0.000	0.001
	(-0.597)	(-0.138)	(-0.135)	(-0.099)	(-0.019)	(0.660)
Constant	1.080	-0.204	-0.327	2.496	3.301	-6.911
	(0.095)	(-0.020)	(-0.032)	(0.247)	(0.330)	(-0.923)
Observations	960	960	960	960	960	960
R-squared	0.165	0.198	0.198	0.236	0.252	0.092
Number of households	480	480	480	480	480	480
HH FE	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Year FE	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Year*Region dummies	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*

Notes: Robust t-statistics in parentheses. ***Significant at 1% level, **Significant at 5%, *Significant at 10%. Robust standard errors are clustered at community level. Estimates are weighted by attrition weights. HH: Household, HHH: Household head. In columns 1-3 soil quality index is created by using all six soil variables. In column (4) soil quality index is created by using five macro-nutrients (excluding soil pH). In column (5) soil quality index by using six soil variables but soil pH enters as a dummy variable i.e. 1 if neutral (soil pH >=6.6 & soil pH<=7.3) and zero otherwise. In column (6) soil quality index is created using nitrogen, phosphorus, and potassium (NPK)-key soil macro-nutrients.

Table 2.9: Impact of population pressure on input adoption and intensification index

Explanatory Variables	(1) Manure (t/ha)	(2) Chemical (10kg/ha)	(3) ln Chemical (10kg/ha)	(4) Maizehyv (=1)	(5) Intens. index	(6) Intens. Index2
Log inverse of owned land per capita	0.325	0.513*	0.116	0.014	0.128*	0.155**
	(1.522)	(1.780)	(1.217)	(0.582)	(1.934)	(2.274)
Log population density	0.845	0.321	0.616**	0.132*	0.329**	0.258
	(1.437)	(0.529)	(2.441)	(1.770)	(2.280)	(1.621)
Cultivated plot size (ha)	-0.888***	-1.550***	-0.173	0.041	-0.260***	-0.445***
	(-3.859)	(-3.526)	(-0.974)	(1.157)	(-3.083)	(-5.264)
1 if female HHH	-0.425	-0.626	-0.243	0.058	-0.056	-0.196*
	(-1.656)	(-1.063)	(-1.059)	(1.161)	(-0.427)	(-1.689)
Age of HHH	-0.000	0.019	0.015**	-0.001	0.001	0.003
	(-0.033)	(1.124)	(2.151)	(-0.485)	(0.344)	(0.706)
Years of education of HHH	0.038	-0.024	0.027	0.003	0.005	0.006
	(1.019)	(-0.349)	(1.115)	(0.382)	(0.378)	(0.444)
Number of adult males	-0.030	-0.301	-0.044	0.008	-0.032	-0.051
	(-0.384)	(-1.298)	(-0.739)	(0.610)	(-0.869)	(-1.328)
Number of adult females	0.065	0.275	0.113	0.024	0.078**	0.056
	(0.654)	(1.541)	(1.496)	(1.612)	(1.990)	(1.377)
Family size	0.008	-0.085	-0.045	-0.015	-0.031	-0.010
	(0.125)	(-0.898)	(-1.204)	(-1.498)	(-1.259)	(-0.431)
Average yrs of schooling of female adults	-0.060	0.054	0.004	0.005	0.007	-0.007
	(-1.376)	(0.867)	(0.150)	(0.785)	(0.474)	(-0.508)
Average yrs of schooling of male adults	-0.003	0.064	0.028	0.001	0.010	0.008
	(-0.097)	(1.318)	(1.306)	(0.275)	(0.848)	(0.701)
Log value of assets Ushs	0.049	0.263	0.161**	0.033*	0.087**	0.050
	(0.284)	(1.440)	(2.431)	(1.848)	(2.020)	(0.978)
Log value of livestock	0.148***	0.104	-0.002	0.003	0.036*	0.052***
	(3.007)	(1.139)	(-0.054)	(0.283)	(1.863)	(2.821)
Log land used other than owned land	-0.231*	-0.245	-0.071	-0.039**	-0.116**	-0.093*
	(-1.876)	(-0.943)	(-0.865)	(-2.130)	(-2.418)	(-1.727)
Log travel time to nearby big town	-1.635	-2.529	-2.260	-0.016	-0.561	-0.773
	(-0.759)	(-0.997)	(-1.629)	(-0.039)	(-0.729)	(-1.225)
Constant	0.935	8.787	4.125	-0.644	-1.176	0.583
	(0.093)	(0.788)	(0.693)	(-0.374)	(-0.349)	(0.196)
Observations	2,851	2,851	2,851	2,851	2,851	2,851
R-squared	0.079	0.118	0.101	0.209	0.187	0.120
Number of pid	1,184	1,184	1,184	1,184	1,184	1,184
HH FE	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
pid FE	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Year FE	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Year*Division	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*

Notes: Robust t-statistics in parentheses; ***Significant at 1% level, **Significant at 5%, *Significant at 10%. Robust standard errors are clustered at community level. Estimates are weighted by attrition weights. HH: Household, HHH: Household head. In column (5) agricultural intensification index is created by using three intensification variables. In column (6) index created by using two intensification variables (excluding improved maize adoption).

Table 2.10: Correlation between change in agricultural intensification and change in soil quality

Dependent variable: *Change in soil quality index (2004-2012)*

Explanatory Variables	(1)	(2)	(3)	(4)
Change in Manure (t/ha) (2004-2012)	-0.000			
	(-0.015)			
Change in Chemical fertilizer (10kg/ha) (2004-2012)		0.076**		
		(2.331)		
Change in in ln Chemical (10kg/ha) (2004-2012)			0.018*	
			(1.900)	
Change in agricultural intensification index‡ (2004-2012)				0.066*
				(1.718)
Ln inverse of owned land per capita	-0.009	-0.009	-0.012	-0.007
	(-0.137)	(-0.141)	(-0.193)	(-0.107)
Ln population density	0.352***	0.333***	0.336***	0.347***
	(2.759)	(2.701)	(2.683)	(2.750)
1 if female HHH	0.105	0.068	0.114	0.107
	(0.949)	(0.671)	(1.067)	(0.986)
Years of education of HHH	-0.016	-0.018	-0.015	-0.015
	(-0.941)	(-1.104)	(-0.919)	(-0.907)
Age of HHH	-0.004	-0.004	-0.004	-0.004
	(-0.639)	(-0.584)	(-0.605)	(-0.626)
Family size	0.011	0.002	0.007	0.007
	(0.329)	(0.071)	(0.230)	(0.216)
Number of adult males	0.008	0.020	0.012	0.011
	(0.171)	(0.449)	(0.267)	(0.246)
Number of adult females	-0.066	-0.052	-0.067	-0.065
	(-1.111)	(-0.856)	(-1.102)	(-1.084)
Average yrs of schooling of male adults	0.026	0.025	0.026	0.027
	(1.018)	(1.026)	(1.014)	(1.051)
Average yrs of schooling of female adults	-0.001	-0.000	-0.002	0.000
	(-0.074)	(-0.002)	(-0.100)	(0.008)
Per capita value of productive assets	0.000	0.000	0.000	0.000
	(0.356)	(0.094)	(0.257)	(0.417)
Per capita value of nonproductive assets	0.000	0.000	0.000	0.000
	(1.321)	(1.370)	(1.322)	(1.210)
Ln value of livestock	0.016	0.016	0.020	0.018
	(0.539)	(0.512)	(0.637)	(0.596)
Ln land used other than owned land	0.055	0.060	0.057	0.051
	(0.654)	(0.700)	(0.658)	(0.595)
Log travel time to nearby big town	0.665**	0.548*	0.607*	0.643**
	(2.155)	(1.792)	(1.980)	(2.104)
Rainfall mm (5 year average)	-0.030***	-0.028***	-0.028***	-0.029***
	(-5.028)	(-4.873)	(-4.687)	(-4.873)
Temperature (5 year average)	0.000*	0.000	0.000	0.000
	(1.709)	(1.457)	(1.619)	(1.615)
Wind (5 year average)	-0.023***	-0.022***	-0.022***	-0.022***
	(-5.184)	(-5.068)	(-4.890)	(-5.031)
Constant	65.784***	62.271***	62.500***	63.893***
	(4.745)	(4.652)	(4.460)	(4.602)
Observations	480	480	480	480
R-squared	0.360	0.374	0.367	0.363
Province dummies	*Yes*	*Yes*	*Yes*	*Yes*

Notes: Robust t-statistics in parentheses; ***Significant at 1% level, **Significant at 5%, *Significant at 10%. Robust standard errors are clustered at community level. HH: Household, HHH: Household head.
‡The intensification index is created by using Manure (t/ha) and Chemical fertilizer (10kg/ha)

Table 2.11: Correlation between agricultural intensification and soil quality

Dependent variable: *Soil quality index*

Explanatory Variables	(1)	(2)	(3)	(4)
Manure (t/ha)	0.000			
	(0.336)			
ln Chemical fertilizer (10kg/ha)		0.138***		
		(3.116)		
Chemical fertilizer (10kg/ha)			0.036***	
			(2.668)	
Ag intensification index ‡				0.148**
				(2.038)
Inverse of owned land per capita	-0.001	-0.002	-0.002	-0.002
	(-0.492)	(-0.684)	(-0.856)	(-0.677)
Ln population density	-0.283**	-0.255**	-0.251**	-0.268**
	(-2.331)	(-2.361)	(-2.292)	(-2.357)
1 if female HHH	0.415*	0.417**	0.332*	0.378*
	(1.926)	(2.116)	(1.720)	(1.861)
Years of education of HHH	0.026	0.032	0.026	0.023
	(1.184)	(1.481)	(1.180)	(1.061)
Age of HHH	0.011	0.010	0.010	0.010
	(1.301)	(1.328)	(1.290)	(1.268)
Family size	-0.007	-0.001	-0.001	-0.001
	(-0.199)	(-0.016)	(-0.037)	(-0.023)
Number of adult males	0.011	0.004	0.001	0.002
	(0.212)	(0.074)	(0.015)	(0.032)
Number of adult females	0.028	0.019	0.025	0.021
	(0.518)	(0.346)	(0.459)	(0.378)
Average yrs of schooling of male adults	-0.018	-0.021	-0.019	-0.019
	(-0.921)	(-1.157)	(-1.032)	(-1.009)
Average yrs of schooling of female adults	0.022	0.018	0.021	0.022
	(1.055)	(0.814)	(1.036)	(1.065)
Per capita value of productive assets	-0.000	-0.000	-0.000	-0.000
	(-0.356)	(-0.339)	(-0.243)	(-0.423)
Per capita value of nonproductive assets	-0.000	-0.000	-0.000	-0.000
	(-0.778)	(-1.140)	(-0.982)	(-0.725)
Ln value of livestock	-0.019	-0.025	-0.029	-0.027
	(-0.667)	(-0.890)	(-0.987)	(-0.940)
Ln land used other than owned land	-0.028	-0.026	-0.021	-0.020
	(-0.431)	(-0.406)	(-0.315)	(-0.300)
Log travel time to nearby big town	0.135	-0.184	-0.018	0.147
	(0.133)	(-0.186)	(-0.019)	(0.151)
Rainfall mm (5 year average)	0.007	0.010	0.008	0.007
	(0.581)	(0.998)	(0.726)	(0.677)
Temperature (5 year average)	-0.001	-0.001	-0.001	-0.001
	(-1.155)	(-1.473)	(-1.203)	(-1.064)
Wind (5 year average)	-0.000	-0.001	-0.000	-0.000
	(-0.185)	(-0.241)	(-0.131)	(-0.138)
Constant	-0.012	-0.692	-0.430	-1.144
	(-0.001)	(-0.071)	(-0.046)	(-0.116)
Observations	960	960	960	960
R-squared	0.191	0.241	0.225	0.208
Number of hhdid	480	480	480	480
HH FE	*Yes*	*Yes*	*Yes*	*Yes*
Year*Province dummies	*Yes*	*Yes*	*Yes*	*Yes*

Notes: Robust t-statistics in parentheses; ***Significant at 1% level, **Significant at 5%, *Significant at 10%. Robust standard errors are clustered at community level. Estimates are weighted by attrition weights. HH: Household, HHH: Household head.

‡The intensification index is created by using Manure (t/ha) and Chemical fertilizer (10kg/ha)

Table 2.12: Correlation between past soil fertility and current agricultural intensification

Explanatory variables	(1) Manure (t/ha)	(2)	(3) ln Chemical fertilizer (10kg/ha)	(4)	(5) Chemical fertilizer (10kg/ha)	(6)	(7) Agricultural intensification index‡	(8)
Inverse of owned land per capita	0.029**	0.028**	0.006	0.005	0.040	0.034	0.006	0.006
	(2.008)	(1.996)	(0.787)	(0.634)	(0.928)	(0.819)	(1.112)	(1.018)
Ln population density	0.463**	0.419**	0.972***	0.926***	0.832	0.599	0.127*	0.096
	(2.538)	(2.395)	(4.067)	(3.782)	(1.378)	(0.922)	(1.756)	(1.237)
Past soil quality (in 2004)	0.067	0.183	0.275***	0.397***	1.034***	1.652***	0.128***	0.208***
	(1.194)	(1.606)	(3.788)	(3.522)	(3.944)	(3.854)	(4.019)	(4.070)
Past soil quality (in 2004) squared		-0.029		-0.031		-0.154*		-0.020**
		(-1.477)		(-1.340)		(-1.923)		(-2.054)
Area cultivated (ha)	-0.213**	-0.222**	0.003	-0.007	-0.517*	-0.566*	-0.074**	-0.081**
	(-2.087)	(-2.188)	(0.033)	(-0.067)	(-1.841)	(-1.968)	(-2.055)	(-2.220)
1 if female HHH	-0.512**	-0.482**	-0.221	-0.190	0.060	0.220	-0.023	-0.002
	(-2.379)	(-2.304)	(-0.954)	(-0.805)	(0.045)	(0.166)	(-0.141)	(-0.012)
Age of HHH	-0.001	-0.002	-0.004	-0.006	-0.026	-0.033	-0.003	-0.004
	(-0.060)	(-0.211)	(-0.492)	(-0.674)	(-0.989)	(-1.254)	(-0.974)	(-1.250)
Years of education of HHH	-0.014	-0.015	-0.021	-0.021	-0.041	-0.043	-0.006	-0.006
	(-0.325)	(-0.335)	(-0.699)	(-0.714)	(-0.418)	(-0.452)	(-0.464)	(-0.499)
Number of adult males	0.114	0.131	-0.170*	-0.152*	-0.048	0.042	0.001	0.013
	(1.321)	(1.541)	(-1.966)	(-1.862)	(-0.220)	(0.199)	(0.036)	(0.501)
Number of adult females	-0.075	-0.070	-0.093	-0.088	0.113	0.140	0.009	0.013
	(-0.687)	(-0.641)	(-0.837)	(-0.794)	(0.445)	(0.541)	(0.282)	(0.384)
Family size	-0.067	-0.070	0.034	0.032	-0.012	-0.025	-0.005	-0.007
	(-1.602)	(-1.641)	(0.725)	(0.681)	(-0.091)	(-0.204)	(-0.343)	(-0.477)
Average yrs of schooling of female adults	0.020	0.019	0.033	0.031	0.104	0.099	0.014	0.013
	(0.707)	(0.674)	(1.195)	(1.180)	(1.029)	(0.979)	(1.100)	(1.047)
Average yrs of schooling of male adults	-0.001	-0.001	0.058***	0.058***	0.103	0.105	0.012	0.013
	(-0.036)	(-0.022)	(3.029)	(3.082)	(1.190)	(1.235)	(1.142)	(1.187)
Ln value of assets	0.311**	0.318**	0.242***	0.249***	0.456*	0.493**	0.073**	0.078**
	(2.216)	(2.229)	(2.740)	(2.864)	(1.824)	(2.043)	(2.320)	(2.562)
Ln value of livestock	0.368***	0.361***	0.002	-0.005	0.065	0.027	0.029	0.024
	(3.964)	(4.026)	(0.035)	(-0.096)	(0.347)	(0.159)	(1.293)	(1.181)
Ln land used other than owned land	-0.103	-0.118	0.198*	0.183*	0.068	-0.007	0.002	-0.008
	(-1.086)	(-1.197)	(1.837)	(1.689)	(0.224)	(-0.022)	(0.056)	(-0.205)
Log travel time to nearby big town	-0.539	-0.482	1.099***	1.159***	3.043***	3.345***	0.332***	0.372***
	(-1.077)	(-0.982)	(3.575)	(3.633)	(3.132)	(3.215)	(2.787)	(2.916)
Constant	-5.769**	-5.705**	-13.85***	-13.79***	-21.78***	-21.44***	-3.559***	-3.515***
	(-2.330)	(-2.316)	(-6.409)	(-6.407)	(-4.069)	(-3.949)	(-4.972)	(-4.846)
Observations	480	480	480	480	480	480	480	480
R-squared	0.198	0.200	0.302	0.307	0.172	0.181	0.195	0.205
Province dummies	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*

Notes: Robust t-statistics in parentheses; ***Significant at 1% level, **Significant at 5%, *Significant at 10%. Robust standard errors are clustered at community level. HH: Household, HHH: Household head.
‡The intensification index is created by using Manure (t/ha) and Chemical fertilizer (10kg/ha).

Table 3.1: Distribution of soil sampled households

Region	District	Community	Households
Eastern	Bugiri	3	17
	Busia	1	6
	Iganga	3	25
	Jinja	3	19
	Kamuli	3	22
	Mayuge	6	39
	Mbale	6	42
	Pallisa	1	7
	Sironko	5	36
	Tororo	2	14
Central	Kayunga	1	2
	Luwero	2	8
	Masaka	6	32
	Mpigi	2	8
	Mubende	3	3
	Mukono	4	11
	Nakasongola	2	10
	Rakai	4	18
	Wakiso	2	8
West	Kabale	8	36
	Kabarole	3	15
	Kasese	2	5
	Kisoro	2	9
	Mbarara	2	16
	Rukungiri	1	1
	Total	77	409

Source: Author's computation using 2003 and 2012 RePEAT data

Table 3.2: Summary statistics and *ttest* for equality of means of key variables

	Year=2003		Year=2012			
Variable	Mean	Sd	Mean	Sd	Mean Diff	Sign
Soil quality index	0.069	1.86	-0.069	1.77	0.138	
Carbon (%)	2.38	1.44	2.40	0.39	-0.02	
Nitrogen (%)	0.22	0.14	0.17	0.03	0.05	***
Extractable Phosphorus ($cmol_c$ /kg)	11.96	7.60	31.79	25.93	-19.83	***
Extractable Potassium (cmolc /kg)	0.65	0.32	0.99	0.48	-0.35	***
Extractable Calcium (cmolc /kg)	7.26	6.33	9.91	6.34	-2.65	***
Soil pH	6.62	0.53	6.19	0.54	0.43	***
Land-labor ratio	0.50	1.38	0.49	1.53	0.01	
Land ownership (ha)	2.04	14.13	1.81	13.14	0.01	*
Owned land per capita	0.25	0.41	0.16	0.52	0.09	***
Community population density	447.43	621.23	496.49	569.13	-49.07	
Inorganic fertilizer use (Kgs/ha)[d]	0.31	2.73	2.26	9.01	-1.95	***
Manure use (Kgs/ha)	12.44	95.88	0.81	8.29	11.63	**
% of households used inorganic fertilizer	0.03	0.18	0.14	0.35	-0.11	***
% of households used manure	0.03	0.17	0.05	0.22	-0.02	
% of households used fertilizer	0.06	0.24	0.17	0.38	-0.11	***
1 female headed household	0.115	0.32	0.161	0.37	-0.046	**
Age of household head	45.826	14.24	53.743	13.22	-7.917	***
Years of schooling of household head	5.919	3.82	6.103	3.87	-0.183	
Family size	8.592		10.296		-1.704	***
Observations	409		409			

Notes: [d]Converted to NPK equivalent

Table 3.3: Pairwise correlations between soil variables and key determinants

	1)	2)	3)	4	5)	6)	7)	8)	9)	10)
1)SQ	1									
2)Carbon	0.725***	1								
3)N	0.655***	0.934***	1							
4)P	0.431***	0.211***	0.004	1						
5)K	0.740***	0.474***	0.299***	0.459***	1					
6)Cal	0.692***	0.267***	0.157***	0.407***	0.631***	1				
7)pH	0.433***	0.001	0.064*	0.054	0.160***	0.474***	1			
8)IOLpc	-0.049	-0.030	-0.041	-0.013	-0.001	-0.010	-0.020	1		
9) Pop	-0.094***	-0.122***	-0.138***	-0.027	-0.009	-0.038	0.050	0.191***	1	
10)Private	0.109***	0.055	0.108***	-0.016	0.018	0.032	0.064	-0.067*	0.004	1

Notes: ***1%, **5%, and *10% significance level, respectively. 1) Soil quality index, 3) N=Nitrogen, 4) P=Phosphorus, 5) K=Potassium, 6) Cal=Calcium, 7) pH=Soil pH, 8) IOLpc=Inverse of owned land per capita 9) Pop=Population density

Table 3.4: Pairwise correlations between changes in soil variables and key determinants

	1)	2)	3)	4	5)	6)	7)	8)	9)
1)SQ	1								
2)Carbon	0.543***	1							
3)N	0.479***	0.970*	1						
4)P	0.407***	-0.111**	-0.178***	1					
5)K	0.678***	0.193***	0.127***	0.227***	1				
6)Cal	0.595***	0.009	-0.045	0.475***	0.423***	1			
7)pH	0.456***	-0.002	0.009	0.164***	0.297***	0.540***	1		
8) IOLpc	-0.050	-0.0026	0.007	-0.028	-0.020	-0.044	-0.050	1	
9) Pop	0.038	0.014	-0.024	0.132***	0.024	0.018	-0.044	0.128***	1

