Land conservation in Kenya: The role of property rights

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Abstract

Land conservation technologies are known to play an important role in improving farm incomes. For this reason substantial investments have been made in research to improve agricultural technologies in various parts of the world, from the development of new crop varieties to new practices of land management. The present study responds to the paucity of literature on determinants of land conservation practices in Kenya. The study builds on the few existing studies in this area and explores the impact of land rights and assets among other factors on adoption of soil conservation practices. The study further tests for Boserup's hypothesis and the evolutionary theory of land rights using both descriptive and econometric procedures. Primary data from households in a semi-arid district in Kenya are used to achieve the study objectives. Random effects probits are used to derive the parametric estimates of our models. The findings are that property right regimes and assets affect both the decision to conserve land and the type of conservation practices used by farmers. The results further suggest a positive correlation between land tenure security and population density, thus supporting Boserup's hypothesis as well as the evolutionary land rights theory. We also find that the poor are less likely to adopt land conservation practices than the non-poor. Education, available biomass, market development and location of the farm are also found to be important determinants of adoption. These findings call for pursuit of both short-term and long-term policy measures that offer incentives for land conservation through government initiatives and involvement of local communities. The recommended policy measures include enhanced security of tenure, targeted programmes for poverty alleviation, improved access to education, and development of social and physical infrastructure.

Key words: Land conservation, property rights, assets, population density

1. Introduction

In many countries in sub-Saharan Africa, Kenya included, agriculture remains one of the largest sectors in terms of contribution to GDP, employment generation, foreign exchange earnings and ensuring food security. The sector also provides important linkages with other sectors of the economy, including provision of raw materials to the industrial sector, purchase of inputs from the industrial sectors and exchange with the services sector (mostly banking and insurance). These countries are also characterized by large subsistence sectors, which make agriculture even more important for food security. Over the last two decades, however, agricultural production has declined because of soil erosion and degradation of agricultural land among other factors. Declining agricultural production contributes to rural poverty, which further exacerbates land degradation. It is well documented that poverty, agricultural stagnation and resource degradation are interlinked and that a set of exogenous and endogenous factors condition this link (WCED, 1987; see also Pleskovic and Stiglitz, 1997). The technologies people use play a fundamental role in shaping the efficiency, equity and environmental sustainability of natural resources. This has been reason for substantial investments in research to improve agricultural technologies, from new crop varieties to natural resource management practices (McCulloch et al., 1998).

Traditionally, many African pastoralists and farm households responded to declining land productivity by abandoning existing degraded pasture and cropland and moving into new lands (Barbier, 1999). Today, with privatization of land and population pressure, rural people are compelled to remain on the same parcel of land. Where households are neither able to generate a market surplus nor fall back on markets for both agricultural produce and factors of production, they continue to use traditional production techniques. In such cases, soil fertility and structure deteriorate rapidly, crop yields decline, and soils erode.

Land pressure and degradation is most acute in marginal pastoral areas, where livestock husbandry tends to have adverse effects on the environment. Available estimates show that overgrazing causes 35% of all human-induced soil degradation worldwide and 49% in Africa (Haen, 1993; Pinstrup-Anderson and Pandya-Lorch, 1994). Available evidence from Kenya also indicates that livestock activities and crop farming have contributed to environmental degradation and poverty especially in the arid and semi arid areas, which are characterized by a limited natural resource base and low carrying capacity. About 25% of the poorest people in rural Kenya are concentrated on low-potential lands where inadequate or unreliable rainfall, adverse soil conditions, low soil fertility, and topography limit agricultural production and increase the risk of chronic land degradation (Republic of Kenya, 1999). These less favourable agricultural lands, with their lower productivity potential, poor soils and physical characteristics, are easily prone to land degradation due to over cropping, poor farming practices and inadequate conservation measures, aggravated by rapidly increasing human and livestock populations.

In spite of increased agricultural extension services, adoption of soil conservation practices is still poor especially in marginal ecological and socioeconomic settings. Conservation practices in crop and animal husbandry are still characterized by extensive systems, low level of external inputs and poor resource base, leading to further reduction in soil productivity. This not withstanding, little empirical evidence exists on the economic impact, drivers and consequences of degradation of agricultural land. Most studies focus on the impact of soil conservation on productivity (Tiffen et al., 1994). Lack of adequate empirical farm level data on the impact of socioeconomic factors on environmental degradation has hindered economic evaluation of alternative options and policies for sustainable land management in fragile ecological environments. Understanding the roots of environmental degradation and the deepening poverty, and designing appropriate policies and strategies for reversing the problem, requires careful analysis of the microeconomic behaviour of smallholder farmers (Shiferaw and Holden, 1999). This study addresses this research gap, focusing on the incentives for land conservation among smallholder farmers in fragile ecological environments in Kenya. It is motivated by the paucity of literature on determinants of land conservation practices in Kenya. We explore the impact of land rights and assets among other variables on the adoption of land improvements. Property rights are an important determinant of adoption of land conservation practices because they determine who benefits from productivity increases, both directly by determining who can reap the benefits of improvements in factor productivity, and indirectly through their effects on land markets, access to credit and the like (Place and Otsuka, 2000; Kebede, 2002).

The study addresses the following questions: What are the main land conservation practices adopted by farmers in fragile ecological environments? What is the relationship between population density and property rights? Is there any correlation between land use practices and property right regimes? Are the poor able to conserve land? What factors favour land conservation? What is the link between property rights in land and investment in land conservation? What are the major policy issues that can ensure sustainable land conservation practices?