Notes: ***1%, **5%, and *10% significance level, respectively. 1) Soil quality index, 3) N=Nitrogen, 4) P=Phosphorus, 5) K=Potassium, 6) Cal=Calcium, 7) pH=Soil pH, 8) IOLpc=Inverse of owned land per capita 9) Pop=Population density

Table 3.5: Factor loadings of soil quality index

	Year		
	2003	2012	Pooled years
	Factor loadings		
Individual elements			
Carbon (%)	0.48	0.45	0.47
Nitrogen (%)	0.46	0.33	0.41
Extractable Phosphorus ($cmol_c$ /kg)	0.40	0.33	0.37
Extractable Potassium (cmolc /kg)	0.44	0.49	0.46
Extractable Calcium (cmolc /kg)	0.42	0.50	0.46
Soil pH	0.19	0.31	0.24
Proportion of variation explained	0.56	0.55	0.55
Mean of soil quality index	0.069	-0.069	0.00
S.D of soil quality index	1.86	1.77	1.82

Table 3.6: Factor loadings of agricultural intensification

	Year		
	2003	2012	Pooled years
	Factor loadings		
Household-level			
Individual elements			
Quantity of chemical fertilizer (Kg/Ha)[d]	0.52	0.71	0.67
Quantity of manure (Kg/Ha)	0.57	0.03	0.26
Improved maize seeds (=1)	0.64	0.71	0.70
Proportion of variation explained	0.36	0.42	0.40
Mean of agricultural intensification index	-0.08	0.08	0.00
S.D of agricultural intensification index	1.00	1.18	1.10
Parcel-level			
Quantity of chemical fertilizer (Kg/Ha)[d]	0.67	0.70	0.70
Quantity of manure (Kg/Ha)	0.58	0.07	0.18
Improved maize seeds (=1)	0.46	0.71	0.69
Proportion of variation explained	0.38	0.40	0.39
Mean of agricultural intensification index	-0.12	0.09	0.00
S.D of agricultural intensification index	0.87	1.21	1.08

[d]Converted to NPK equivalent

Table 3.7: Impact of population pressure on soil nutrients

Explanatory Variables	(1) lnc	(2) lnc	(3) lnNitr	(4) lnNitr	(5) lnpho	(6) lnpho
Inverse of owned land per capita	-0.0002	-0.0001	0.0002	-0.0001	-0.002	-0.005***
	(-0.299)	(-0.389)	(0.170)	(-0.016)	(-1.602)	(-3.580)
Log population density	-0.005	0.009	-0.021	-0.002	-0.090*	-0.109*
	(-0.141)	(0.336)	(-0.643)	(-0.059)	(-1.699)	(-1.956)
1=female head	-0.007	0.006	-0.026	-0.036	-0.019	-0.059
	(-0.140)	(0.101)	(-0.462)	(-0.522)	(-0.177)	(-0.460)
Head's education	0.002	-0.002	0.005	0.000	0.002	0.002
	(0.264)	(-0.268)	(0.540)	(0.003)	(0.104)	(0.106)
Age of HHH	0.003	0.003	0.005***	0.004*	-0.003	-0.003
	(1.622)	(1.244)	(2.685)	(1.753)	(-1.033)	(-0.787)
Household size	0.005	-0.001	0.006	0.001	0.013	0.018
	(1.031)	(-0.148)	(1.105)	(0.089)	(1.190)	(1.542)
Number of adult men	0.005	0.002	0.000	-0.005	0.032	0.022
	(0.401)	(0.167)	(0.004)	(-0.332)	(1.510)	(0.801)
Number of adult women	-0.004	0.004	-0.008	0.001	0.035	-0.017
	(-0.239)	(0.176)	(-0.442)	(0.052)	(1.283)	(-0.463)
Av. yrs of schooling of male adults	0.009	0.005	0.006	0.001	0.008	0.011
	(1.451)	(0.663)	(0.889)	(0.115)	(0.890)	(0.925)
Av. yrs of schooling of female adults	-0.001	0.001	0.000	0.002	-0.009	-0.005
	(-0.107)	(0.097)	(0.002)	(0.239)	(-0.865)	(-0.352)
Log per capita value of productive assets	0.019	0.021	0.016	0.015	0.027	0.031
	(1.320)	(1.075)	(0.956)	(0.717)	(0.958)	(0.965)
Log per capita value of nonproductive assets	-0.024	-0.025	-0.024	-0.021	-0.031	-0.044
	(-1.451)	(-1.341)	(-1.316)	(-1.053)	(-1.051)	(-1.410)
Log value of livestock	0.010	0.007	0.011	0.008	0.002	0.004
	(1.098)	(0.779)	(1.215)	(0.837)	(0.138)	(0.219)
Log land used other than own land	-0.000	0.002	-0.004	0.001	0.020	0.018
	(-0.043)	(0.240)	(-0.522)	(0.107)	(1.652)	(1.247)
Log distance to the nearest district town	-0.003	-0.018	-0.007	-0.023	-0.004	-0.038
	(-0.108)	(-0.628)	(-0.209)	(-0.730)	(-0.066)	(-0.668)
Rainfall mm (5 year average)	0.001	0.005	0.001	0.005	-0.002	-0.013
	(0.149)	(0.521)	(0.070)	(0.424)	(-0.111)	(-0.693)
Temperature °c (5 year average)	0.029	0.033	0.023	0.024	-0.060	-0.094*
	(1.017)	(1.013)	(0.721)	(0.646)	(-1.065)	(-1.706)
Wind 10m (m/s) (5 year average)	0.105	0.150	0.191**	0.281**	0.282	0.171
	(1.171)	(1.524)	(2.178)	(2.567)	(1.430)	(0.899)
Constant	-2.339	-2.907	-4.830**	-5.445*	5.479	9.120**
	(-1.097)	(-1.191)	(-1.998)	(-1.916)	(1.319)	(2.335)
Observations	818	649	818	649	818	649
R-squared	0.234	0.262	0.299	0.308	0.686	0.700
Number of households	409	336	409	336	409	336
HH FE	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Year FE	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Year*Region	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*

Notes: Robust t-statistics in parentheses. ***,**,and * represent significance at 1%, 5%, and 10%, respectively. Robust standard errors are clustered at community level. Estimates are weighted by attrition weights. HH: Household, HHH: Household head, lnc: log of carbon content, lnNitr: log of nitrogen, lnpho: log of phosphorous. In even-numbered columns soil were collected from similar parcels in both rounds. In odd-numbered columns we are not very sure whether soils were collected in the same parcels, although during second round of survey households were insisted to indicate the parcel from which soils were taken in the first round so that soils could be taken from the same parcels.

Table 3.7 cont.: Impact of population pressure on soil nutrients

Explanatory Variables	(7) lnPot	(8) lnpot	(9) lnCa	(10) lnca	(11) pH	(12) pH	(13) pH dum.	(14) pH dum.
Inverse of owned land per capita	0.0002	-0.001	-0.001**	-0.003***	-0.002**	-0.003*	-0.002***	-0.002
	(0.100)	(-1.139)	(-2.183)	(-3.042)	(-2.093)	(-1.968)	(-3.181)	(-1.343)
Log population density	-0.077*	-0.127***	-0.095**	-0.171***	-0.008	-0.080	0.009	-0.045
	(-1.770)	(-2.835)	(-2.141)	(-4.121)	(-0.167)	(-1.656)	(0.249)	(-1.111)
1=female head	0.022	0.117	-0.042	0.030	-0.122	-0.129	-0.158	-0.185*
	(0.253)	(1.105)	(-0.551)	(0.349)	(-1.247)	(-1.144)	(-1.588)	(-1.773)
Head's education	-0.024**	-0.035***	-0.004	-0.009	0.006	0.009	-0.011	-0.010
	(-2.335)	(-2.699)	(-0.329)	(-0.614)	(0.416)	(0.548)	(-0.725)	(-0.576)
Age of HHH	-0.001	-0.000	-0.004	-0.002	0.002	0.003	0.004	0.008*
	(-0.554)	(-0.136)	(-1.536)	(-0.596)	(0.663)	(0.836)	(1.217)	(1.803)
Household size	-0.007	-0.002	-0.011	-0.008	-0.007	-0.007	-0.000	0.002
	(-0.840)	(-0.241)	(-1.080)	(-0.767)	(-0.740)	(-0.573)	(-0.007)	(0.135)
Number of adult men	0.003	-0.002	0.036*	0.035	0.018	0.006	-0.020	-0.044
	(0.171)	(-0.103)	(1.734)	(1.442)	(0.759)	(0.214)	(-0.973)	(-1.541)
Number of adult women	0.025	0.005	0.066**	0.046	0.074***	0.064*	0.019	0.041
	(0.953)	(0.146)	(2.619)	(1.378)	(2.900)	(1.753)	(0.789)	(1.467)
Av. yrs of schooling of male adults	0.016*	0.024**	0.012	0.016	0.001	0.005	0.007	0.006
	(1.807)	(2.096)	(1.402)	(1.630)	(0.071)	(0.415)	(0.585)	(0.465)
Av. yrs of schooling of female adults	-0.015	-0.013	-0.014	-0.012	-0.019*	-0.026**	-0.003	-0.006
	(-1.393)	(-0.952)	(-1.465)	(-0.877)	(-1.977)	(-2.035)	(-0.309)	(-0.441)
Log per capita value of productive assets	0.040*	0.029	0.023	0.016	-0.006	-0.012	0.014	0.012
	(1.722)	(1.103)	(0.818)	(0.488)	(-0.240)	(-0.408)	(0.583)	(0.435)
Log per capita value of nonproductive assets	-0.080**	-0.076**	-0.040*	-0.027	0.013	0.024	0.016	0.026
	(-2.292)	(-2.029)	(-1.747)	(-0.941)	(0.509)	(0.746)	(0.587)	(0.850)
Log value of livestock	0.038**	0.040**	0.009	0.009	-0.008	-0.008	0.013	0.024
	(2.556)	(2.443)	(0.622)	(0.524)	(-0.412)	(-0.402)	(0.823)	(1.385)
Log land used other than own land	-0.005	-0.013	0.003	0.004	0.007	0.020	-0.017	-0.007
	(-0.358)	(-0.736)	(0.318)	(0.310)	(0.552)	(1.368)	(-1.253)	(-0.461)
Log distance to the nearest district town	-0.055	-0.092	-0.008	-0.030	0.045	0.028	0.035	0.025
	(-0.956)	(-1.660)	(-0.189)	(-0.757)	(1.115)	(0.614)	(1.056)	(0.631)
Rainfall mm (5 year average)	0.011	0.013	0.007	0.004	0.001	-0.012	0.020**	0.014
	(0.778)	(0.914)	(0.482)	(0.360)	(0.051)	(-0.662)	(2.034)	(1.349)
Temperature °c (5 year average)	0.025	0.013	-0.032	-0.035	-0.073	-0.091	0.016	-0.007
	(0.593)	(0.278)	(-0.832)	(-0.828)	(-1.340)	(-1.422)	(0.422)	(-0.170)
Wind 10m (m/s) (5 year average)	0.139	0.077	0.082	-0.027	0.256	0.141	0.037	0.161
	(0.934)	(0.547)	(0.689)	(-0.248)	(1.412)	(0.684)	(0.261)	(0.907)
Constant	-2.606	-1.058	4.294	5.522*	10.082**	12.676***	-1.939	-1.033
	(-0.820)	(-0.308)	(1.374)	(1.756)	(2.613)	(2.775)	(-0.723)	(-0.343)
Observations	818	649	818	649	818	649	818	649
R-squared	0.400	0.445	0.330	0.382	0.357	0.361	0.156	0.181
Number of households	409	336	409	336	409	336	409	336
HH FE	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Year FE	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Year*Region	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*

Notes: Robust t-statistics in parentheses. ***Significant at 1% level, Significant at 5%, Significant at 10%. Robust standard errors are clustered at community level. Estimates are weighted by attrition weights. HH: Household, HHH: Household head, lnPot: log of potassium, lnCal: log of calcium, pH: soil pH. In even-numbered columns I use a subsample of households whose soil parcels were exactly matched in both rounds. In odd-numbered columns, I use full sample including households that had no parcel identification in one of the rounds.

In columns 13 and 14, I use soil pH as a dummy variable equals to one if soil pH >=6.6 & soil pH<=7.3 (neutral) and zero otherwise

Table 3.8: Impact of population pressure on soil quality

Dependent variable: *Soil quality index*

	Full sample			Sub-sample		
	(1)	(2)	(3)	(4)	(5)	(6)
Explanatory Variables	index	index5	sindexdu my	index	index5	sindexdu my
Inverse of owned land per capita	-0.005	-0.004	-0.004	-0.010***	-0.009***	-0.009***
	(-1.541)	(-1.363)	(-1.541)	(-3.844)	(-3.367)	(-3.566)
Log population density	-0.291***	-0.287***	-0.284***	-0.430***	-0.392***	-0.403***
	(-2.789)	(-2.913)	(-2.809)	(-3.797)	(-3.458)	(-3.503)
1=female head	-0.088	-0.035	-0.076	0.034	0.091	0.043
	(-0.295)	(-0.124)	(-0.259)	(0.094)	(0.258)	(0.117)
Head's education	-0.022	-0.026	-0.029	-0.052	-0.059	-0.061
	(-0.560)	(-0.722)	(-0.761)	(-1.143)	(-1.419)	(-1.407)
Age of HHH	0.001	0.001	0.002	0.003	0.002	0.004
	(0.132)	(0.072)	(0.202)	(0.328)	(0.207)	(0.413)
Household size	0.002	0.007	0.006	0.009	0.014	0.014
	(0.088)	(0.247)	(0.232)	(0.273)	(0.409)	(0.407)
Number of adult men	0.046	0.033	0.029	0.015	0.008	-0.003
	(0.839)	(0.639)	(0.543)	(0.208)	(0.111)	(-0.045)
Number of adult women	0.109	0.069	0.075	0.034	-0.002	0.010
	(1.376)	(0.890)	(0.964)	(0.309)	(-0.019)	(0.090)
Av. yrs of schooling of male adults	0.050	0.052*	0.053*	0.057	0.056	0.057
	(1.625)	(1.815)	(1.831)	(1.459)	(1.537)	(1.555)
Av. yrs of schooling of female adults	-0.037	-0.028	-0.029	-0.030	-0.018	-0.020
	(-1.177)	(-0.928)	(-0.976)	(-0.657)	(-0.413)	(-0.455)
Log per capita value of productive assets	0.105	0.111	0.114	0.097	0.105	0.107
	(1.435)	(1.563)	(1.594)	(1.030)	(1.144)	(1.151)
Log per capita value of nonproductive assets	-0.175**	-0.188**	-0.183**	-0.154	-0.173*	-0.165*
	(-2.031)	(-2.243)	(-2.156)	(-1.592)	(-1.871)	(-1.757)
Log value of livestock	0.052	0.058	0.061	0.051	0.058	0.063
	(1.205)	(1.440)	(1.483)	(0.980)	(1.226)	(1.332)
Log land used other than own land	0.003	-0.003	-0.008	0.009	-0.003	-0.004
	(0.076)	(-0.105)	(-0.224)	(0.202)	(-0.061)	(-0.094)
Log distance to the nearest district town	-0.045	-0.068	-0.059	-0.167	-0.187	-0.180
	(-0.294)	(-0.454)	(-0.388)	(-1.225)	(-1.376)	(-1.312)
Rainfall mm (5 year average)	0.032	0.033	0.038	0.023	0.029	0.033
	(0.749)	(0.818)	(0.933)	(0.519)	(0.700)	(0.774)
Temperature °c (5 year average)	0.025	0.067	0.069	-0.031	0.017	0.014
	(0.214)	(0.628)	(0.645)	(-0.232)	(0.138)	(0.109)
Wind 10m (m/s) (5 year average)	0.737*	0.649	0.653	0.623	0.604	0.638
	(1.725)	(1.565)	(1.585)	(1.539)	(1.460)	(1.573)
Constant	-5.244	-7.670	-8.077	0.904	-2.832	-3.007
	(-0.561)	(-0.864)	(-0.905)	(0.092)	(-0.301)	(-0.317)
Observations	818	818	818	649	649	649
R-squared	0.114	0.124	0.123	0.149	0.154	0.154
Number of households	409	409	409	336	336	336
HH FE	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Year FE	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Year*Region	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*

Notes: Robust t-statistics in parentheses. ***Significant at 1% level, Significant at 5%, Significant at 10%. Robust standard errors are clustered at community level. Estimates are weighted by attrition weights. HH: Household, HHH: Household head. In columns (2 and 5) soil quality index is created by using five macro-nutrients (excluding soil pH). In columns (3 and 6) soil quality index by using six soil variables but soil pH enters as a dummy variable i.e. 1 if neutral (soil pH >=6.6 & soil pH<=7.3) and 0 otherwise.
In columns 1-3 I use full sample including households that had no parcel identification in one of the rounds. In columns 4-6 I use subsample of households whose soil parcels were exactly matched in both rounds.

Table 3.9: Impact of land ownership rights on soil nutrients

Explanatory Variables	(1) lnc	(2) lnc	(3) lnNitr	(4) lnNitr	(5) lnpho	(6) lnpho
Inverse of owned land per capita	-0.000	0.001	-0.000	0.001	-0.005***	-0.005
	(-0.529)	(0.581)	(-0.108)	(0.464)	(-3.826)	(-1.494)
Log population density	0.009	0.016	-0.002	0.006	-0.110*	-0.100
	(0.321)	(0.503)	(-0.066)	(0.185)	(-1.990)	(-1.572)
1 if a parcel is under private ownership	0.050		0.033		0.122	
	(1.462)		(0.909)		(1.663)	
§Private dummy*Year dummy(year=2012)		0.039		0.038		-0.002
		(0.712)		(0.630)		(-0.001
1=female head	0.017	-0.037	-0.029	-0.109	-0.034	0.133
	(0.269)	(-0.486)	(-0.427)	(-1.230)	(-0.274)	(0.787)
Head's education	-0.003	-0.006	-0.000	-0.007	0.002	0.006
	(-0.284)	(-0.464)	(-0.004)	(-0.511)	(0.095)	(0.281)
Age of HHH	0.002	0.002	0.004*	0.003	-0.003	-0.005
	(1.103)	(0.851)	(1.667)	(1.169)	(-0.977)	(-0.911)
Household size	-0.001	-0.007	0.000	-0.005	0.017	0.015
	(-0.218)	(-0.946)	(0.049)	(-0.667)	(1.439)	(0.929)
Number of adult men	0.002	-0.021	-0.005	-0.028	0.022	0.002
	(0.168)	(-1.221)	(-0.330)	(-1.501)	(0.826)	(0.064)
Number of adult women	0.005	0.026	0.002	0.022	-0.014	-0.016
	(0.232)	(1.029)	(0.088)	(0.879)	(-0.383)	(-0.308)
Av. yrs of schooling of male adults	0.006	0.002	0.001	-0.004	0.013	0.007
	(0.742)	(0.173)	(0.163)	(-0.408)	(1.056)	(0.398)
Av. yrs of schooling of female adults	-0.000	-0.000	0.001	0.000	-0.008	0.005
	(-0.067)	(-0.014)	(0.138)	(0.016)	(-0.534)	(0.368)
Log per capita value of productive assets	0.023	0.024	0.017	0.012	0.036	0.032
	(1.142)	(1.090)	(0.761)	(0.523)	(1.072)	(0.692)
Log per capita value of nonproductive assets	-0.024	-0.021	-0.020	-0.022	-0.043	-0.048
	(-1.338)	(-0.903)	(-1.044)	(-0.883)	(-1.410)	(-1.047)
Log value of livestock	0.007	-0.001	0.008	0.004	0.004	-0.001
	(0.769)	(-0.085)	(0.831)	(0.288)	(0.211)	(-0.034)
Log land used other than own land	0.002	0.008	0.001	0.005	0.018	0.012
	(0.239)	(0.752)	(0.105)	(0.397)	(1.295)	(0.607)
Log distance to the nearest district town	-0.018	0.006	-0.023	-0.004	-0.038	0.026
	(-0.616)	(0.157)	(-0.720)	(-0.114)	(-0.684)	(0.417)
Rainfall mm (5 year average)	0.005	0.001	0.005	0.000	-0.014	-0.015
	(0.493)	(0.087)	(0.409)	(0.004)	(-0.722)	(-0.734)
Temperature °c (5 year average)	0.034	0.030	0.024	0.023	-0.092*	-0.089
	(1.006)	(0.740)	(0.647)	(0.497)	(-1.681)	(-1.307)
Wind 10m (m/s) (5 year average)	0.143	0.122	0.276**	0.252**	0.153	0.122
	(1.458)	(1.256)	(2.550)	(2.455)	(0.815)	(0.569)
Constant	-2.963	-2.387	-5.481*	-4.944	9.232**	8.920*
	(-1.168)	(-0.780)	(-1.884)	(-1.433)	(2.376)	(1.802)
Observations	649	406	649	406	649	406
R-squared	0.267	0.294	0.310	0.325	336	0.699
Number of households	336	203	336	203	0.703	203
HH FE	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Year FE	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Year*Region	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*

Notes: §Private land rights are time-invariant. Robust t-statistics in parentheses.***Significant at 1% level, **Significant at 5%, *Significant at 10%. Robust standard errors are clustered at community level. Estimates are weighted by attrition weights. HH: Household, HHH: Household head, lnc: log of carbon content, lnNitr: log of nitrogen, lnpho: log of phosphorous.

Table 3.9 cont.: Impact of land ownership rights on soil nutrients

Explanatory Variables	(7) lnpot	(8) lnpot	(9) lnca	(10) lnca	(11) pH	(12) pH	(13) pH dum.	(14) pH dum.
Inverse of owned land per capita	-0.002	-0.001	-0.003***	-0.003	-0.003**	-0.002	-0.002	-0.003
	(-1.405)	(-0.248)	(-3.332)	(-1.273)	(-2.023)	(-0.574)	(-1.418)	(-1.287)
Log population density	-0.128***	-0.123***	-0.172***	-0.202***	-0.080	-0.104*	-0.045	-0.069
	(-2.927)	(-2.681)	(-4.189)	(-4.215)	(-1.660)	(-1.904)	(-1.118)	(-1.584)
1 if a parcel is under private ownership	0.166***		0.124***		0.041		0.026	
	(3.253)		(2.853)		(0.611)		(0.484)	
§Private dummy *Year dummy(year=2012)		0.299***		0.161		0.169*		0.187*
		(2.601)		(1.602)		(1.712)		(1.733)
1=female head	0.151	0.183	0.056	0.108	-0.121	-0.036	-0.179*	-0.311**
	(1.410)	(1.120)	(0.689)	(0.989)	(-1.077)	(-0.212)	(-1.762)	(-2.465)
Head's education	-0.036***	-0.024	-0.009	-0.007	0.009	0.015	-0.010	-0.010
	(-2.834)	(-1.347)	(-0.655)	(-0.328)	(0.546)	(0.551)	(-0.580)	(-0.475)
Age of HHH	-0.001	0.001	-0.002	-0.003	0.003	0.007	0.008*	0.009
	(-0.423)	(0.242)	(-0.809)	(-0.559)	(0.771)	(1.209)	(1.769)	(1.653)
Household size	-0.004	-0.006	-0.009	-0.006	-0.007	0.009	0.001	0.001
	(-0.414)	(-0.568)	(-0.878)	(-0.488)	(-0.608)	(0.604)	(0.115)	(0.092)
Number of adult men	-0.002	-0.012	0.036	0.021	0.006	-0.022	-0.044	-0.057*
	(-0.100)	(-0.512)	(1.470)	(0.761)	(0.216)	(-0.631)	(-1.537)	(-1.681)
Number of adult women	0.009	0.002	0.049	0.048	0.065*	0.027	0.041	0.062
	(0.274)	(0.041)	(1.516)	(1.101)	(1.773)	(0.554)	(1.495)	(1.390)
Av. yrs of schooling of male adults	0.026**	0.012	0.017*	0.007	0.006	-0.023	0.007	-0.012
	(2.296)	(0.769)	(1.780)	(0.514)	(0.454)	(-1.223)	(0.486)	(-0.665)
Av. yrs of schooling of female adults	-0.017	-0.001	-0.015	-0.001	-0.027**	-0.006	-0.006	0.002
	(-1.185)	(-0.033)	(-1.053)	(-0.052)	(-2.067)	(-0.378)	(-0.484)	(0.149)
Log per capita value of productive assets	0.035	0.013	0.021	0.009	-0.010	-0.032	0.013	0.044
	(1.283)	(0.304)	(0.631)	(0.206)	(-0.349)	(-0.801)	(0.472)	(1.160)
Log per capita value of nonproductive assets	-0.075**	-0.062	-0.025	-0.018	0.025	0.030	0.027	0.010
	(-2.064)	(-1.417)	(-0.921)	(-0.479)	(0.760)	(0.707)	(0.861)	(0.246)
Log value of livestock	0.040**	0.030*	0.009	-0.002	-0.008	0.009	0.024	0.028
	(2.463)	(1.846)	(0.511)	(-0.129)	(-0.406)	(0.363)	(1.379)	(1.522)
Log land used other than own land	-0.013	-0.016	0.004	0.008	0.020	0.006	-0.007	-0.015
	(-0.768)	(-0.795)	(0.312)	(0.471)	(1.367)	(0.338)	(-0.461)	(-0.786)
Log distance to the nearest district town	-0.092	-0.072	-0.030	0.009	0.028	0.035	0.025	0.049
	(-1.665)	(-1.152)	(-0.779)	(0.169)	(0.615)	(0.642)	(0.630)	(1.147)
Rainfall mm (5 year average)	0.013	0.020	0.004	0.009	-0.012	0.000	0.014	0.009
	(0.899)	(1.259)	(0.326)	(0.481)	(-0.665)	(0.004)	(1.332)	(0.805)
Temperature °c (5 year average)	0.016	0.051	-0.032	-0.013	-0.091	-0.061	-0.007	-0.036
	(0.351)	(0.923)	(-0.803)	(-0.229)	(-1.399)	(-0.811)	(-0.160)	(-0.703)
Wind 10m (m/s) (5 year average)	0.054	0.008	-0.045	-0.084	0.135	0.150	0.157	0.199
	(0.388)	(0.045)	(-0.418)	(-0.528)	(0.660)	(0.627)	(0.883)	(1.153)
Constant	-1.239	-3.403	5.386*	4.536	12.632***	10.114*	-1.062	0.817
	(-0.376)	(-0.859)	(1.772)	(1.024)	(2.733)	(1.928)	(-0.354)	(0.222)
Observations	649	406	649	406	649	406	649	406
R-squared	0.459	0.466	0.393	0.390	0.362	0.375	0.182	0.229
Number of hhid	336	203	336	203	336	203	336	203
HH FE	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Year FE	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Year*Region	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*

Notes: §Private land rights are time-invariant. Robust t-statistics in parentheses.***Significant at 1% level, **Significant at 5%, *Significant at 10%. Robust standard errors are clustered at community level. Estimates are weighted by attrition weights. HH: Household, HHH: Household head, lnPot: log of potassium, lnCal: log of calcium, pH: soil pH.
In columns 13 and 14, I use soil pH as a dummy variable equals to one if pH >=6.6 & pH<=7.3 (neutral) and zero otherwise

Table 3.10: Impact of land ownership rights on soil quality
Dependent variable: *Soil quality index*

Explanatory Variables	(1) index	(2) index	(3) index5	(4) sindexdumy
Inverse of owned land per capita	-0.011***	-0.008	-0.007	-0.008
	(-4.196)	(-1.184)	(-1.056)	(-1.168)
Log population density	-0.434***	-0.469***	-0.417***	-0.434***
	(-3.882)	(-3.688)	-0.007	(-3.431)
1 if a parcel is under private ownership	0.506***			
	(3.243)			
§Private dummy*Year dummy(year=2012)		0.679**	0.624*	0.669*
		(1.981)	(1.841)	(1.923)
1=female head	0.140	0.205	0.214	0.133
	(0.396)	(0.445)	(0.477)	(0.291)
Head's education	-0.053	-0.054	-0.065	-0.067
	(-1.240)	(-0.960)	(-1.301)	(-1.333)
Age of HHH	0.000	0.002	-0.001	0.001
	(0.050)	(0.129)	(-0.119)	(0.057)
Household size	0.005	0.003	-0.002	-0.002
	(0.148)	(0.063)	(-0.047)	(-0.039)
Number of adult men	0.015	-0.063	-0.058	-0.072
	(0.217)	(-0.755)	(-0.740)	(-0.895)
Number of adult women	0.047	0.038	0.021	0.038
	(0.434)	(0.268)	(0.152)	(0.272)
Av. yrs of schooling of male adults	0.063	0.012	0.024	0.021
	(1.635)	(0.241)	(0.506)	(0.441)
Av. yrs of schooling of female adults	-0.042	0.000	0.003	0.003
	(-0.884)	(0.008)	(0.050)	(0.060)
Log per capita value of productive assets	0.116	0.053	0.068	0.079
	(1.199)	(0.399)	(0.529)	(0.599)
Log per capita value of nonproductive assets	-0.149	-0.120	-0.140	-0.137
	(-1.602)	(-0.887)	(-1.079)	(-1.017)
Log value of livestock	0.050	0.023	0.022	0.029
	(0.973)	(0.393)	(0.419)	(0.540)
Log land used other than own land	0.009	0.012	0.007	0.004
	(0.203)	(0.197)	(0.127)	(0.061)
Log distance to the nearest district town	-0.167	0.016	-0.001	0.011
	(-1.247)	(0.089)	(-0.008)	(0.064)
Rainfall mm (5 year average)	0.021	0.020	0.019	0.022
	(0.472)	(0.355)	(0.375)	(0.413)
Temperature °c (5 year average)	-0.022	0.028	0.061	0.051
	(-0.166)	(0.160)	(0.369)	(0.302)
Wind 10m (m/s) (5 year average)	0.551	0.388	0.359	0.404
	(1.385)	(0.748)	(0.743)	(0.821)
Constant	0.325	-1.584	-3.771	-3.501
	(0.033)	(-0.121)	(-0.300)	(-0.275)
Observations	649	406	406	406
R-squared	0.172	0.146	203	0.147
Number of households	336	203	0.145	203
HH FE	*Yes*	*Yes*	*Yes*	*Yes*
Year*Region	*Yes*	*Yes*	*Yes*	*Yes*

Notes: Robust t-statistics in parentheses. ***Significant at 1% level, **Significant at 5%, *Significant at 10%. Robust standard errors are clustered at community level. Estimates are weighted by attrition weights. HH: Household, HHH: Household head. In columns 1-2 soil index is created by using all six soil variables. In column (3) soil quality index is created by using five macro-nutrients (excluding soil pH). In column (4) soil quality index is created by using six soil variables but soil pH enters as a dummy variable i.e., 1 if neutral (soil pH >=6.6 & soil pH<=7.3) and 0 otherwise. §Private land rights are time-invariant.

Table 3.11: Impact of population pressure on input use and intensification

Explanatory Variables	(1) Manure (t/ha)	(2) Chemical (10kg/ha)	(3) Maizehyv (=1)	(4) Intens. index	(5) Intens. Index2
Inverse of owned land per capita	-0.000	0.003	0.000	0.001	-0.001
	(-1.335)	(1.485)	(0.301)	(0.375)	(-0.534)
Log population density	0.001	0.138**	-0.014	0.062	0.101*
	(0.685)	(2.073)	(-0.414)	(1.038)	(1.731)
Cultivated plot size (ha)	0.001	0.023	0.016	0.027	0.019
	(1.106)	(0.299)	(0.412)	(0.460)	(0.954)
1 if female HHH	0.007*	-0.234	-0.089	-0.165	0.041
	(1.748)	(-1.302)	(-1.032)	(-1.031)	(0.402)
Age of HHH	-0.000	0.008*	0.000	0.002	0.000
	(-0.849)	(1.950)	(0.134)	(0.409)	(0.077)
Years of education of HHH	0.000	-0.015	-0.005	-0.019	-0.009
	(0.213)	(-0.657)	(-0.506)	(-0.927)	(-0.634)
Number of adult males	0.003**	-0.014	-0.032*	-0.026	0.057*
	(2.330)	(-0.454)	(-1.730)	(-0.774)	(1.888)
Number of adult females	0.002*	-0.002	0.018	0.018	0.018
	(1.923)	(-0.040)	(0.862)	(0.477)	(0.696)
Family size	-0.001*	-0.000	0.003	-0.002	-0.021
	(-1.961)	(-0.026)	(0.311)	(-0.099)	(-1.640)
Average education attainment of female adults	0.000	-0.042*	0.001	-0.011	-0.007
	(0.615)	(-1.908)	(0.076)	(-0.490)	(-0.364)
Average education attainment of male adults	-0.000	0.013	-0.008	-0.010	-0.004
	(-0.504)	(0.717)	(-1.058)	(-0.697)	(-0.250)
Log value of assets (Ushs)	0.004*	0.007	0.011	0.043	0.081
	(1.973)	(0.082)	(0.402)	(0.548)	(0.915)
Log value of livestock	0.001	0.021	0.035**	0.067**	0.035
	(1.246)	(0.713)	(2.551)	(2.292)	(1.182)
Distance to the nearest district town in kms	0.000	-0.001	-0.000	-0.000	0.001
	(0.443)	(-0.397)	(-0.179)	(-0.234)	(0.258)
Constant	-0.060**	-5.470***	0.048	-1.506**	-1.757**
	(-2.277)	(-6.043)	(0.124)	(-2.070)	(-2.409)
Observations	2,433	2,433	2,433	2,433	2,433
R-squared	0.024	0.053	0.072	0.070	0.028
Number of parcels	1,204	1,204	1,204	1,204	1,204
Parcel fixed effects	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Year FE	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Year*Region dummies	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*

Notes: Robust t-statistics in parentheses. ***Significant at 1% level, **Significant at 5%, *Significant at 10%. Robust standard errors are clustered at community level. Estimates are weighted by attrition weights. HH: Household, HHH: Household head. In column (5) index is created by using three intensification variables. In column (6) index created by using two intensification variables (excluding improved maize adoption).

Table 3.12: Impact of land rights on agricultural intensification

Explanatory variables	(1) Manure (t/ha)	(2) Chemical (10kg/ha)	(5) Agricultural intensification index‡
Inverse of owned land per capita	-0.000	0.003	-0.001
	(-1.287)	(1.464)	(-0.530)
Ln population density	0.001	0.147**	0.103*
	(0.627)	(2.201)	(1.723)
1 if a parcel is under private ownership	0.001	0.344***	0.171*
	(0.405)	(2.985)	(1.668)
Cultivated land size (ha)	0.001	0.038	0.027
	(1.197)	(0.509)	(1.303)
1 if female HHH	0.007*	-0.182	0.073
	(1.745)	(-1.059)	(0.686)
Age of HHH	-0.000	0.006	-0.001
	(-0.864)	(1.658)	(-0.228)
Years of education of HHH	0.000	-0.008	-0.006
	(0.248)	(-0.341)	(-0.393)
Number of adult males	0.003**	-0.002	0.063**
	(2.333)	(-0.066)	(1.998)
Number of adult females	0.002*	-0.009	0.015
	(1.886)	(-0.226)	(0.575)
Family size	-0.001*	0.001	-0.020
	(-1.952)	(0.088)	(-1.552)
Average education attainment of female adults	0.000	-0.048**	-0.009
	(0.605)	(-2.255)	(-0.518)
Average education attainment of male adults	-0.000	0.007	-0.007
	(-0.559)	(0.392)	(-0.470)
Ln value of assets Ushs	0.004**	-0.002	0.079
	(1.994)	(-0.018)	(0.902)
Ln value of livestock	0.001	0.021	0.036
	(1.248)	(0.705)	(1.207)
Distance to the nearest district town in kms	0.000	-0.001	0.001
	(0.437)	(-0.268)	(0.329)
Constant	-0.061**	-5.662***	-1.889**
	(-2.232)	(-6.560)	(-2.552)
Observations	1,945	1,945	1,945
R-squared	0.025	0.079	0.038
Number of pid	872	872	872
HH FE	*Yes*	*Yes*	*Yes*
Year*Region dummies	*Yes*	*Yes*	*Yes*

Notes: Robust t-statistics in parentheses. ***Significant at 1% level, **Significant at 5%, *Significant at 10%. Robust standard errors are clustered at community level. Estimates are weighted by attrition weights. HH: Household, HHH: Household head. In column (3) index created by using two intensification variables (excluding improved maize adoption).

‡The intensification index is created by using Manure (t/ha) and Chemical fertilizer (10kg/ha).

Table 3.13: Correlation between soil quality and agricultural intensification

Dependent variable: *Soil quality index*

Explanatory variables	(1)	(2)	(3)	(4)	(5)
Manure (t/ha)	0.761				
	(1.638)				
Ln Chemical fertilizer (10kg/ha)		0.123**			
		(2.574)			
Chemical fertilizer (10kg/ha)			0.318**		
			(2.403)		
Agriculture intensification index				0.133**	
				(2.143)	
Agriculture intensification index‡					0.009
					(0.103)
Inverse of own land per capita	-0.001	-0.000	-0.001	-0.000	-0.001
	(-0.274)	(-0.192)	(-0.306)	(-0.175)	(-0.351)
Ln population density	-0.200**	-0.205**	-0.207**	-0.203**	-0.192*
	(-2.081)	(-2.113)	(-2.248)	(-2.169)	(-1.939)
1 if female HHH	-0.096	-0.117	-0.098	-0.075	-0.132
	(-0.300)	(-0.374)	(-0.308)	(-0.235)	(-0.410)
Years of education of HHH	-0.016	-0.018	-0.019	-0.015	-0.015
	(-0.600)	(-0.685)	(-0.702)	(-0.585)	(-0.534)
Age of HHH	-0.009	-0.011	-0.010	-0.010	-0.010
	(-1.113)	(-1.242)	(-1.166)	(-1.167)	(-1.161)
Family size	0.006	0.001	0.000	0.001	0.005
	(0.297)	(0.040)	(0.006)	(0.026)	(0.246)
Number of adult males	-0.017	-0.031	-0.023	-0.021	-0.018
	(-0.358)	(-0.602)	(-0.465)	(-0.424)	(-0.359)
Number of adult females	0.061	0.072	0.074	0.075	0.062
	(1.237)	(1.484)	(1.502)	(1.472)	(1.267)
Average education attainment for female adults	-0.045	-0.048	-0.051	-0.049	-0.049
	(-1.420)	(-1.549)	(-1.617)	(-1.550)	(-1.536)
Average education attainment for male adults	0.036	0.040	0.043	0.041	0.037
	(1.243)	(1.340)	(1.463)	(1.393)	(1.237)
Log per capita value of productive assets	0.045	0.042	0.041	0.034	0.050
	(0.637)	(0.585)	(0.561)	(0.467)	(0.695)
Log per capita value of nonproductive assets	-0.103	-0.109	-0.112	-0.110	-0.106
	(-1.330)	(-1.419)	(-1.459)	(-1.429)	(-1.391)
Ln value of livestock	0.040	0.046	0.040	0.038	0.044
	(0.923)	(1.064)	(0.939)	(0.876)	(1.040)
Ln Distance to the nearest district town in kms	-0.082	-0.064	-0.062	-0.072	-0.077
	(-0.587)	(-0.444)	(-0.437)	(-0.500)	(-0.536)
Rainfall mm (5 year average)	-0.001	-0.001	-0.001	-0.001	-0.001
	(-1.414)	(-1.377)	(-1.416)	(-1.266)	(-1.418)
Temperature (5 year average)	0.000*	0.000**	0.001**	0.000**	0.000*
	(1.860)	(2.066)	(2.185)	(2.063)	(1.861)
Wind (5 year average)	0.001	0.001	0.001	0.001	0.000
	(0.741)	(0.910)	(0.953)	(0.922)	(0.690)
Constant	-0.462	-0.215	-1.046	-0.868	-0.457
	(-0.165)	(-0.079)	(-0.382)	(-0.311)	(-0.165)
Observations	818	818	818	818	818
R-squared	0.110	0.108	0.109	0.107	0.098
Number of hhdid	409	409	409	409	409
HH FE	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Year*Region dummies	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*

Notes: Robust t-statistics in parentheses. ***Significant at 1% level, **Significant at 5%, *Significant at 10%. Robust standard errors are clustered at community level. Estimates are weighted by attrition weights. HH: Household, HHH: Household head.

‡The intensification index is created by using Manure (t/ha) and Chemical fertilizer (10kg/ha).

Table 3.14: Correlation between change in soil quality and change in agricultural intensification

Dependent variable: *Change in soil quality index*

Explanatory variables	(1)	(2)	(3)	(4)	(5)
Change in Manure (t/ha)	0.903**				
	(2.148)				
Change in ln Chemical (10kg/ha)		0.071			
		(1.349)			
Change in Chemical (10kg/ha)			0.226*		
			(1.725)		
Change in agricultural intensification index				0.132**	
				(2.128)	
Change in agricultural intensification index‡					0.051
					(0.629)
Inverse of own land per capita	-0.001	-0.001	-0.001	-0.001	-0.001
	(-0.418)	(-0.356)	(-0.325)	(-0.416)	(-0.336)
Ln population density	-0.300***	-0.288***	-0.295***	-0.302***	-0.293***
	(-2.783)	(-2.661)	(-2.698)	(-2.749)	(-2.701)
1 if female HHH	-0.204	-0.181	-0.181	-0.184	-0.185
	(-0.813)	(-0.702)	(-0.704)	(-0.727)	(-0.723)
Years of education of HHH	0.016	0.015	0.015	0.017	0.013
	(0.564)	(0.524)	(0.537)	(0.597)	(0.466)
Age of HHH	0.008	0.008	0.008	0.008	0.009
	(1.072)	(1.057)	(0.987)	(1.037)	(1.102)
Family size	-0.006	-0.005	-0.008	-0.005	-0.007
	(-0.220)	(-0.174)	(-0.292)	(-0.170)	(-0.264)
Number of adult males	0.019	0.017	0.020	0.015	0.022
	(0.355)	(0.306)	(0.360)	(0.271)	(0.384)
Number of adult females	-0.080	-0.075	-0.074	-0.078	-0.075
	(-1.324)	(-1.244)	(-1.221)	(-1.283)	(-1.222)
Average education attainment for female adults	0.014	0.011	0.011	0.009	0.014
	(0.397)	(0.314)	(0.293)	(0.260)	(0.380)
Average education attainment for male adults	-0.069*	-0.061*	-0.063*	-0.064*	-0.067*
	(-1.943)	(-1.714)	(-1.800)	(-1.851)	(-1.918)
Log per capita value of productive assets	0.063	0.070	0.072	0.077	0.062
	(0.862)	(0.930)	(0.951)	(1.017)	(0.810)
Log per capita value of nonproductive assets	-0.011	-0.006	-0.008	-0.005	-0.008
	(-0.105)	(-0.054)	(-0.080)	(-0.052)	(-0.076)
Ln value of livestock	-0.023	-0.016	-0.015	-0.014	-0.021
	(-0.507)	(-0.356)	(-0.336)	(-0.314)	(-0.464)
Ln Distance to the nearest district town in kms	0.095	0.062	0.061	0.079	0.077
	(0.808)	(0.511)	(0.511)	(0.660)	(0.629)
Rainfall mm (5 year average)	0.000	-0.000	-0.000	-0.000	0.000
	(0.188)	(-0.000)	(-0.025)	(-0.057)	(0.256)
Temperature (5 year average)	-0.000	-0.000	-0.000	-0.000	-0.000
	(-0.443)	(-0.383)	(-0.466)	(-0.459)	(-0.456)
Wind (5 year average)	0.001	0.001	0.001	0.001	0.001
	(1.432)	(1.239)	(1.202)	(1.161)	(1.389)
Constant	2.221	2.159	2.719	2.669	2.132
	(0.471)	(0.455)	(0.573)	(0.562)	(0.454)
Observations	409	409	409	409	409
R-squared	0.112	0.099	0.101	0.105	0.097
Region dummies	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*

Notes: Robust t-statistics in parentheses. ***Significant at 1% level, **Significant at 5%, *Significant at 10%. Robust standard errors are clustered at community level. HH: Household, HHH: Household head.
‡The intensification index is created by using Manure (t/ha) and Chemical fertilizer (10kg/ha).

Table 3.15: Correlation between current agricultural intensification and past soil quality

Explanatory variables	(1) Manure (t/ha)	(2)	(3) ln Chemical (10kg/ha)	(4)	(5) Chemical (10kg/ha)	(6)	(9) Agricultural intensification index‡	(10)
Inverse of own land per capita	0.001	0.001	-0.000	-0.000	-0.000	-0.000	0.003	0.003
	(1.261)	(1.268)	(-0.285)	(-0.252)	(-1.019)	(-0.955)	(1.445)	(1.451)
Ln population density	0.012	0.013	-0.064	-0.061	-0.011	-0.011	0.069	0.069
	(1.024)	(1.035)	(-0.816)	(-0.775)	(-1.043)	(-0.995)	(1.310)	(1.306)
Past soil quality (in 2003)	0.008	0.011	0.068***	0.107***	0.009***	0.016***	0.018	0.019
	(0.861)	(0.981)	(2.643)	(3.022)	(2.955)	(3.213)	(0.459)	(0.393)
Past soil quality (in 2003) squared		-0.001		-0.017**		-0.003**		-0.000
		(-0.609)		(-2.514)		(-2.409)		(-0.053)
Cultivated land size (ha)	-0.012**	-0.013**	0.003	0.001	-0.004	-0.005	-0.043**	-0.043**
	(-2.584)	(-2.503)	(0.118)	(0.023)	(-1.202)	(-1.311)	(-2.155)	(-2.076)
1 if female HHH	-0.036	-0.035	0.079	0.086	0.015	0.016	-0.169	-0.169*
	(-1.443)	(-1.430)	(0.712)	(0.766)	(0.611)	(0.646)	(-1.663)	(-1.671)
Age of HHH	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(0.028)	(0.021)	(0.047)	(0.021)	(0.109)	(0.073)	(0.007)	(0.007)
Years of education of HHH	-0.004	-0.004	0.043**	0.041**	0.011	0.010	-0.032	-0.032
	(-0.638)	(-0.656)	(2.304)	(2.223)	(1.126)	(1.101)	(-1.157)	(-1.143)
Number of adult males	0.006	0.006	0.058	0.062	0.001	0.001	0.024	0.024
	(0.458)	(0.470)	(1.516)	(1.563)	(0.095)	(0.208)	(0.433)	(0.426)
Number of adult females	0.012	0.012	-0.021	-0.024	-0.001	-0.001	0.049	0.049
	(0.969)	(0.948)	(-0.543)	(-0.603)	(-0.106)	(-0.176)	(0.983)	(0.977)
Family size	-0.004*	-0.004*	0.009	0.011	0.003	0.003	-0.020**	-0.020**
	(-1.806)	(-1.776)	(0.683)	(0.798)	(0.838)	(0.921)	(-2.183)	(-2.158)
Average education attainment for female adults	-0.004	-0.004	0.013	0.013	-0.004	-0.004	-0.012	-0.012
	(-0.745)	(-0.751)	(0.861)	(0.837)	(-0.551)	(-0.561)	(-0.478)	(-0.477)
Average education attainment for male adults	0.006	0.006	-0.036**	-0.035**	-0.003	-0.003	0.030	0.030
	(1.303)	(1.312)	(-2.129)	(-2.106)	(-1.071)	(-1.013)	(1.509)	(1.495)
Ln value of assets Ushs	0.010	0.010	0.018	0.019	0.003	0.003	0.037	0.037
	(0.961)	(0.950)	(0.242)	(0.259)	(0.289)	(0.310)	(0.787)	(0.784)
Ln value of livestock	0.012**	0.012**	-0.004	-0.003	0.006	0.006	0.039*	0.039*
	(2.369)	(2.354)	(-0.189)	(-0.134)	(0.979)	(1.015)	(1.716)	(1.704)
Distance to the nearest district town in kms	-0.001	-0.001	-0.001	-0.001	-0.000	-0.000	-0.002	-0.002
	(-1.484)	(-1.538)	(-0.732)	(-1.251)	(-1.230)	(-1.461)	(-1.194)	(-1.198)
Constant	-0.251**	-0.251**	-4.162***	-4.155***	-0.027	-0.026	-0.945**	-0.945**
	(-2.443)	(-2.419)	(-5.801)	(-5.828)	(-0.246)	(-0.235)	(-2.255)	(-2.254)
Observations	409	409	409	409	409	409	409	409
R-squared	0.055	0.056	0.117	0.129	0.049	0.054	0.052	0.052
Region dummies	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*

Notes: Robust t-statistics in parentheses. ***Significant at 1% level, **Significant at 5%, *Significant at 10%. Robust standard errors are clustered at community level. HH: Household, HHH: Household head.
‡The intensification index is created by using Manure (t/ha) and Chemical fertilizer (10kg/ha).

Table 4.1: Distribution of sample households

Sub-Region	District	Non-displaced	Displaced	Total	% Displaced
Acholi	Agago (part of Pader until 2010)	2	28	30	93.3
	Pader	16	29	45	64.4
	Gulu	0	15	15	100
	Kitgum	2	43	45	95.6
	Lamwo (part of Kitgum until 2009)	6	9	15	60
	Nwoya (part of Amuru until 2010)	1	14	15	93.3
Lango	Apac	58	1	59	1.7
	Kole (part of Apac until 2010)	0	15	15	100
	Lira	35	40	75	53.3
	Oyam (part of Apac until 2006)	19	11	30	36.7
	Total	139	205	344	59.6

Notes: 84% of Acholi households were displaced, 48% of Lango households were displaced

Table 4.2: Parcel-level descriptive statistics by concerned about and by new land conflicts

	By concerned about land conflicts				By new land conflicts (since 2006)			
	Land conflict=0 (n=902)	Land conflict =1 (n=108)			Land conflict=0 (n=910)	Land conflict=1 (n=100)		
Variable	Mean	Mean	Mean Diff	Mean Diff	Mean	Mean	Mean Diff	Mean Diff
Parcel size (ha)	1.041	1.843	-0.80		1.000	2.071	-1.072	**
Walking distance from homestead(minutes)	27.256	32.167	-4.91		26.959	33.875	-6.916	
Length of ownership (years)	14.334	18.111	-3.78	**	14.347	17.633	-3.286	**
1 if purchased	0.059	0.065	-0.01		0.057	0.075	-0.018	
1 if received as gift or inherited	0.669	0.880	-0.21	***	0.666	0.875	-0.209	***
1 if rented-in	0.244	0.028	0.22	***	0.248	0.017	0.232	***
1 if just walked-in	0.029	0.028	0.001		0.028	0.033	-0.005	
1 if owner	0.725	0.935	-0.21	***	0.720	0.950	-0.230	***
1 if occupant	0.141	0.056	0.09	***	0.144	0.042	0.102	***
1 if tenant	0.134	0.009	0.13	***	0.136	0.008	0.128	***
1 if have land title	0.038	0.019	0.02		0.038	0.017	0.022	
1 if have land certificate	0.011	0.019	-0.01		0.010	0.025	-0.015	
1 if have transaction agreement with council's endorsement	0.070	0.093	-0.02		0.070	0.092	-0.022	
1 if have transaction agreement without council's endorsement	0.049	0.074	-0.03		0.047	0.083	-0.036	
1 if have any ownership document	0.131	0.120	0.01		0.130	0.125	0.005	
1 if has ever used it as collateral	0.008	0.037	-0.03		0.008	0.033	-0.025	
1 if freehold	0.034	0.065	-0.03		0.031	0.083	-0.052	**
1 if leasehold	0.053	0.019	0.04	**	0.054	0.017	0.037	***
1 if customary	0.91	0.92	-0.01		0.915	0.900		
1 if has had land conflict	0.086	0.843	-0.76	***				
1 if has concern of land conflict over the parcel					0.019	0.950	0.015	***

***, **, * indicates significance at 1%, 5%, 10%, respectively.

Table 4.3: Household-and community- level descriptive statistics

Variable	Obs	Mean	SD.
Household level characteristics			
1 if household is female headed	344	0.253	0.435
Age of household head	344	45.788	15.219
Years of schooling of household head	344	5.884	4.384
Family size	344	6.314	2.642
Average years of schooling of adult members	344	6.315	3.764
Value of assets (Ushs)	344	550138	1658881
Land holding (ha)	344	2.744	5.740
1 if ethnicity is Acholi	344	0.478	0.500
1 if ethnicity is Langi	344	0.519	0.500
1 if Catholic	344	0.650	0.478
1 if Protestant	344	0.262	0.441
1 if other Christian	344	0.087	0.283
1 if any HH member was threatened to be killed, or tortured during the war	344	0.446	0.498
1 if houses were damaged during the war	344	0.455	0.499
1 if non-residential buildings were damaged during the war	344	0.373	0.484
1 if new settler after the LRA insurgency	344	0.125	0.331
1 if displaced	344	0.596	0.491
1 if displaced within the LC1	205	0.459	0.499
1 if displaced outside the LC1 but within the sub-county	205	0.361	0.481
1 if displaced outside the sub-county	205	0.180	0.386
When displaced	205	2002	2.379
When returned	205	2007	1.833
Duration of displacement (months)	205	60.408	34.346
1 if is concerned about land disputes	344	0.262	0.440
1 if has had new land disputes	344	0.264	0.442
Proportion of parcels with concerns about land disputes	344	0.117	0.242
Proportion of parcels that have faced new land disputes	344	0.102	0.202
Community level characteristics			
% of HHs in this LC1 whose heads were born outside this LC1	344	4.950	15.901
No. of HHs who moved out of this LC1 permanently during the past 10 years	344	1.788	6.139
Community population density (persons /square km)	344	436.6	1042.8
Distance to the nearest district town in kms.	344	32.397	20.655
1 if there have been land conflicts prior 1996	344	0.433	0.500
1 if there have been land conflicts prior 2006	344	0.477	0.500
1 if there has been land conflicts in the LC1 until 2015	344	0.956	0.205
1 if road to the nearest district town is tarmac	344	0.087	0.283
1 if road to the nearest district town is all season dirt road	344	0.826	0.380
1 if road to the nearest district town is seasonal dirt	344	0.087	0.283
Cost to rent an acre of good quality land during last cropping season (Ushs)	344	49745.6	60928.7

Table 4.4: Household-and community-level summary statistics by displacement status

Variable	Displaced=0 (n=139) Mean	Displaced=1 (n=205) Mean	Mean Difference	Testing difference in means
1 if household is female headed	0.245	0.259	-0.014	
Age of household head	43.482	47.351	-3.869	**
Years of schooling of household head	6.734	5.307	1.426	***
Family size	6.101	6.459	-0.358	
Average years of schooling of adults	7.003	5.849	1.154	***
Value of assets (Ushs)	779470	394640	384830	*
Land holding (ha)	2.258	3.073	-0.815	
Distance to Uganda- Sudan border (kms)	172.479	136.798	35.681	***
1 if HH is a new settler after the LRA insurgency	0.129	0.122	0.008	
1 if ethnicity is Acholi	0.188	0.673	-0.485	***
1 if ethnicity is Langi	0.806	0.327	0.478	***
1 if Catholic	0.604	0.683	-0.081	
1 if Protestant	0.273	0.254	0.022	
1 if other Christian	0.122	0.063	0.06	*
1 if any HH member was threatened to killed, beaten or tortured during the war	0.288	0.551	-0.261	***
1 if houses were damaged during the war	0.201	0.624	-0.421	***
1 if non-residential buildings were damaged during the war	0.180	0.502	-0.321	***
1 if any item was stolen during the war	0.275	0.688	-0.412	***
1 if any livestock was stolen during the war	0.174	0.698	-0.524	***
1 if any other valuables were stolen during the war	0.341	0.395	-0.055	***
Number of cattle stolen during the war	0.507	1.751	-1.244	***
Number of goats stolen during the war	0.913	5.029	-4.116	***
Number of pigs stolen during the war	0.072	0.317	-0.245	**
Number of chicken stolen during the war	2.116	11.956	-9.84	***
Total livestock stolen during the war	3.862	19.688	-2.094	***
Value of livestock (in tropical units) stolen during the war	0.677	2.771	-15.825	***
1 if the household is concerned about land disputes	0.288	0.244	0.044	
1 if the has had new land disputes	0.259	0.268	-0.009	
Proportion of parcels with concerns about land conflicts	0.151	0.094	0.057	**
Proportion of parcels that have faced new land conflicts	0.113	0.095	0.018	
1 if there have been land conflicts in the LC1 prior 1996	0.698	0.254	0.444	***
1 if there have been land conflicts in the LC1 prior 2006	0.799	0.259	0.540	***

***, **, * indicates significance at 1%, 5%, and 10%, respectively.

Table 4.5: Pairwise correlation of land conflicts and displacement variables

	Has concerned about land conflicts =1	Has had land conflicts over the parcel=1	Displaced within the LC1	Displaced outside LC1 but within sub-county=1	Displaced outside the sub-county=1	Displacement duration
Has concerned about land conflicts =1	1					
Has had land conflicts over the parcel=1	0.7740***	1				
Displaced within the LC1=1	-0.0322	-0.0341	1			
Displaced outside the LC1 but within sub-county=1	-0.0612	-0.0636	-0.7307****	1		
Displaced outside the sub-county=1	0.1268***	0.1327***	-0.3901***	0.3901***	1	
Displacement duration	-0.0093	0.0249	0.0110	-0.011	0.1216**	1

***, ** indicates significance at 1%, and 5%, respectively.

Table 4.6: Correlation between displacement experiences and pre-displacement or pre-return characteristics

	Pre-displacement					Pre-return				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Explanatory Variables	1 if displaced	When displaced	1 if displaced within LC1	1 if displaced outside LC1 but within subcounty	1 if displaced outside subcounty	1 if displaced	When displaced	1 if displaced within LC1	1 if displaced outside LC1 but within subcounty	1 if displaced outside subcounty
1 if HH had disputes before 1996	-0.027	0.594	-0.007	-0.004	0.011					
	(-0.169)	(0.424)	(-0.196)	(-0.067)	(0.219)					
Land holding (ha) prior 1996	-0.011	0.015	-0.018	0.086	-0.068					
	(-0.398)	(0.070)	(-0.923)	(1.543)	(-1.249)					
1 if HH had disputes before 2006						0.071	0.221	-0.056	-0.122	0.178
						(0.941)	(0.350)	(-0.667)	(-1.172)	(1.358)
Land holding (ha) prior 2006						-0.028	-0.005	-0.021	0.103	-0.082
						(-1.046)	(-0.021)	(-1.052)	(1.693)	(-1.345)
1 if Catholic+	-0.037	-0.408	0.024	-0.066	0.042	-0.033	-0.404	0.021	-0.063	0.042
	(-0.879)	(-1.302)	(0.887)	(-1.196)	(0.828)	(-0.797)	(-1.287)	(0.782)	(-1.217)	(0.896)
1 if Other Christian+	0.001	0.299	-0.045	-0.013	0.058	0.010	0.320	-0.051	-0.036	0.088
	(0.022)	(0.539)	(-0.783)	(-0.073)	(0.362)	(0.156)	(0.570)	(-0.864)	(-0.204)	(0.553)
HH-level altitude	-0.000	0.001	0.000	-0.000	0.000	-0.000	0.000	-0.000	-0.000	0.000
	(-1.322)	(0.377)	(0.093)	(-0.998)	(0.982)	(-1.158)	(0.292)	(-0.200)	(-1.493)	(1.470)
Years of schooling of HHH	-0.014***	0.016	0.002	-0.010	0.008	-0.014***	0.016	0.002	-0.009	0.007
	(-3.667)	(0.516)	(0.711)	(-1.411)	(1.164)	(-3.603)	(0.515)	(0.798)	(-1.257)	(0.968)
Constant	1.021***	2,001.5***	0.451***	0.500**	0.049	0.989***	2,001.7***	0.489***	0.575***	-0.065
	(4.363)	(1,038.003)	(5.659)	(2.483)	(0.252)	(4.323)	(1,121.93)	(4.242)	(3.141)	(-0.324)
Observations	344	205	205	205	205	344	205	205	205	205
R-squared	0.055	0.019	0.019	0.039	0.027	0.060	0.019	0.028	0.053	0.044
LC1 fixed effects	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Number of lc1code	23	18	18	18	18	23	18	18	18	18

Notes: Robust t-statistics in parentheses. ***, **, * indicates significance at 1%, 5%, 10%, respectively. Standard errors are clustered at community level. +Reference group: 1 if protestant. HH: Household, HHH: Household head.

Table 4.7: Displacement and land conflicts: Full sample

	1 if there has been concern about land disputes		1 if there has been new land disputes		Proportion of parcels with concerns about land disputes		Proportion of parcels with new land disputes	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1 if the HH was displaced	0.050	0.182**	-0.028	0.097	-0.001	0.042	-0.023	0.030
	(0.635)	(2.136)	(-0.375)	(1.276)	(-0.026)	(0.990)	(-0.645)	(0.831)
1 if female HHH	0.059	0.069	0.024	0.033	0.031	0.040	0.018	0.026
	(0.713)	(0.831)	(0.259)	(0.375)	(0.750)	(0.988)	(0.489)	(0.714)
Age of HHH	-0.001	-0.001	-0.000	0.000	0.000	0.000	0.000	0.001
	(-0.621)	(-0.656)	(-0.062)	(0.103)	(0.106)	(0.170)	(0.590)	(0.965)
Years of schooling of HHH	0.001	0.004	0.003	0.006	0.001	0.003	0.001	0.003
	(0.142)	(0.549)	(0.431)	(0.845)	(0.315)	(0.944)	(0.494)	(1.092)
Family size	-0.006	-0.005	-0.007	-0.008	-0.002	-0.001	-0.002	-0.001
	(-0.710)	(-0.512)	(-0.792)	(-0.821)	(-0.443)	(-0.252)	(-0.504)	(-0.296)
Log of values of assets (Ushs)	0.023	0.020	0.026	0.028	0.014	0.014	0.010	0.011
	(0.945)	(0.804)	(1.168)	(1.232)	(1.017)	(0.958)	(1.026)	(1.136)
Log of landholding (ha)	0.079**	0.048*	0.054*	0.026	0.050***	0.037**	0.023*	0.007
	(2.720)	(1.737)	(2.024)	(0.945)	(3.311)	(2.337)	(2.073)	(0.745)
Number of parcels	0.029	0.043*	0.050**	0.066***	-0.020*	-0.013	-0.007	0.001
	(1.164)	(1.952)	(2.146)	(2.926)	(-1.731)	(-1.196)	(-0.853)	(0.090)
Log of average walking distance in minutes to the parcels	0.016	0.001	0.003	-0.013	-0.004	-0.014	-0.002	-0.010
	(0.686)	(0.021)	(0.164)	(-0.751)	(-0.302)	(-0.939)	(-0.189)	(-1.178)
1 if HH is a new settler after the LRA insurgency	0.015	0.072	-0.032	0.018	0.023	0.049	0.016	0.051
	(0.246)	(1.138)	(-0.438)	(0.238)	(0.619)	(1.440)	(0.366)	(1.226)
Log of population density	0.055		-0.021		0.024		-0.009	
	(1.128)		(-0.496)		(1.020)		(-0.408)	
Log of distance to the nearest district town	-0.007		-0.010		0.035		0.019	
	(-0.091)		(-0.137)		(0.935)		(0.519)	
Prop of HH in the LC1 whose HHH were born outside the LC1	-0.002		-0.004		-0.000		-0.001	
	(-0.724)		(-1.484)		(-0.155)		(-0.843)	
1 if road to the nearest district town is tarmac^{+++}	-0.437*		-0.277		-0.293*		-0.177	
	(-1.944)		(-1.098)		(-1.782)		(-1.233)	
1 if road to the nearest district town is all season dirty^{+++}	-0.024		-0.083		0.003		-0.015	
	(-0.448)		(-1.086)		(0.114)		(-0.496)	
Log of altitude	0.417		0.677		0.497*		0.380	
	(0.745)		(1.556)		(1.792)		(1.520)	
Rainfall mm (10 year average:2006-2015)	-0.001		-0.001		-0.001		-0.001	
	(-0.694)		(-0.621)		(-1.525)		(-0.863)	
Temperature ºc (10 year average:2006-015)	0.000		0.000		0.000		0.000	
	(0.425)		(0.073)		(0.805)		(0.228)	
Log no. of HH who moved out the LC1 permanently in the past 10 years	0.123*		0.103		0.070		0.058	
	(1.828)		(1.529)		(1.558)		(1.490)	
Log of average land size per HH (acres)	0.016		-0.005		0.010		-0.003	
	(0.308)		(-0.090)		(0.359)		(-0.096)	
Log of cost to rent an acre of good quality land during last cropping season	-0.016		-0.047**		-0.027		-0.026**	
	(-0.624)		(-2.267)		(-1.612)		(-2.132)	
1 if the LC1 had land disputes prior 2006	0.255***		0.079		0.157***		0.054*	
	(4.272)		(1.444)		(4.886)		(2.031)	
Constant	-3.195	-0.196	-4.134	-0.316	-3.468*	-0.057	-2.366	-0.094
	(-0.808)	(-0.556)	(-1.340)	(-0.914)	(-1.818)	(-0.329)	(-1.362)	(-0.659)
Observations	344	344	344	344	344	344	344	344
R-squared	0.121	0.061	0.090	0.058	0.136	0.051	0.060	0.022
Number of LC1		23		23		23		23
LC1 FE		*Yes*		*Yes*		*Yes*		*Yes*

Notes: Robust t-statistics in parentheses. ***, **, * indicates significance at 1%, 5%, 10%, respectively. Standard errors are clustered at community level. $^{+++}$Reference group: 1 if the road to the nearest district town is seasonal dirt. HH: Household, HHH: Household head.

Table 4.8: Displacement and land conflicts: Subsample of households that were displaced- IV estimation

	IV estimation								First Stage
	1 if there has been concern about land conflicts		1 if there has been new land conflicts		Proportion of parcels with concerns about land conflicts		Proportion of parcels with new land conflicts		Log displacement duration
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Log of duration of displacement (months)	0.014	-0.144	0.042	-0.103	0.019	-0.085	0.008	-0.071	
	(0.149)	(-1.091)	(0.444)	(-0.808)	(0.430)	(-1.567)	(0.181)	(-1.429)	
1 if displaced outside the LC1 but within the sub-county[+]	0.003	0.206	-0.068	-0.165	0.009	0.194	-0.030	-0.107	0.019
	(0.028)	(1.139)	(-1.243)	(-1.479)	(0.227)	(1.442)	(-1.089)	(-1.644)	(0.176)
1 if displaced outside the sub-county[+]	0.230**	0.389**	0.200***	0.043	0.137**	0.300**	0.127***	0.023	-0.126
	(2.064)	(2.046)	(2.772)	(0.338)	(2.541)	(2.406)	(3.055)	(0.295)	(-1.532)
1 if female HHH	0.019	0.040	0.005	0.034	0.018	0.022	-0.013	0.002	-0.058
	(0.230)	(0.365)	(0.042)	(0.295)	(0.410)	(0.549)	(-0.309)	(0.050)	(-0.780)
Age of HHH	-0.000	-0.000	0.002	0.003	-0.000	0.000	0.001	0.001	0.002
	(-0.166)	(-0.064)	(0.802)	(0.863)	(-0.129)	(0.109)	(0.885)	(1.108)	(1.068)
Years of schooling of HHH	0.006	0.005	0.011	0.010	0.001	-0.000	0.003	0.002	0.008
	(0.575)	(0.390)	(1.015)	(0.874)	(0.206)	(-0.019)	(0.609)	(0.399)	(0.504)
Family size	-0.004	-0.002	-0.004	-0.002	-0.003	-0.004	-0.004	-0.003	0.003
	(-0.271)	(-0.124)	(-0.246)	(-0.120)	(-0.549)	(-0.664)	(-0.607)	(-0.456)	(0.198)
Log of values of assets (Ushs)	0.027	0.028	0.029	0.032	0.021	0.025	0.010	0.014	-0.063
	(1.064)	(0.890)	(1.312)	(1.250)	(1.245)	(1.326)	(1.401)	(1.387)	(-1.286)
Log of landholding (ha)	0.072**	0.052*	0.076**	0.051	0.035***	0.025**	0.028**	0.015	0.031
	(2.140)	(1.870)	(2.192)	(1.415)	(2.663)	(2.073)	(2.294)	(1.165)	(1.224)
Number of parcels	0.065**	0.063**	0.061*	0.060*	0.003	0.001	0.001	0.000	-0.033
	(2.036)	(2.026)	(1.813)	(1.739)	(0.186)	(0.090)	(0.104)	(0.034)	(-1.215)
Log of average walking distance in minutes to the parcels	0.001	0.015	0.014	0.021	-0.010	-0.001	0.006	0.010	0.029
	(0.027)	(0.440)	(0.579)	(0.787)	(-0.639)	(-0.042)	(0.525)	(0.856)	(1.400)
1 if HH is a new settler after the LRA insurgency	0.038	-0.003	0.033	0.023	0.050	0.012	0.069	0.071	0.040
	(0.451)	(-0.028)	(0.282)	(0.155)	(0.989)	(0.219)	(1.043)	(0.898)	(0.602)
Log of population density	0.120*		0.052		0.043*		0.014		-0.128**
	(1.860)		(1.322)		(1.925)		(0.883)		(-2.805)
Log distance to the nearest district town	0.154		0.061		0.081		0.035		-0.325***
	(1.220)		(0.542)		(1.531)		(0.732)		(-3.283)
Prop of HH whose HHH were born outside the LC1	-0.001		-0.003		-0.001		-0.002		-0.019***
	(-0.216)		(-0.861)		(-0.628)		(-1.109)		(-5.746)
1 if road to the nearest district town is tarmac[+++]	-0.229		0.254		-0.063		0.067		0.821**
	(-0.464)		(0.718)		(-0.300)		(0.397)		(2.592)
1 if road to the nearest district is all season dirty[+++]	-0.283		-0.079		-0.168***		-0.059		0.486***
	(-1.484)		(-0.585)		(-2.902)		(-1.023)		(3.618)
Log of altitude	-0.121		-0.130		-0.140		-0.231		0.363
	(-0.170)		(-0.174)		(-0.392)		(-0.745)		(0.623)
Rainfall mm (10 year average:2006-2015)	0.001		0.003		0.001		0.002*		-0.001
	(0.236)		(1.323)		(1.196)		(1.832)		(-0.476)
Temperature ^{o}c (10 year average:2006-2015)	0.000		-0.000		0.000**		-0.000		-0.000***
	(1.191)		(-0.899)		(2.462)		(-0.485)		(-3.872)
Log no. of HH who moved out the LC1 permanently in the past 10 years	0.008		0.005		-0.027		0.006		-0.211**
	(0.068)		(0.055)		(-0.517)		(0.149)		(-2.304)
Log of average land size per HH (acres)	0.032		0.055		0.019		0.021		-0.110*
	(0.395)		(0.992)		(0.645)		(0.825)		(-1.826)
Log of cost to rent an acre of good quality land during last cropping season	-0.030		-0.011		-0.012		-0.005		-0.012
	(-0.611)		(-0.309)		(-0.723)		(-0.281)		(-0.303)
1 if the LC1 had land disputes prior 2006	0.068		-0.038		0.018		-0.037		0.308**
	(0.561)		(-0.431)		(0.387)		(-0.951)		(2.794)
When Displaced (Timing of displacement)									-0.146***
									(-7.337)
Constant	-1.965		0.546	236.62***	-0.797		1.388		300.19***
	(-0.357)		(0.091)	(2.817)	(-0.294)		(0.565)		(7.844)
Observations	205	204	205	204	205	204	205	204	205
R-squared	0.207	0.080	0.174	0.091	0.193	0.068	0.158	0.058	0.589
Weak IV									
First Stage F-stat									74.526
Cragg-Donald Wald F statistic									94.185
Stock-Yogo weak test critical values 10%									16.38
Number of LC1		17		17		17		17	
LC1 fixed effects		*Yes*		*Yes*		*Yes*		*Yes*	

Notes: Robust t-statistics in parentheses. ***, **, * indicates significance at 1%, 5%, 10%, respectively. Standard errors are clustered at community level. [+]Reference group: 1 if the household was displaced within its LC1. [+++]Reference group: 1 if road to the nearest district town is seasonal dirt. HH: Household, HHH: Household head.

Table 4.9: Subsample of households whose LC1s had no land conflicts prior 2006

	(1)	(2)	(2)	(4)	(5)	(6)	(7)	(8)
	1 if there has been concern about land conflicts				1 if there has been new land conflicts			
1 if the HH was displaced	0.127	0.152			0.041	0.072		
	(0.830)	(1.058)			(0.283)	(0.523)		
Log duration of displacement			-0.083	-0.079			-0.138	-0.134
			(-0.549)	(-0.522)			(-0.927)	(-0.898)
1 if displaced outside LC1 but within sub-county[+]			0.472***	0.302			0.449***	0.254
			(3.883)	(1.238)			(3.251)	(0.987)
1 if displaced outside the sub-county[+]			0.679***	0.501**			0.684***	0.480*
			(5.392)	(1.968)			(4.876)	(1.759)
1 if female headed HH	0.034	0.049	-0.024	-0.016	0.015	0.033	-0.045	-0.036
	(0.320)	(0.482)	(-0.204)	(-0.141)	(0.145)	(0.342)	(-0.414)	(-0.336)
Age of HHH	-0.002	-0.002	-0.001	-0.001	0.000	-0.000	0.002	0.002
	(-0.574)	(-0.759)	(-0.193)	(-0.232)	(0.067)	(-0.112)	(0.526)	(0.477)
Years of schooling of HHH	0.006	0.005	0.002	0.002	0.014	0.012	0.010	0.010
	(0.457)	(0.403)	(0.176)	(0.171)	(1.181)	(1.145)	(0.757)	(0.761)
Family size	-0.012	-0.007	-0.004	-0.003	-0.012	-0.006	-0.005	-0.003
	(-0.919)	(-0.558)	(-0.250)	(-0.192)	(-0.758)	(-0.379)	(-0.198)	(-0.150)
Log of value of assets (Ushs)	-0.010	-0.016	-0.011	-0.014	0.023	0.015	0.026	0.023
	(-0.292)	(-0.510)	(-0.399)	(-0.509)	(0.682)	(0.438)	(1.041)	(0.876)
Log of landholding (ha)	0.033	0.028	0.050	0.047	0.027	0.021	0.066**	0.063**
	(1.033)	(0.930)	(1.589)	(1.484)	(0.737)	(0.604)	(2.523)	(2.349)
Number of parcels owned	0.048	0.055*	0.063*	0.066*	0.071*	0.079**	0.065	0.068
	(1.627)	(1.999)	(1.849)	(1.930)	(1.920)	(2.210)	(1.419)	(1.499)
Log average walking distance to parcels	0.024	0.026	0.034	0.034	-0.011	-0.008	0.010	0.010
	(0.836)	(0.954)	(0.935)	(0.925)	(-0.405)	(-0.311)	(0.363)	(0.349)
1 if new settler after the LRA insurgence	-0.008	0.034	-0.168*	-0.144	-0.104	-0.053	-0.158	-0.130
	(-0.081)	(0.349)	(-1.712)	(-1.253)	(-0.841)	(-0.428)	(-0.856)	(-0.665)
Log of population density (persons/sq kms)	-0.073		0.116		-0.174**		-0.013	
	(-1.251)		(1.125)		(-2.363)		(-0.107)	
Log distance to the nearest district town	-0.188		0.513***		-0.313*		0.330	
	(-1.774)		(2.767)		(-2.014)		(1.464)	
Prop of HHs whose heads were born outside the LC1	0.073**		0.026		0.094**		0.057	
	(2.625)		(0.780)		(3.031)		(1.021)	
1 if road to district is tarmac	-0.866*		5.405***		0.444		6.860***	
	(-1.917)		(3.720)		(0.747)		(5.531)	
1 if road to district is all season dirt road	-0.126		5.965***		0.786		7.125***	
	(-0.234)		(3.881)		(1.080)		(5.201)	
Log of altitude	-0.189		1.881***		0.652		2.453***	
	(-0.217)		(2.657)		(0.667)		(3.443)	
Annual rainfall mm (9 yr average:2006-2015)	0.005		-0.027***		0.003		-0.028***	
	(1.711)		(-4.448)		(0.771)		(-5.131)	
Annual temp (9 yr average:2006-2015)	-0.000		-0.003***		-0.001		-0.004***	
	(-0.145)		(-3.594)		(-1.649)		(-5.107)	
Log of no. of HHs who moved out permanently in the last 10 yrs	0.301***		0.189**		0.238***		0.189	
	(4.770)		(2.338)		(3.387)		(1.514)	
Log of average land holding (acres)	-0.096		-0.028		-0.168*		-0.094	
	(-1.260)		(-0.293)		(-2.020)		(-0.806)	
Log rent during last crop season for good quality land (Ushs/acre)	0.037		0.002		0.027		0.021	
	(1.330)		(0.074)		(0.711)		(0.525)	
Constant	2.146	0.154	12.271**		2.906	-0.168	16.355**	
	(0.496)	(0.329)	(2.146)		(0.530)	(-0.314)	(2.550)	
Observations	195	195	153	152	195	195	153	152
R-squared	0.140	0.068	0.204	0.102	0.137	0.074	0.211	0.110
Number of LC1		13		12		13		12
LC1 FE		*Yes*		*Yes*		*Yes*		*Yes*

Notes: Results in columns 1,2, 5, and 6 are estimated by OLS; Results in remaining columns are estimated by IV.
Robust t-statistics in parentheses. ***, **, * indicates significance at 1%, 5%, 10%, respectively. Standard errors are clustered at community level. [+]Reference group: 1if household was displaced within its LC1. [+++]Reference group: 1 if road to the nearest district town is seasonal dirt.
HH: Household, HHH: Household head.

Table 4.9 cont.: Subsample of households whose LC1s had no land conflicts prior 2006

	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
	Proportion of parcels with concerns about land conflicts				Proportion of parcels with new land conflicts			
1 if the HH was displaced	0.039	0.053			0.023	0.039		
	(0.565)	(0.813)			(0.382)	(0.702)		
Log duration of displacement			-0.035	-0.033			-0.064	-0.062
			(-0.645)	(-0.604)			(-1.141)	(-1.093)
1 if displaced outside LC1 but within sub-county[+]			0.192***	0.101			0.177***	0.071
			(3.212)	(1.068)			(3.318)	(0.796)
1 if displaced outside the sub-county[+]			0.324***	0.228**			0.330***	0.220**
			(6.611)	(2.491)			(6.200)	(2.294)
1 if female headed HH	0.012	0.020	-0.017	-0.013	0.004	0.013	-0.033	-0.028
	(0.344)	(0.630)	(-0.448)	(-0.348)	(0.107)	(0.409)	(-0.819)	(-0.713)
Age of HHH	-0.000	-0.001	0.000	0.000	0.000	-0.000	0.001	0.001
	(-0.417)	(-0.710)	(0.320)	(0.253)	(0.143)	(-0.114)	(0.916)	(0.844)
Years of schooling of HHH	0.004	0.003	0.001	0.001	0.004	0.003	0.001	0.001
	(0.944)	(0.875)	(0.195)	(0.187)	(1.048)	(0.981)	(0.230)	(0.225)
Family size	-0.001	0.002	-0.001	-0.001	-0.003	-0.000	-0.002	-0.001
	(-0.161)	(0.217)	(-0.191)	(-0.103)	(-0.568)	(-0.042)	(-0.236)	(-0.167)
Log of value of assets (Ushs)	-0.010	-0.014	-0.005	-0.006	0.002	-0.003	0.010	0.008
	(-0.712)	(-0.992)	(-0.490)	(-0.675)	(0.103)	(-0.168)	(1.058)	(0.841)
Log of landholding (ha)	0.016	0.013	0.016	0.014	0.010	0.007	0.020**	0.018*
	(1.295)	(1.153)	(1.365)	(1.201)	(0.846)	(0.631)	(2.074)	(1.791)
Number of parcels owned	0.003	0.007	0.013	0.014	0.002	0.006	0.005	0.006
	(0.326)	(0.769)	(1.005)	(1.130)	(0.174)	(0.562)	(0.281)	(0.385)
Log average walking distance to parcels	0.001	0.002	0.012	0.012	-0.007	-0.005	0.009	0.008
	(0.075)	(0.192)	(0.761)	(0.747)	(-0.573)	(-0.459)	(0.680)	(0.665)
1 if new settler after the LRA insurgence	-0.005	0.018	-0.046	-0.033	-0.019	0.008	-0.024	-0.009
	(-0.095)	(0.371)	(-0.980)	(-0.636)	(-0.324)	(0.141)	(-0.300)	(-0.106)
Log of population density (persons/sq kms)	-0.083***		0.028		-0.104***		-0.005	
	(-3.088)		(0.857)		(-3.500)		(-0.119)	
Log distance to the nearest district town	-0.171**		0.196***		-0.194**		0.141*	
	(-2.807)		(3.398)		(-2.561)		(1.923)	
Prop of HHs whose heads were born outside the LC1	0.058***		0.004		0.053***		0.001	
	(4.757)		(0.257)		(4.297)		(0.034)	
1 if road to district is tarmac	-0.651***		2.389***		-0.255		2.775***	
	(-3.560)		(4.253)		(-1.081)		(5.950)	
1 if road to district is all season dirt road	-0.251		2.609***		0.003		2.897***	
	(-1.131)		(4.415)		(0.011)		(5.629)	
Log of altitude	-0.167		0.777**		0.055		0.850***	
	(-0.386)		(2.526)		(0.112)		(2.964)	
Annual rainfall mm (9 yr average:2006-2015)	0.005**		-0.011***		0.004*		-0.011***	
	(2.901)		(-4.405)		(1.980)		(-5.312)	
Annual temp (9 yr average:2006-2015)	0.000		-0.001***		-0.000		-0.002***	
	(0.363)		(-4.154)		(-0.848)		(-5.478)	
Log of no. of HHs who moved out permanently in the last 10 yrs	0.157***		0.078***		0.133***		0.080*	
	(6.252)		(2.886)		(5.275)		(1.834)	
Log of average land holding (acres)	-0.076*		-0.022		-0.093**		-0.035	
	(-2.106)		(-0.670)		(-2.692)		(-0.879)	
Log rent during last crop season for good quality land (Ushs/acre)	0.039**		0.001		0.028		0.002	
	(2.442)		(0.098)		(1.493)		(0.147)	
Constant	1.182	0.183	5.838***		1.604	0.095	7.722***	
	(0.546)	(0.856)	(3.129)		(0.599)	(0.384)	(3.451)	
Observations	195	195	153	152	195	195	153	152
R-squared	0.190	0.018	0.205	0.091	0.124	0.008	0.220	0.093
Number of LC1		13		12		13		12
LC1 FE		*Yes*		*Yes*		*Yes*		*Yes*

Notes: Results in columns 9,10, 13, and 14 are estimated by OLS; Results in remaining columns are estimated by IV.
Robust t-statistics in parentheses. ***, **, * indicates significance at 1%, 5%, 10%, respectively. Standard errors are clustered at community level. [+]Reference group: 1if household was displaced within its LC1. [+++]Reference group: 1 if road to the nearest district town is seasonal dirt. HH: Household, HHH: Household head.

Table 4.10: Subsample of households whose LC1s had land conflicts prior 2006

	1 if there has been concern about land conflicts		1 if there has been new land conflicts		Proportion of parcels with concerns about land conflicts		Proportion of parcels with new land conflicts	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1 if the HH was displaced	0.228**	0.228**	0.167	0.167	0.028	0.028	0.033	0.033
	(2.357)	(2.438)	(1.687)	(1.745)	(0.466)	(0.482)	(0.566)	(0.585)
1 if female headed HH	0.057	0.057	0.068	0.068	0.051	0.051	0.022	0.022
	(0.460)	(0.476)	(0.451)	(0.466)	(0.793)	(0.820)	(0.455)	(0.471)
Age of HHH	-0.002	-0.002	-0.001	-0.001	-0.000	-0.000	0.001	0.001
	(-0.533)	(-0.551)	(-0.224)	(-0.232)	(-0.106)	(-0.109)	(0.585)	(0.605)
Years of schooling of HHH	0.004	0.004	0.003	0.003	0.004	0.004	0.003	0.003
	(0.482)	(0.498)	(0.298)	(0.308)	(0.730)	(0.755)	(0.735)	(0.760)
Family size	-0.004	-0.004	-0.005	-0.005	-0.007	-0.007	-0.000	-0.000
	(-0.277)	(-0.287)	(-0.402)	(-0.416)	(-0.885)	(-0.916)	(-0.006)	(-0.006)
Log of value of assets (Ushs)	0.049	0.049	0.029	0.029	0.037	0.037	0.022	0.022
	(1.388)	(1.436)	(0.860)	(0.889)	(1.721)	(1.780)	(1.370)	(1.417)
Log of landholding (ha)	0.131*	0.131*	0.068	0.068	0.114**	0.114**	0.037	0.037
	(2.160)	(2.234)	(1.470)	(1.521)	(2.729)	(2.823)	(1.514)	(1.566)
Number of parcels owned	0.026	0.026	0.049*	0.049*	-0.039	-0.039*	-0.011	-0.011
	(0.772)	(0.798)	(1.856)	(1.920)	(-1.787)	(-1.848)	(-0.722)	(-0.746)
Log average walking distance to parcels	-0.024	-0.024	-0.030	-0.030	-0.031	-0.031	-0.026*	-0.026*
	(-0.691)	(-0.715)	(-1.430)	(-1.479)	(-1.361)	(-1.407)	(-1.914)	(-1.980)
1 if new settler after the LRA insurgence	0.066	0.066	0.077	0.077	0.049	0.049	0.085	0.085
	(0.886)	(0.916)	(0.640)	(0.662)	(1.349)	(1.395)	(1.157)	(1.196)
Constant	27.365***	-0.375	17.37***	-0.246	17.14***	-0.158	11.23***	-0.189
	(9.027)	(-0.768)	(11.157)	(-0.617)	(11.137)	(-0.709)	(12.131)	(-1.256)
Observations	149	149	149	149	149	149	149	149
R-squared	0.232	0.113	0.140	0.065	0.268	0.191	0.168	0.093
Number of LC1		10		10		10		10
LC1 FE		*Yes*		*Yes*		*Yes*		*Yes*

Notes: In this subsample it was not possible to estimate the impact of distance and duration of displacement among the "subsample" that was displaced due to small sample size

Robust t-statistics in parentheses. Asterisks ***, **, * indicates significance at 1%, 5%, 10%, respectively. Standard errors are clustered at community level. HH: Household, HHH: Household head.

Additional controls: Log of population density (persons/sq kms), Log distance to the nearest district town, Proportion of HHs whose heads were born outside the LC1, road condition (1 if road to the nearest district town is tarmac, 1 if road to the nearest district town is all season dirt road),Annual rainfall mm (10 year average:2006-2015), Annual temp ºc (10 year average:2006-2015), Log of no. of HHs who moved out permanently in the last 10 years, Log of average land holding (acres), Log of cost to rent an acre of good quality land during last cropping season.

Table 4.11: Displacement (placebo treatment) and land conflicts: A falsification test using pre-2006 variables

	1 if has old land conflicts		Proportion of old parcels with old land conflicts		Log of displacement duration
	OLS	IV	OLS	IV	First Stage
Variables	(1)	(2)	(3)	(4)	(5)
1if the HH was displaced	-0.005		0.005		
	(-0.479)		(0.687)		
1 if displaced outside the LC1 but within the sub-county+		-0.024		-0.018	-0.055
		(-1.127)		(-1.123)	(-0.379)
1 if displaced outside the sub-county+		-0.019		-0.014	-0.051
		(-1.086)		(-1.081)	(-0.306)
Log duration of displacement		-0.006		-0.003	
		(-0.598)		(-0.379)	
Years of schooling of HHH	0.001	0.001	0.000	-0.003	-0.003
	(0.611)	(0.943)	(1.150)	(-0.379)	(-0.311)
Land holding (ha) prior 2006	0.006	0.002	0.000	-0.003	0.018***
	(1.107)	(0.934)	(0.662)	(-0.379)	(3.527)
Number of parcels prior 2006	0.003	0.000	0.002	-0.003	-0.027*
	(0.378)	(0.165)	(1.390)	(-0.379)	(-2.020)
Log of annual rainfall (26 year average:2005-1979)	-0.007	0.000	0.002	-0.003	0.318
	(-0.165)	(0.009)	(0.128)	(-0.379)	(0.433)
Log of annual temperature (26 year average:2005-1979)	0.104	-0.122	-0.056	-0.003	-0.508
	(0.264)	(-0.207)	(-0.296)	(-0.379)	(-0.067)
Log altitude	0.034	-0.016	-0.010	-0.003	-0.138
	(0.904)	(-0.293)	(-0.480)	(-0.379)	(-0.172)
Timing of displacement (WhenDisp)					-0.149***
					(-5.763)
Constant	-1.169	1.261	0.570	0.999	306.210***
	(-0.308)	(0.225)	(0.315)	(0.237)	(3.539)
Observations	344	205	344	205	205
R-squared	0.082	0.022	0.007	0.019	0.439
Weak IV					
First Stage F-stat					123.06
Cragg-Donald Wald F statistic					33.21
Stock-Yogo weak test critical values 10%					16.38

Notes: Column 1 & 3: full sample, Column 2 & 4: subsample that was displaced.
Robust t-statistics in parentheses. Asterisks ***, **, * indicates significance at 1%, 5%, 10%, respectively. Standard errors are clustered at community level. HH: Household, HHH: Household head. +Reference group: 1 if the household was displaced within its LC1.

Table 4.12: Displacement experiences and years the HH could not do farming in its home village during displacement

Dependent variable: Number of years the household could not do farming in its home village during displacement

	(1)	(2)	(3)	(4)
1 if displaced outside the LC1 but within the sub-county+	1.280***	1.656**	1.111*	4.377***
	(3.041)	(2.594)	(1.948)	(13.371)
1 if displaced outside the sub-county +	2.366***	2.373**	1.771**	4.976***
	(5.184)	(2.801)	(2.889)	(5.713)
Log duration of displacement (months)	1.964***	1.957***	1.898***	1.947***
	(4.921)	(4.230)	(4.211)	(4.412)
1 if female headed HH	-0.583	-0.520	-0.053	0.066
	(-0.931)	(-0.827)	(-0.104)	(0.124)
Age of HHH	0.024*	0.017	0.013	0.006
	(1.826)	(1.412)	(1.152)	(0.538)
Years of education of HHH	-0.077*	-0.072	-0.045	-0.030
	(-1.792)	(-1.699)	(-1.342)	(-1.026)
Family size	-0.039	-0.022	0.002	0.017
	(-0.547)	(-0.283)	(0.037)	(0.278)
Log of value of assets (Ushs)	0.147	0.090	0.149	0.002
	(1.108)	(0.661)	(0.923)	(0.013)
Log of land holding	-0.257*	-0.252	-0.241**	-0.193
	(-1.961)	(-1.337)	(-2.495)	(-1.525)
Log of average walking distance (minutes) from HH's residence to plots	0.113	0.082	0.149	0.221**
	(1.060)	(0.678)	(1.734)	(2.527)
1 if HH is a new settler after the LRA insurgency	-0.314	-0.576		
	(-0.484)	(-0.958)		
Log of community population density	-0.053		-0.356*	
	(-0.204)		(-1.842)	
Log of distance to the nearest district town	-0.148		-0.596	
	(-0.301)		(-1.061)	
Prop of HH whose HHH were born outside the LC1	0.029*		-0.019	
	(1.979)		(-0.058)	
1 if road to the nearest district town is tarmac+++	-4.932***		-5.032***	
	(-8.129)		(-8.405)	
1 if road to the nearest district town is all season dirty+++	-3.077***		-3.393***	
	(-5.674)		(-4.997)	
Log of altitude	-7.026**		-7.130	
	(-2.349)		(-1.343)	
Rainfall mm (10-year average)	-0.011		-0.004	
	(-1.428)		(-0.456)	
Temperature (10-year average)	0.002***		0.002***	
	(4.134)		(4.917)	
1 if the community had land disputes prior 2006	-1.562***		-1.672**	
	(-3.015)		(-2.161)	
Constant	27.448	-7.814**	28.613	-8.681**
	(1.256)	(-2.587)	(0.786)	(-2.641)
Observations	205	205	180	180
R-squared	0.479	0.221	0.518	0.249
Number of LC1		18		16
LC1 FE		*Yes*		*Yes*

Notes: Robust t-statistics in parentheses. Asterisks ***, **, * indicates significance at 1%, 5%, 10%, respectively.
Standard errors are clustered at community level. HH: Household, HHH: Household head. +Reference group: 1 if the household was displaced within its LC1. +++Reference group: 1if the road to the nearest district town is seasonal dirt.
Column (3 &4) is a sub sample (excluding new settlers after the LRA insurgency), thus does not include new settler dummy as a control.

Table 4.13: Displacement intensity and weakening of informal institutions of land governance.

Dependent variable: 1 if household resorted to informal means to resolve land conflicts

Variables	(1)	(2)	(3)	(4)	(5)	(6)
Proportion of households in the LC1 that were displaced	-0.189**	-0.279**				
	(-2.479)	(-2.091)				
Log of average duration of displacement in the LC1			-0.050**	-0.064**		
			(-2.773)	(-2.091)		
Proportion of households that were displaced outside the LC1					0.075	-0.333**
					(0.811)	(-2.091)
1 if female headed HH	-0.110	0.014	-0.110	0.014	-0.105	0.014
	(-0.960)	(0.094)	(-0.930)	(0.094)	(-0.866)	(0.094)
Age of HHH	0.005*	0.006	0.005*	0.006	0.005*	0.006
	(1.988)	(1.571)	(2.062)	(1.571)	(2.078)	(1.571)
Years of education of HHH	0.006	0.011	0.006	0.011	0.004	0.011
	(0.942)	(1.596)	(0.923)	(1.596)	(0.646)	(1.596)
Family size	-0.041**	-0.040*	-0.038**	-0.040*	-0.036*	-0.040*
	(-2.265)	(-1.922)	(-2.210)	(-1.922)	(-1.976)	(-1.922)
Log of value of assets (Ushs)	-0.004	0.002	-0.003	0.002	-0.001	0.002
	(-0.094)	(0.038)	(-0.070)	(0.038)	(-0.016)	(0.038)
Log of land holding (ha)	0.007	-0.002	0.005	-0.002	-0.008	-0.002
	(0.158)	(-0.032)	(0.116)	(-0.032)	(-0.172)	(-0.032)
Log of average walking distance to all plots operated	-0.003	0.009	0.001	0.009	0.004	0.009
	(-0.101)	(0.219)	(0.051)	(0.219)	(0.134)	(0.219)
1 if HH is a new settler after the LRA insurgency	0.102	0.101	0.123	0.101	0.106	0.101
	(0.846)	(0.721)	(1.001)	(0.721)	(0.865)	(0.721)
Log of community population density	0.002	-0.047	0.003	-0.075	0.011	0.098
	(0.071)	(-0.841)	(0.098)	(-1.334)	(0.386)	(1.073)
Log of distance to the nearest district town	-0.073	-0.176*	-0.073	-0.160*	-0.066	-0.303***
	(-0.948)	(-2.053)	(-0.954)	(-1.821)	(-0.911)	(-3.228)
Prop of HH whose HHH were born outside the LC1	0.004	0.008	0.005	-0.003	0.005	0.039
	(1.507)	(0.229)	(1.684)	(-0.089)	(1.689)	(0.828)
1 if road to the nearest district town is tarmac^{+++}	-0.268***	-0.262	-0.286***	0.564	-0.311**	-2.848
	(-2.997)	(-0.107)	(-3.116)	(0.263)	(-2.618)	(-0.813)
1 if road to the nearest district town is all season dirty^{+++}	-0.132**	-0.427	-0.127***	-0.389	-0.068	0.305
	(-2.497)	(-1.344)	(-2.893)	(-1.282)	(-1.047)	(1.396)
Log of altitude	-0.643	-3.964	-0.657	-3.430	-0.380	-0.180
	(-1.579)	(-1.459)	(-1.562)	(-1.356)	(-0.865)	(-0.100)
Rainfall mm (10-year average)	-0.000	-0.005	-0.001	-0.006	-0.002	0.001
	(-0.404)	(-1.394)	(-0.867)	(-1.669)	(-1.329)	(0.105)
Temperature (10-year average)	0.000	0.000	0.000	0.000	0.000	0.000
	(0.336)	(1.113)	(0.979)	(1.001)	(0.854)	(1.106)
1 if the community had land conflicts prior 2006	-0.244***	-0.630**	-0.247***	-0.568**	-0.098	-0.437**
	(-4.260)	(-2.664)	(-4.619)	(-2.671)	(-0.950)	(-2.595)
Constant	6.003*	29.942	6.054*	26.498	3.799	1.657
	(1.981)	(1.584)	(1.945)	(1.494)	(1.117)	(0.128)
Observations	91	91	91	91	91	91
R-squared	0.231	0.286	0.235	0.286	0.219	0.286
LC1 dummies		*Yes*		*Yes*		*Yes*

Notes: Robust t-statistics in parentheses. Asterisks ***, **, * indicates significance at 1%, 5%, 10%, respectively. Standard errors are clustered at community level. HH: Household, HHH: Household head. $^{+++}$Reference group: 1 if the road to the nearest district town is seasonal dirt.

Table 4.14: Land conflicts and value of crop yield- plot-level analysis

Dependent variable: *Value of crop yield (Ushs/ha)*

	OLS			Household fixed effects		
Explanatory Variables	(1)	(2)	(3)	(4)	(5)	(6)
1 if there has been concern about land conflicts over the parcel	-84,682.906**			-175,972.563		
	(-2.560)			(-1.193)		
1 if HH has had any land conflicts over the parcel		-58,977.395*			-74,678.124	
		(-1.991)			(-1.269)	
1 if HH has pending conflicts on the parcel			-111,627.121**			-177,532.16**
			(-2.121)			(-2.074)
Walking time in minutes from homestead	1,099.953***	1,108.762***	1,098.560***	1,024.113**	1,021.092**	1,068.971**
	(3.557)	(3.561)	(3.584)	(2.400)	(2.378)	(2.704)
1 if owner ++++	34,137.800	32,833.464	25,707.396	90,169.802	82,864.704	68,750.065
	(0.506)	(0.496)	(0.373)	(0.845)	(0.780)	(0.651)
1 if occupant ++++	-12,692.108	-16,709.217	-13,239.349	17,798.522	7,830.772	6,473.137
	(-0.265)	(-0.357)	(-0.285)	(0.161)	(0.076)	(0.062)
Log of amount willing to pay rent in (Ushs/acre)	46,325.444	46,813.802	48,148.971	-68,822.219	-66,949.223	-70,333.966
	(1.670)	(1.678)	(1.708)	(-0.695)	(-0.669)	(-0.694)
1 if purchased	90,738.704	91,163.867	101,532.207	-23,932.565	-10,806.231	18,901.018
	(0.800)	(0.797)	(0.884)	(-0.141)	(-0.064)	(0.114)
1 if received as gift/inheritance	-4,193.902	-4,558.933	-2,368.300	-80,665.283	-83,654.145	-77,723.632
	(-0.095)	(-0.103)	(-0.052)	(-0.693)	(-0.712)	(-0.687)
1 if just walked-in	-10,383.715	-3,190.729	3,795.022	-140,602.517	-129,673.729	-111,632.706
	(-0.122)	(-0.039)	(0.047)	(-1.309)	(-1.175)	(-1.037)
Log of farm size (ha)	-292,788.9***	-291,888.5***	-293,289.78***	-357,638.9**	-357,805.24**	-359,701.82**
	(-3.541)	(-3.507)	(-3.529)	(-2.789)	(-2.775)	(-2.777)
Log of length of ownership	6,708.211	6,616.117	5,817.304	52,281.174	49,433.582	49,632.339
	(0.286)	(0.281)	(0.243)	(1.388)	(1.400)	(1.379)
1 if female headed HH	-51,925.738	-54,186.094	-58,793.687			
	(-1.038)	(-1.066)	(-1.167)			
Age of HHH	2,681.873*	2,663.764*	2,792.866*			
	(1.874)	(1.822)	(1.860)			
Years of schooling of HHH	-4,387.137	-4,378.772	-4,420.067			
	(-1.083)	(-1.080)	(-1.107)			
Log of HH members of working age (15-64 years)	-35,832.439	-36,547.221	-35,870.722			
	(-0.779)	(-0.778)	(-0.756)			
Log of number of dependents (<15 &>64 years)	54,394.510	53,264.644	52,243.869			
	(1.710)	(1.666)	(1.595)			
Log of value of assets (Ushs)	43,482.082*	44,252.714*	42,901.628			
	(1.728)	(1.750)	(1.700)			
1 if road to district is tarmac+++	-320,630.824*	-326,736.89**	-291,248.093*			
	(-2.063)	(-2.153)	(-1.864)			
1 if road to district is all season dirt road+++	783,095.79***	803,538.73***	787,757.235***			
	(4.112)	(4.304)	(4.034)			
Log distance to the nearest district town	-221,451.1***	-220,413.9***	-210,002.982**			
	(-2.911)	(-3.066)	(-2.794)			
Log annual rainfall mm (25 yr average)	2494524.1***	2550521.2***	2496099.270***			
	(3.750)	(3.962)	(3.692)			
Altitude (meter)	1,086.329**	1,184.356**	1,060.174**			
	(2.664)	(2.780)	(2.510)			
Constant	-1.455e+07***	-1.496e+07***	-1.459e+07***	6385547.663	6411106.623	6074997.305
	(-3.876)	(-4.076)	(-3.802)	(0.669)	(0.668)	(0.631)
Observations	2,177	2,177	2,177	2,177	2,177	2,177
R-squared	0.095	0.095	0.095	0.074	0.073	0.073
Number of households				339	339	339
Season Season fixed effects *Household fixed				*Yes*	*Yes*	*Yes*

Notes: Robust t-statistics in parentheses. Asterisks ***, **, * indicates significance at 1%, 5%, 10%, respectively. Standard errors are clustered at community level. HH: Household, HHH: Household head. ++++Reference category: 1 if tenant, +++Reference group: 1 if road to the nearest district town is seasonal dirt, ++ Reference category: 1 if rented-in.
In all regressions, we include season dummy, village dummies, and crop dummies.

Table 4.15: Land conflicts and households' investment behaviour

Dependent variable: *1 if improved seeds adopted*

Explanatory Variables	(1) hyvsd	(2) hyvsd	(3) hyvsd
1 if has been concerned about land conflicts over the parcel	-0.003		
	(-0.144)		
1 if has had any land conflicts over the parcel		-0.021	
		(-0.759)	
1 if plot has pending land conflict			-0.113***
			(-3.228)
Walking time in minutes from homestead	0.000	0.000	0.000
	(0.161)	(0.174)	(0.328)
1 if owner++++	-0.108	-0.107	-0.114
	(-1.488)	(-1.475)	(-1.624)
1 if occupant++++	-0.042	-0.042	-0.043
	(-0.793)	(-0.782)	(-0.789)
Log of amount willing to pay rent in (Ushs/acre)	0.027*	0.026*	0.024
	(1.832)	(1.823)	(1.587)
1 if purchased++	-0.026	-0.025	-0.004
	(-0.359)	(-0.348)	(-0.064)
1 if received as gift/inheritance++	0.054	0.054	0.059
	(0.710)	(0.723)	(0.811)
1 if just walked-in++	0.060	0.060	0.071
	(0.953)	(0.943)	(1.142)
Log of farm size (ha)	0.023*	0.023*	0.023*
	(2.002)	(1.997)	(1.926)
Log of length of ownership of the plot	0.028	0.029	0.030*
	(1.655)	(1.673)	(1.737)
Constant	0.798	0.829	0.643
	(0.406)	(0.420)	(0.326)
Observations	2,177	2,177	2,177
R-squared	0.283	0.284	0.285
Number of households	339	339	339
CID FE	*Yes*	*Yes*	*Yes*
Season FE	*Yes*	*Yes*	*Yes*
LC1 FE	*Yes*	*Yes*	*Yes*
Ss*hh	*Yes*	*Yes*	*Yes*

Notes: Robust t-statistics in parentheses. Asterisks ***, **, * indicates significance at 1%, 5%, 10%, respectively. Standard errors are clustered at community level.

++++Reference category: 1 if tenant, ++ Reference category: 1 if rented-in.

List of Figures

Figure 2.1: Conceptual Framework linking population pressure and soil quality

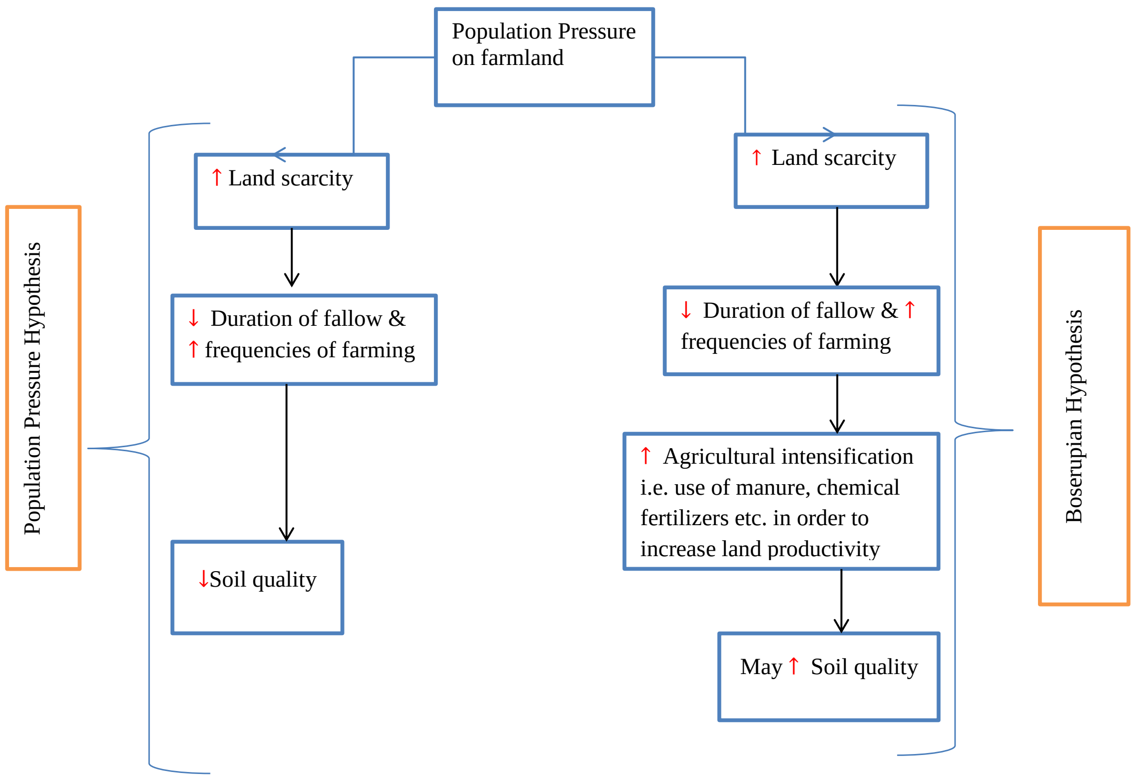
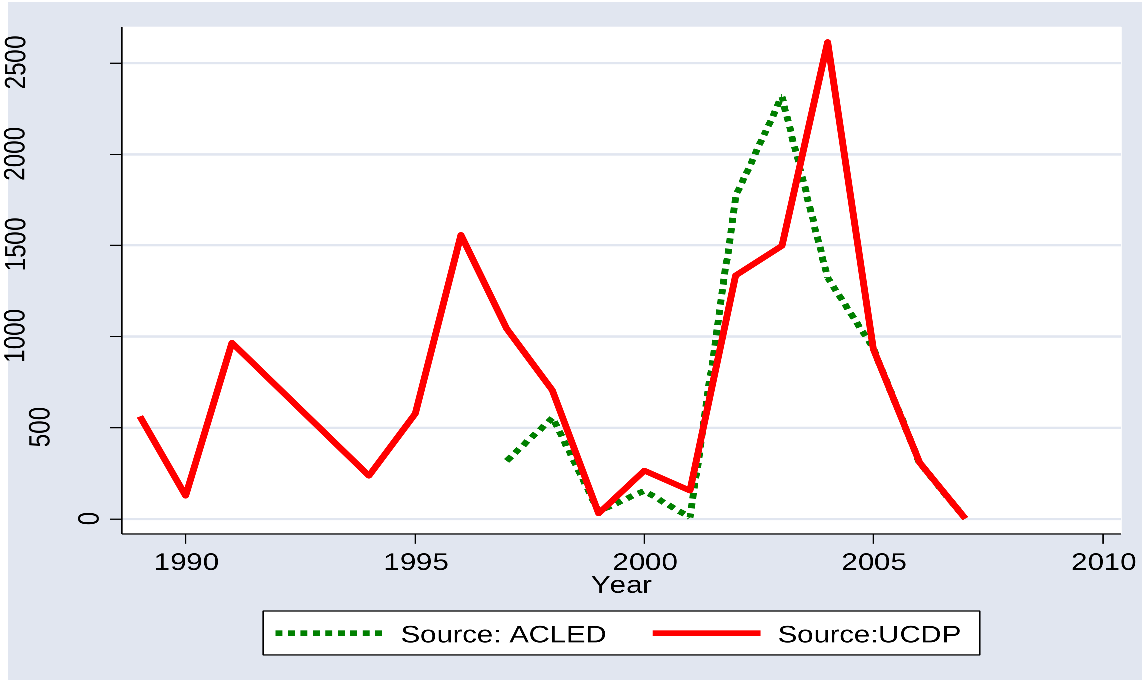


Figure 4.1: Number of fatalities during LRA insurgency in Northern Uganda



Source: Author's computation using Armed Conflict Location and Event Data (ACLED) (1997-2007) and Uppsala Conflict Data Program (UCDP) (1989-2007)

Figure 4.2: Conceptual model linking displacement, land conflicts and agricultural productivity in Northern Uganda

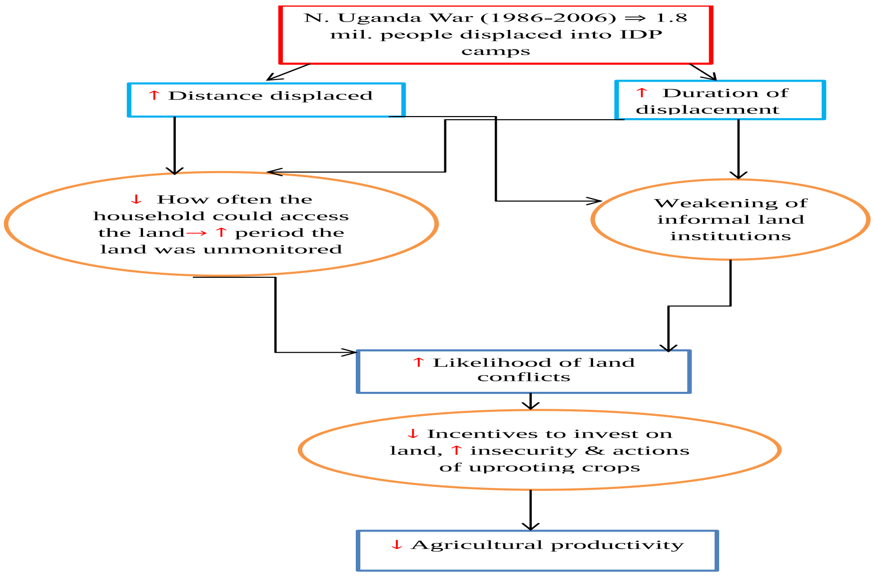
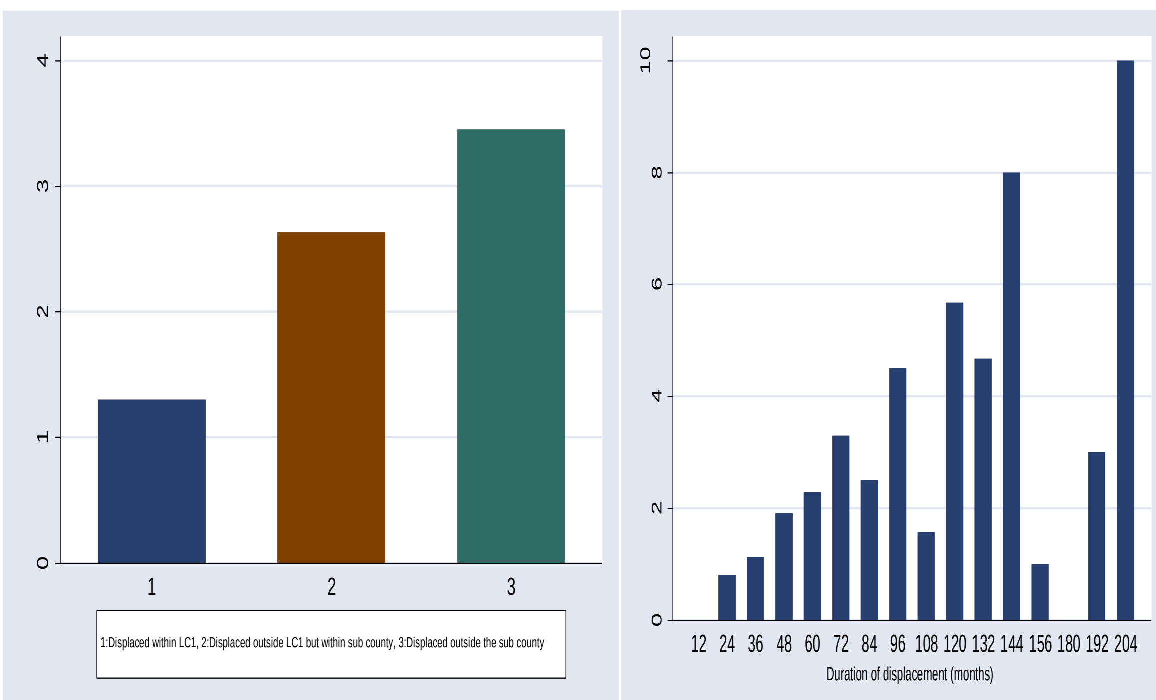


Figure 4.3: Average years the households could not do farming in their home villages during displacement by distance displaced and duration of displacement



Source: Author's computation using RePEAT data

Appendices

Table 2.A1: Determinants of attrition in the household survey and soil samples in Kenya

	(1)	(2)	(3)
Dependent variable	att1	att2	att3
Household characteristics in 2004			
Household head's age	-0.006	0.006	0.003
	(0.006)	(0.008)	(0.006)
Household head's education	-0.022	0.043	0.015
	(0.010)	(0.032)	(0.021)
1 if household head is female	0.262*	0.033	0.249*
	(0.152)	(0.241)	(0.147)
Number of female adults	-0.110	-0.045	-0.087
	(0.078)	(0.094)	(0.075)
Number of male adults	-0.026	-0.029	-0.049
	(0.061)	(0.103)	(0.061)
Av. years of schooling of female adults	0.001	-0.022	0.028
	(0.021)	(0.033)	(0.021)
Av. years of schooling of male adults	-0.003	-0.009	-0.007
	(0.022)	(0.027)	(0.021)
Log of value of assets	-0.011	0.017	0.010
	(0.050)	(0.0744)	(0.054)
Log of land holdings (ha)	-0.013	-0.152	-0.053
	(0.0547)	(0.094)	(0.064)
Region dummies[§]			
Western	0.933***	1.323***	0.504
	(0.228)	(0.335)	(0.324)
Rift Valley	0.072	0.049	-0.726**
	(0.206)	(0.363)	(0.308)
Central	0.157	0.134	-0.572*
	(0.226)	(0.324)	(0.295)
Eastern	-0.151	0.333	-0.712**
	(0.248)	(0.420)	(0.305)
Constant	-0.432	-2.323***	-0.391
	(0.549)	(0.860)	(0.659)
Number of households	899	899	598

Notes: Robust standard errors are in parentheses. *** Significance at the 1% level, ** significance at the 5% level, * significance at the 10% level. att1: 1 if not interviewed in second survey, att2: 1 if no soil sample in the first survey.att3: 1 if soil sample available in the first survey but household not available in the second survey or available but soil sample not available. [§]Reference category is Nyanza province.

Table 2.A2: Percentage of soil samples below the thresholds in Kenya

	Thresholds (low) <	% of samples below the thresholds		Recommendations
		2004	2012	
Carbon	2%[+]	44	25	Apply FYM or compost to gradually improve organic matter levels as well as providing valuable nutrient for plants. Apply organic fertilizers: poultry, pig and cattle manure all add organic matter to soil.
Nitrogen	0.2%	50.2	76.04	Inorganic or high quality organic fertilizers are required for good yields on farms with very low or low N levels (<0.2%),
Soil pH	6.0	40.8	48.8	Careful management is required to prevent further acidification, which may reduce nutrient availability. Organic or lime additions, and minimizing leaching losses (by maintaining good plant growth during rainy seasons and integrating deep rooted plants).
Exchangeable K	0.2 $cmol_c\ kg^{-1}$	0.42	1.04	Kenyan soils have good K-status
Exchangeable Ca	4 $cmol_c\ kg^{-1}$	11.04	13.3	The management strategy on these soils should focus on supplying adequate N and P inputs to support good crop yields.
Extractable P	7 $mg\ kg^{-1}$	8.3	17.7	P-deficient farms should give P-fertilizer or good quality manure additions highest priority

Source: Thresholds by Frank Palace, % computed by the author.

[+]Threshold obtained from the literature

Table 2.A3: Past population density and soil quality in Kenya

Dependent variable*: Soil quality index*

Explanatory variables	(1) index	(2) index	(3) sindexdumy	(4) npk
Ln population density	-0.283**	-0.233*	-0.281**	-0.175*
	(-2.337)	(-1.867)	(-2.311)	(-1.911)
1 if female HHH	0.413*	0.245	0.377*	0.244**
	(1.923)	(1.169)	(1.732)	(2.334)
Years of education of HHH	0.026	0.009	0.023	0.020
	(1.182)	(0.426)	(1.027)	(1.195)
Age of HHH	0.011	0.008	0.010	0.007*
	(1.291)	(0.993)	(1.222)	(1.698)
Family size	-0.011	0.005	-0.006	0.009
	(-0.268)	(0.145)	(-0.146)	(0.304)
Number of boys	0.013	-0.022	0.010	0.011
	(0.270)	(-0.584)	(0.231)	(0.254)
Number of adult males	0.015	0.020	0.017	-0.013
	(0.260)	(0.325)	(0.287)	(-0.352)
Number of adult females	0.031	-0.019	0.020	0.002
	(0.557)	(-0.310)	(0.348)	(0.048)
Average years of schooling of male adults	-0.018	-0.021	-0.019	-0.005
	(-0.913)	(-1.092)	(-0.982)	(-0.377)
Average years of schooling of female adults	0.021	0.030	0.023	0.017
	(1.039)	(1.421)	(1.108)	(0.964)
Per capita value of productive assets	-0.000	-0.000	-0.000	-0.000
	(-0.345)	(-0.371)	(-0.346)	(-0.190)
Per capita value of nonproductive assets	-0.000	-0.000	-0.000	-0.000
	(-0.788)	(-0.785)	(-0.938)	(-1.051)
Ln value of livestock	-0.018	0.000	-0.013	0.002
	(-0.651)	(0.000)	(-0.445)	(0.088)
Ln land used other than owned land	-0.029	-0.057	-0.044	0.036
	(-0.449)	(-0.865)	(-0.702)	(0.590)
Log travel time to nearby big town	0.125	-0.643	-0.116	-0.227
	(0.122)	(-0.556)	(-0.109)	(-0.370)
Rainfall mm (5 year average)	0.007	-0.003	0.004	0.012
	(0.579)	(-0.301)	(0.382)	(1.452)
Temperature (5 year average)	-0.001	-0.001*	-0.001	-0.000
	(-1.174)	(-1.918)	(-1.430)	(-1.446)
Wind (5 year average)	-0.000	-0.000	-0.000	0.001
	(-0.194)	(-0.087)	(-0.091)	(0.609)
Constant	0.064	13.750	3.727	-6.631
	(0.006)	(1.383)	(0.362)	(-0.864)
Observations	960	960	960	960
R-squared	0.191	0.360	0.243	0.088
Number of hhdid	480	480	480	480
HH FE	Yes	Yes	Yes	Yes
Year*Region dummies	Yes	Yes	Yes	Yes

Notes: Robust t-statistics in parentheses. ***Significant at 1% level, **Significant at 5%, *Significant at 10%. Robust standard errors are clustered at community level. Estimates are weighted by attrition weights. In column (2) the index is created by using five macro-nutrients (excluding soil pH). In column (3) the index is created by using six soil variables but soil pH enters as the dummy variable i.e 1 if neutral (soil pH >=6.6 &soil pH<=7.3) and zero otherwise. In column (4) the index is created by using nitrogen, phosphorus, and potassium (NPK) i.e., key macro-nutrients.

Table 2.A4: Population Pressure and soil quality in Kenya (by using "current" population density)

Dependent variable*: Soil quality index*

Explanatory variables	(1)	(2)	(3)	(4)	(5)	(6)
Inverse of owned land per capita	-0.002		-0.001	-0.002	-0.001	-0.002
	(-0.595)		(-0.544)	(-0.594)	(-0.499)	(-1.119)
Ln population density		-0.283**	-0.283**	-0.283**	-0.281**	-0.175*
		(-2.337)	(-2.330)	(-2.311)	(-2.304)	(-1.903)
1 if female HHH	0.402*	0.413*	0.417*	0.393*	0.381*	0.249**
	(1.822)	(1.923)	(1.934)	(1.809)	(1.744)	(2.359)
Years of education of HHH	0.024	0.026	0.026	0.023	0.023	0.020
	(1.045)	(1.182)	(1.187)	(1.067)	(1.033)	(1.201)
Age of HHH	0.011	0.011	0.011	0.010	0.010	0.007*
	(1.391)	(1.291)	(1.289)	(1.245)	(1.219)	(1.691)
Family size	-0.009	-0.011	-0.011	-0.007	-0.006	0.009
	(-0.218)	(-0.268)	(-0.278)	(-0.186)	(-0.155)	(0.296)
Number of boys	0.019	0.013	0.016	0.009	0.013	0.014
	(0.374)	(0.270)	(0.332)	(0.204)	(0.303)	(0.335)
Number of adult males	0.005	0.015	0.016	0.017	0.018	-0.012
	(0.086)	(0.260)	(0.280)	(0.294)	(0.307)	(-0.319)
Number of adult females	0.029	0.031	0.031	0.021	0.020	0.003
	(0.541)	(0.557)	(0.571)	(0.376)	(0.361)	(0.067)
Average yrs of schooling of male adults	-0.015	-0.018	-0.018	-0.019	-0.020	-0.005
	(-0.773)	(-0.913)	(-0.918)	(-0.979)	(-0.987)	(-0.386)
Average yrs of schooling of female adults	0.021	0.021	0.022	0.024	0.023	0.018
	(1.011)	(1.039)	(1.069)	(1.165)	(1.139)	(0.999)
Per capita value of productive assets	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
	(-0.556)	(-0.345)	(-0.344)	(-0.400)	(-0.345)	(-0.188)
Per capita value of nonproductive assets	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
	(-0.595)	(-0.788)	(-0.788)	(-0.837)	(-0.938)	(-1.048)
Ln value of livestock	-0.018	-0.018	-0.019	-0.016	-0.013	0.001
	(-0.656)	(-0.651)	(-0.684)	(-0.586)	(-0.480)	(0.052)
Ln land used other than owned land	-0.028	-0.029	-0.029	-0.036	-0.044	0.037
	(-0.417)	(-0.449)	(-0.441)	(-0.560)	(-0.693)	(0.598)
Log travel time to nearby big town	0.859	0.125	0.138	-0.011	-0.103	-0.213
	(0.874)	(0.122)	(0.135)	(-0.011)	(-0.097)	(-0.345)
Rainfall mm (5 year average)	-0.001	0.007	0.007	0.005	0.004	0.012
	(-0.049)	(0.579)	(0.586)	(0.437)	(0.391)	(1.458)
Temperature °c (5 year average)	-0.000	-0.001	-0.001	-0.001	-0.001	-0.000
	(-0.703)	(-1.174)	(-1.177)	(-1.361)	(-1.433)	(-1.452)
Wind 10m (m/s) (5 year average)	-0.002	-0.000	-0.000	-0.000	-0.000	0.001
	(-0.597)	(-0.194)	(-0.191)	(-0.167)	(-0.088)	(0.612)
Constant	1.080	0.064	-0.161	2.668	3.471	-6.748
	(0.095)	(0.006)	(-0.015)	(0.257)	(0.339)	(-0.878)
Observations	960	960	960	960	960	960
R-squared	0.165	0.191	0.191	0.227	0.244	0.088
Number of households	480	480	480	480	480	480
HH FE	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Year FE	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Year*Region dummies	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*

Notes: Robust t-statistics in parentheses. ***Significant at 1% level, **Significant at 5%, *Significant at 10%. Robust standard errors are clustered at community level. Estimates are weighted by attrition weights. In column (4) the index is created by using five macro-nutrients (excluding soil pH). In column (5) the index is created by using six soil variables but soil pH enters as the dummy variable i.e 1 if neutral (soil pH >=6.6 &soil pH<=7.3) and zero otherwise. In column (6) the index is created by using nitrogen, phosphorus, and potassium (NPK) i.e., key macro-nutrients.

Table 3.A1: Determinants of attrition in the household survey and soil samples in Uganda

Dependent variable	(1) att1	(2) att2	(3) att3
Household characteristics in the baseline survey			
Household head's age	-0.012***	-0.001	-0.008
	(0.004)	(0.003)	(0.005)
Household head's education	0.002	0.006	-0.001
	(0.023)	(0.017)	(0.025)
1 if household head is female	0.216	0.087	0.083
	(0.147)	(0.121)	(0.189)
Number of female adults	0.049	-0.068*	0.002
	(0.039)	(0.038)	(0.043)
Number of male adults	0.039	0.034	0.043
	(0.037)	(0.036)	(0.045)
Av. years of schooling of female adults	-0.013	-0.024	0.015
	(0.016)	(0.018)	(0.023)
Av. years of schooling of male adults	-0.009	-0.018	-0.013
	(0.023)	(0.019)	(0.025)
Log of value of assets	-0.048	0.041	-0.008
	(0.054)	(0.057)	(0.064)
Log of land holdings (ha)	-0.034	-0.099***	-0.079**
	(0.023)	(0.029)	(0.037)
Region dummies[f]			
East	0.274**	0.502**	0.214
	(0.126)	(0.202)	(0.167)
West	0.060	0.411**	0.414**
	(0.115)	(0.207)	(0.192)
Constant	0.122	-0.762	-0.334
	(0.595)	(0.630)	(0.730)
Number of households	940	940	559

Notes: Robust standard errors are in parentheses. *** Significance at the 1% level, ** significance at the 5% level, * significance at the 10% level. att1: 1 if not interviewed in second survey. att2: 1 if no soil sample in the first survey. att3: 1 if soil sample available in the first survey but household not available in the second survey or available but soil sample not available. [f]Reference category is Central.

Table 3.A2: Percentage of soil samples below the thresholds in Uganda

	Thresholds (low) <	% of samples below the thresholds		Recommendations
		2003	2012	
Carbon	2%[+]	49	10	Apply FYM or compost to gradually improve organic matter levels as well as providing valuable nutrient for plants. Apply organic fertilizers: poultry, pig and cattle manure all add organic matter to soil.
Nitrogen	0.2%	56	86	Inorganic or high quality organic fertilizers are required for good yields on farms with very low or low N levels (<0.2%),
Soil pH	6.0	10.3	33.5	Careful management is required to prevent further acidification, which may reduce nutrient availability. Organic or lime additions, and minimizing leaching losses (by maintaining good plant growth during rainy seasons and integrating deep rooted plants).
Exchangeable K	0.2 $cmol_c\ kg^{-1}$	1.5	0.98	Kenyan and Ugandan soils have good K-status
Exchangeable Ca	4 $cmol_c\ kg^{-1}$	16.6	11.98	The management strategy on these soils should focus on supplying adequate N and P inputs to support good crop yields.
Extractable P	7 $mg\ kg^{-1}$	20.2	1.2	P-deficient farms should give P-fertilizer or good quality manure additions highest priority

Source: Thresholds by Frank Palace. % computed by the author

[+]Threshold obtained from the literature

Table 4.A1: Household characteristics by settlement status (original settlers vs. new settlers)

	Original settlers (N=301)	New settlers (N=43)		Diff. in mean
1 if household is female headed	0.27	0.14	0.13	**
Age of household head	46.60	40.14	6.46	***
Years of schooling of household head	5.75	6.84	-1.09	
Family size	6.34	6.16	0.17	
Average years of schooling of adults	6.31	6.38	-0.08	
Value of assets (Ushs)	568740.2	419923.26	148816.94	
Land holding (ha)	2.86	1.94	0.92	
1 if any HH member was threatened to killed, beaten or tortured during the war	0.44	0.47	-0.02	
1 if houses were damaged during the war	0.48	0.56	-0.08	
1 if non-residential buildings were damaged during the war	0.37	0.42	-0.05	
1 if any item was stolen during the war	0.52	0.51	0.01	
1 if any other valuables were stolen during the war	0.03	0.51	-0.48	
Value of livestock (in tropical units) stolen during the war	2.03	1.21	0.82	
1 if the household is concerned about land disputes	0.27	0.23	0.03	
1 if the has had new land disputes	0.27	0.21	0.06	
Proportion of parcels with concerns about land conflicts	0.12	0.12	0.00	
Proportion of parcels that have faced new land conflicts	0.10	0.11	0.00	
1 if there have been land conflicts in the LC1 prior 1996	0.49	0.40	0.09	
1 if there have been land conflicts in the LC1 prior 2006	0.44	0.37	0.07	
1 if displaced	0.60	0.58	0.02	
	N=180	N=25		
1 if displaced within the LC1	0.44	0.60	-0.16	
1 if displaced outside the LC1 but within the sub-county	0.39	0.12	0.27	***
1 if displaced outside the sub-county	0.17	0.28	-0.11	

Table 4.A2: Within villages variation in displacement and distance displaced

Sub-region	Village	Variable	Mean	Variance	Obs.
Acholi	Akuli	1 if displaced	1.00	0.00	15
		1 if displaced within the LC1	0.00	0.00	15
		1 if displaced outside the LC1 but within the sub county	0.53	0.27	15
		1 if displaced outside the sub county	0.47	0.27	15
	Aringa East	1 if displaced	0.87	0.12	15
		1 if displaced within the LC1	0.92	0.08	13
		1 if displaced outside the LC1 but within the sub county	0.08	0.08	13
		1 if displaced outside the sub county	0.00	0.00	13
	Ocaga	1 if displaced	1.00	0.00	15
		1 if displaced within the LC1	0.00	0.00	15
		1 if displaced outside the LC1 but within the sub county	0.67	0.24	15
		1 if displaced outside the sub county	0.33	0.24	15
	Kabete	1 if displaced	0.93	0.07	15
		1 if displaced within the LC1	0.00	0.00	14
		1 if displaced outside the LC1 but within the sub county	0.93	0.07	14
		1 if displaced outside the sub county	0.07	0.07	14
	Teokilo	1 if displaced	1.00	0.00	15
		1 if displaced within the LC1	0.00	0.00	15
		1 if displaced outside the LC1 but within the sub county	0.93	0.07	15
		1 if displaced outside the sub county	0.07	0.07	15
	Palowaga	1 if displaced	0.93	0.07	15
		1 if displaced within the LC1	0.00	0.00	14
		1 if displaced outside the LC1 but within the sub county	0.71	0.22	14
		1 if displaced outside the sub county	0.29	0.22	14
	Dyang BII	1 if displaced	0.60	0.26	15
		1 if displaced within the LC1	1.00	0.00	9
		1 if displaced outside the LC1 but within the sub county	0.00	0.00	9
		1 if displaced outside the sub county	0.00	0.00	9
	Okir-Choorom Centre	1 if displaced	0.93	0.07	15
		1 if displaced within the LC1	0.00	0.00	14
		1 if displaced outside the LC1 but within the sub county	0.21	0.18	14
		1 if displaced outside the sub county	0.79	0.18	14
	Obic West	1 if displaced	0.80	0.17	15
		1 if displaced within the LC1	0.92	0.08	12
		1 if displaced outside the LC1 but within the sub county	0.08	0.08	12
		1 if displaced outside the sub county	0.00	0.00	12
	Mission B	1 if displaced	0.27	0.21	15
		1 if displaced within the LC1	0.00	0.00	4
		1 if displaced outside the LC1 but within the sub county	0.50	0.33	4
		1 if displaced outside the sub county	0.50	0.33	4
	Oratwilo Central	1 if displaced	0.87	0.12	15
		1 if displaced within the LC1	1.00	0.00	13
		1 if displaced outside the LC1 but within the sub county	0.00	0.00	13
		1 if displaced outside the sub county	0.00	0.00	13
Lango	Akuni	1 if displaced	0.00	0.00	15
		1 if displaced within the LC1	*na*	*na*	0
		1 if displaced outside the LC1 but within the sub county	*na*	*na*	0
		1 if displaced outside the sub county	*na*	*na*	0
	Abeibuti	1 if displaced	0.00	0.00	14
		1 if displaced within the LC1	*na*	*na*	0
		1 if displaced outside the LC1 but within the sub county	*na*	*na*	0
		1 if displaced outside the sub county	*na*	*na*	0
	Abongo Kere (Chakali)	1 if displaced	0.00	0.00	15
		1 if displaced within the LC1	*na*	*na*	0
		1 if displaced outside the LC1 but within the sub county	*na*	*na*	0
		1 if displaced outside the sub county	*na*	*na*	0
	Okwoagwe	1 if displaced	0.07	0.07	15
		1 if displaced within the LC1	0.00	*na*	1
		1 if displaced outside the LC1 but within the sub county	0.00	*na*	1
		1 if displaced outside the sub county	1.00	*na*	1

Table 4.A2 cont.: Within variation villages in displacement and distance displaced

Sub-region	Village	Variable	Mean	Variance	Obs.
Lango	Abura	1 if displaced	1.00	0.00	15
		1 if displaced within the LC1	0.00	0.00	15
		1 if displaced outside the LC1 but within the sub county	0.87	0.12	15
		1 if displaced outside the sub county	0.13	0.12	15
	Ket Can Can Itic	1 if displaced	0.80	0.17	15
		1 if displaced within the LC1	1.00	0.00	12
		1 if displaced outside the LC1 but within the sub county	0.00	0.00	12
		1 if displaced outside the sub county	0.00	0.00	12
	Alworo Central	1 if displaced	0.00	0.00	15
		1 if displaced within the LC1	*na*	*na*	0
		1 if displaced outside the LC1 but within the sub county	*na*	*na*	0
		1 if displaced outside the sub county	*na*	*na*	0
	Akwoyo	1 if displaced	0.80	0.17	15
		1 if displaced within the LC1	0.92	0.08	12
		1 if displaced outside the LC1 but within the sub county	0.08	0.08	12
		1 if displaced outside the sub county	0.00	0.00	12
	Alela	1 if displaced	0.87	0.12	15
		1 if displaced within the LC1	1.00	0.00	13
		1 if displaced outside the LC1 but within the sub county	0.00	0.00	13
		1 if displaced outside the sub county	0.00	0.00	13
	Ayomet B	1 if displaced	0.20	0.17	15
		1 if displaced within the LC1	0.00	0.00	3
		1 if displaced outside the LC1 but within the sub county	0.00	0.00	3
		1 if displaced outside the sub county	1.00	0.00	3
	Opoicen	1 if displaced	0.73	0.21	15
		1 if displaced within the LC1	1.00	0.00	11
		1 if displaced outside the LC1 but within the sub county	0.00	0.00	11
		1 if displaced outside the sub county	0.00	0.00	11
	Agomi A	1 if displaced	0.00	0.00	15
		1 if displaced within the LC1	*na*	*na*	0
		1 if displaced outside the LC1 but within the sub county	*na*	*na*	0
		1 if displaced outside the sub county	*na*	*na*	0

Table 4.A3: Displacement and land conflicts: New land conflicts redefined with different cutoff years

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	1 if there has been new land conflicts (2003)		Proportion of parcels with new land conflicts (2003)		1 if there has been new land conflicts (2004)		Proportion of parcels with new land conflicts (2004)		1 if there has been new land conflicts (2005)		Proportion of parcels with new land conflicts (2005)	
Explanatory Variables												
Log duration of displacement	0.054	-0.099	0.017	-0.066	0.054	-0.099	0.015	-0.069	0.053	-0.101	0.015	-0.069
	(0.575)	(-0.768)	(0.382)	(-1.313)	(0.575)	(-0.768)	(0.345)	(-1.374)	(0.552)	(-0.780)	(0.338)	(-1.382)
1 if displaced outside LC1 but within sub-county	-0.085	-0.032	-0.041	-0.067	-0.085	-0.032	-0.043	-0.064	-0.080	-0.042	-0.042	-0.066
	(-1.608)	(-0.164)	(-1.525)	(-0.742)	(-1.608)	(-0.164)	(-1.585)	(-0.717)	(-1.471)	(-0.220)	(-1.525)	(-0.745)
1 if displaced outside the sub-county	0.213***	0.200	0.133***	0.077	0.213***	0.200	0.130***	0.078	0.212***	0.184	0.130***	0.075
	(2.694)	(0.926)	(2.896)	(0.746)	(2.694)	(0.926)	(2.874)	(0.761)	(2.661)	(0.872)	(2.850)	(0.735)
1 if female headed HH	0.019	0.043	-0.016	-0.002	0.019	0.043	-0.015	-0.001	0.024	0.049	-0.014	-0.000
	(0.187)	(0.428)	(-0.442)	(-0.049)	(0.187)	(0.428)	(-0.410)	(-0.036)	(0.227)	(0.463)	(-0.374)	(-0.006)
Age of HHH	0.002	0.002	0.001	0.001	0.002	0.002	0.001	0.001	0.002	0.002	0.001	0.001
	(0.754)	(0.758)	(0.710)	(0.897)	(0.754)	(0.758)	(0.673)	(0.865)	(0.734)	(0.752)	(0.662)	(0.861)
Years of schooling of HHH	0.012	0.011	0.003	0.002	0.012	0.011	0.003	0.002	0.012	0.011	0.003	0.002
	(1.149)	(0.993)	(0.621)	(0.417)	(1.149)	(0.993)	(0.622)	(0.412)	(1.144)	(0.995)	(0.623)	(0.415)
Family size	-0.003	-0.002	-0.005	-0.004	-0.003	-0.002	-0.005	-0.004	-0.006	-0.004	-0.005	-0.005
	(-0.217)	(-0.104)	(-0.768)	(-0.596)	(-0.217)	(-0.104)	(-0.772)	(-0.626)	(-0.366)	(-0.237)	(-0.832)	(-0.680)
Log of value of assets (Ushs)	0.032	0.033	0.015	0.018	0.032	0.033	0.015	0.018	0.032	0.034	0.015	0.018
	(1.350)	(1.256)	(1.473)	(1.464)	(1.350)	(1.256)	(1.438)	(1.457)	(1.362)	(1.268)	(1.444)	(1.463)
Log of landholding (ha)	0.087**	0.064**	0.035***	0.022*	0.087**	0.064**	0.034***	0.022*	0.084**	0.061*	0.033***	0.021*
	(2.540)	(1.969)	(2.685)	(1.769)	(2.540)	(1.969)	(2.602)	(1.710)	(2.477)	(1.865)	(2.583)	(1.668)
Number of parcels owned	0.063*	0.063*	0.000	-0.001	0.063*	0.063*	-0.001	-0.001	0.056	0.056	-0.002	-0.003
	(1.898)	(1.805)	(0.009)	(-0.041)	(1.898)	(1.805)	(-0.062)	(-0.103)	(1.638)	(1.565)	(-0.156)	(-0.195)
Log average walking distance to parcels	0.009	0.020	0.001	0.007	0.009	0.020	0.001	0.007	0.008	0.018	0.001	0.007
	(0.366)	(0.761)	(0.135)	(0.598)	(0.366)	(0.761)	(0.087)	(0.578)	(0.337)	(0.705)	(0.074)	(0.551)
1 if new settler after the LRA insurgence	0.046	0.013	0.067	0.060	0.046	0.013	0.069	0.061	0.047	0.014	0.069	0.061
	(0.405)	(0.082)	(1.031)	(0.737)	(0.405)	(0.082)	(1.072)	(0.750)	(0.413)	(0.094)	(1.078)	(0.758)
Constant	-0.532		0.854		-0.532		1.043		-0.540		1.042	
	(-0.079)		(0.308)		(-0.079)		(0.377)		(-0.080)		(0.377)	
Observations	205	204	205	204	205	204	205	204	205	204	205	204
R-squared	0.204	0.106	0.181	0.070	0.204	0.106	0.182	0.068	0.187	0.094	0.176	0.067
Number of LC1		17		17		17		17		17		17
LC1 FE		*Yes*		*Yes*		*Yes*		*Yes*		*Yes*		*Yes*

Notes: Column 1-4 new land conflict is defined as any land conflicts that started in 2003 or after .Column 5-8 new land conflict is defined as any land conflicts that started in 2004 or after. Column 9-12 new land conflict is defined as any land conflicts that started in 2005 or after.

Results regarding the impact of displacement on new land conflicts not reported but they are not significant.

Robust t-statistics in parentheses. Asterisks ***, **, * indicates significance at 1%, 5%, 10%, respectively. Standard errors are clustered at community level. HH: Household, HHH: Household head.

Additional controls: Log of population density (persons/sq kms), Log distance to the nearest district town, Proportion of HHs whose heads were born outside the LC1, road condition (1 if road to the nearest district town is tarmac, 1 if road to the nearest district town is all season dirt road),Annual rainfall mm (10 year average:2006-2015), Annual temp ºc (10 year average:2006-2015), Log of no. of HHs who moved out permanently in the last 10 years, Log of average land holding (acres), Log of cost to rent an acre of good quality land during last cropping season, 1 if the LC1 had land disputes prior 2003, 2004, 2005 accordingly.

Table 4.A4: Displacement and land conflicts: Parcel-level analysis

	1 if there has been concern about land conflicts			1 if there has been new land conflicts		
	(1)	(2)	(3)	(4)	(5)	(6)
1 if displaced	0.016	0.052*		0.002	0.042	
	(0.545)	(1.727)		(0.094)	(1.431)	
1 if displaced outside the LC1 but within the sub-county^{+}			-0.001			-0.026
			(-0.036)			(-1.069)
1 if displaced outside the sub-county $^{+}$			0.138***			0.148***
			(2.704)			(3.154)
Log duration of displacement			-0.002			0.021
			(-0.045)			(0.555)
Parcel size (ha)	0.008*	0.008*	0.009	0.006	0.005	0.015***
	(1.946)	(1.877)	(1.323)	(1.538)	(1.317)	(4.854)
Log of walking distance from homestead to parcel	0.005	-0.001	0.009	-0.001	-0.006	0.008
	(0.465)	(-0.099)	(0.834)	(-0.191)	(-0.817)	(0.958)
Log length of ownership of parcel	0.005	0.015	0.012	-0.005	0.004	0.006
	(0.438)	(1.204)	(1.064)	(-0.482)	(0.309)	(0.459)
1 if purchased^{++}	0.050	0.011	0.153*	0.132**	0.102*	0.186**
	(1.336)	(0.259)	(1.746)	(2.627)	(1.877)	(2.271)
1 if received as gift or inherited^{++}	0.106***	0.072**	0.075***	0.118***	0.091***	0.085***
	(3.279)	(2.465)	(2.674)	(4.001)	(3.105)	(2.860)
1 if just walked-in^{++}	0.065	0.011	0.030	0.087	0.048	0.113
	(0.724)	(0.114)	(0.542)	(1.043)	(0.515)	(1.255)
Log of cost of rent-in (per acre) in one cropping season	0.006	0.016	0.013	-0.001	0.009	0.015
	(0.360)	(0.807)	(0.670)	(-0.059)	(0.645)	(0.994)
1 if parcel has been used as collateral	0.160	0.161	0.113	0.221	0.227	0.186
	(1.082)	(1.067)	(0.659)	(1.581)	(1.602)	(1.050)
1 if household has a plan to use parcel as a collateral	0.086***	0.079***	0.059	0.028	0.028	0.018
	(3.472)	(3.009)	(1.466)	(1.005)	(0.968)	(0.678)
1 if female headed HH	0.042	0.057	0.009	0.027	0.039	0.009
	(1.189)	(1.565)	(0.274)	(0.875)	(1.203)	(0.230)
Age of HHH	0.000	-0.000	0.000	0.000	-0.000	0.001
	(0.038)	(-0.279)	(0.063)	(0.227)	(-0.038)	(1.033)
Years of schooling of HHH	0.002	0.004	0.000	0.002	0.004	0.003
	(0.548)	(1.239)	(0.011)	(0.678)	(1.416)	(0.815)
Family size	-0.001	-0.002	-0.001	-0.002	-0.003	-0.001
	(-0.295)	(-0.375)	(-0.145)	(-0.544)	(-0.737)	(-0.159)
Log value of assets (Ushs)	0.012	0.013	0.011	0.012	0.014*	0.006
	(1.083)	(1.193)	(0.949)	(1.388)	(1.788)	(0.640)
1 if HH is a new settler after the LRA insurgency	0.012	0.048*	0.022	-0.003	0.030	0.016
	(0.400)	(1.774)	(0.543)	(-0.077)	(0.870)	(0.336)
Population density	0.000**	0.001***	0.000**	0.000**	0.000***	0.000***
	(2.158)	(6.097)	(2.225)	(2.493)	(6.292)	(4.759)
Log distance to the nearest district town	0.009	0.179***	0.024	0.027	0.242***	0.034*
	(0.341)	(4.120)	(0.778)	(1.150)	(6.345)	(1.646)
Prop of HH whose HHH were born outside the LC1	0.000	0.042***	-0.001	-0.000	0.028***	-0.001
	(0.086)	(4.796)	(-0.436)	(-0.178)	(2.834)	(-0.758)
1 if road to the nearest district town is tarmac^{+++}	-0.157	-2.699***	-0.034	-0.010	-1.458**	0.138
	(-0.956)	(-4.337)	(-0.166)	(-0.058)	(-2.231)	(0.903)
1 if road to the nearest district town is all season dirty^{+++}	-0.005	0.276**	-0.142	-0.007	0.327***	-0.064
	(-0.270)	(2.391)	(-1.562)	(-0.254)	(3.277)	(-1.385)
Log of altitude	0.277	2.513***	-0.241	0.327*	3.037***	-0.141
	(1.253)	(3.179)	(-1.378)	(1.851)	(4.261)	(-0.858)
Rainfall mm (10-year average)	-0.000	-0.000	0.002**	-0.000	0.001	0.002***
	(-0.596)	(-0.359)	(2.095)	(-0.158)	(1.548)	(4.110)
Temperature (10-year average)	0.000	0.000***	0.000	-0.000	0.000**	-0.000
	(0.731)	(5.094)	(1.217)	(-0.140)	(2.215)	(-0.288)
Log of no. of HH who moved out the LC1 permanently in the past 10 years	0.051	-0.176***	-0.006	0.026	-0.168***	-0.008
	(1.137)	(-4.508)	(-0.144)	(0.582)	(-5.097)	(-0.256)
Log of average land size per HH (acres)	0.048	0.219***	0.058**	0.077*	0.284***	0.069***
	(1.545)	(4.356)	(1.987)	(2.047)	(5.933)	(3.396)
1 if the community had land conflicts prior 2006	0.108***	0.223***	0.022	0.035	0.197***	-0.028
	(4.747)	(4.098)	(0.458)	(1.568)	(3.637)	(-0.803)
Constant	-2.395	-20.309***	0.358	-2.623*	-23.78***	0.246
	(-1.433)	(-3.629)	(0.278)	(-1.984)	(-4.837)	(0.204)
Observations	1,010	1,010	613	1,010	1,010	613
R-squared	0.086	0.115	0.103	0.055	0.080	0.111
LC1 fixed effects		yes			yes	

Notes: Results in columns 1, 2, 4 and 5 are estimated by OLS; Results in columns 3 & 6 are estimated by IV.

Robust t-statistics in parentheses. Asterisks ***, **, * indicates significance at 1%, 5%, 10%, respectively. Standard errors are clustered at community level. HHH: Household, HHH: Household head, $^{+}$Reference group: 1 if the household was displaced within its LC1, $^{+++}$Reference group: 1 if the road to the nearest district town is seasonal dirt; $^{++}$Reference category: 1 if model of acquisition is rented-in.

Figure 4.A1: Map of Uganda showing areas that were affected by LRA

Source:https://commons.wikimedia.org/wiki/File:Ugandan_districts_affected_by_Lords_Resistance_Army.pn g

Figure 4.A2: Typical IDP camp in Northern Uganda when was no longer populated.

Source: https://justiceinconflict.org/2012/04/09/a-genocide-in-northern-uganda-the-protected-camps-policy-of-1999-to-2006/