Objectives of the study

The general motivation of the study is to investigate the determinants of land conservation practices in Kenya with particular reference to Kajiado District. The specific objectives of the study are:

- To investigate the major factors influencing adoption of land conservation practices.
- To investigate the link between property rights in land, population density and adoption of land conservation practices.

- To determine the link between property rights in land and assets among other covariates on adoption of land conservation practices.
- To simulate the impact of policy changes on adoption of land conservation practices.
- To draw policy conclusions and recommendations for land conservation and poverty alleviation in Kenya.

The rest of the paper is organized as follows: Section two discusses the land titling process and policy in Kenya. Section three describes the study site and also presents a detailed background of the study area. Sections four and five present the literature review and methodology, respectively. Section six presents the results while section seven concludes.

2. Land Titling Process and Policy in Kenya

Kenya's land policy is rooted in the foundation cast by the Berlin Conferences of 1884–1885 that sanctioned the partition of Africa among the European powers. In 1897 all "waste and unoccupied land" in Kenya was declared Crown Land, based on the argument that all land had in fact accrued to the imperial power simply by reason of assumption of jurisdiction. Thereafter, Kenya slipped very quickly into a territory of individual private estate owners the legitimacy of whose titles was derived from the imperial power (Okoth-Ogendo, 1999). By 1920 when Kenya became a colony, all land had been declared "Crown Land" and was therefore available for alienation to white settlers for use as private estates. Little consideration was given to land rights security for African cultivators and their land could be alienated at will by settlers. It was only after several inquiries and commissions that a clear separation in colonial law was made in 1938 between Crown Land out of which private titles could be granted, and "native lands", which were to be held in trust for those in actual occupation.

No consolidated body of land law was enacted until 1963, when a Registered Land Act (now Cap 300) came into effect. This was meant to encourage individualism of tenure in line with the Swynnerton Plan. Up to that point and for a vast number of ex-settler properties, the applicable regime remained the common law of England as modified by the doctrines of equity and statutes of general application. In the meantime, there was a series of attempts at a land policy. This is attested through the Swynnerton Plan of 1954 as well as commissions, task forces and investigations into land policy development. These included the Kenya Land Commission of 1934, the East Africa Royal Commission of 1953–1955 and the Lawrence Commission of 1965–1966 (Okoth-Ogendo, 1999). Five years after independence, the Land (Group Representatives) Act (Cap 287) was enacted to legislate over group ranches.

Despite Kenya's long experience with comprehensive land tenure reforms, little effort has been made to design innovative land rights systems and complementary infrastructure for the country. Not much has changed with respect to ownership rights since 1938, even though a great deal of policy development has in fact occurred. For example, private ownership rights remain as legitimate as they ever were in colonial times, "trust lands" are still held by statutory trustees rather than directly by indigenous occupants and unalienated land remains the private property of the government.

Current situation

The numerous laws and statutes governing land ownership in Kenya include: the Indian Transfer Property Act (1882), the Registered Land Act (Cap 300) and the customary law system. The Indian Transfer of Property Act (ITPA) is an embodiment of English law extended to Kenya from India as early as 1882.This Act was necessary only as part of the administrative infrastructure of land relations within the settler community. It was meant to consolidate the settlers' grip on the acquired land, and governed property with regard to transfers, leases, mortgages and covenants. The Act embodies the freehold estate and applies to lands registered under the Crown Land Ordinances of 1902 and 1915; the Lands Title Ordinance of 1908 (currently Cap 208), and the Conversion of Leases Regulations and Rules of 1960 (Odhiambo and Nyangito, 2002; Okoth-Ogendo, 1999).

The Registered Land Act (Cap 300), enacted in 1963, was the culmination of the reform programme started by the colonial government and aimed at replacing the customary law system of communal ownership of land with the English system. The Act confers ownership rights on individuals in a manner that is meant to be rational, efficient and productive in managing resources. The third legal property regime governing land use in Kenya is the informal law or customary law, which is multifaceted and diverse. In this law, informal rules, culture and community interpretations of the land property rights define governance systems across generations. Further laws governing land property rights include Government Lands Act (Cap 280) and the Land Titles Act (Cap 282) (Odhiambo and Nyangito, 2002). Other laws are embodied in the Land Disputes Tribunals Act (Cap 18, 1990) and the Survey Act (Cap 229).

Under this diverse legal regime three key forms of land ownership have evolved in Kenya: private land, public land and customary land.

Private land refers to individual/private tenure where exclusively individuals or companies own land. It is either freehold where the holder has absolute ownership or leasehold for a term of years subject to the payment of a land rent or certain conditions on development and usage. Acquisition of private land may follow up to three stages: The first is adjudication of individual or group rights under customary tenure to private tenure under the Land Adjudication Act, thus making customary land law obsolete (Kabubo-Mariara, 2003; Odhiambo and Nyangito, 2002). In the second stage, consolidation, each individual or group has rights and is allocated a single consolidated piece of land equivalent to several units under the Land Consolidation Act. Finally, the third stage is registration and entry of rights in the Adjudication Register (in the Land Registry) and the issuance of a certificate of ownership, under the Registered Land Act (Cap 300) and the Land Titles Act (Cap 282).

Customary land

Land under customary tenure is held communally. It is also known as trust land. Under this tenure, absolute rights over land were vested in the group, while individuals enjoy the right of occupancy only for subsistence purposes. This type of tenure exists in areas that have not yet been transferred or alienated through registration. It is administered under the Trust Land Act of 1965, which deals with all trust land. Customary land tenure and land law have been systematically misinterpreted – even undermined – by the judiciary and ignored by legislatures. Contempt for this system dates back to the pre-independence era. Even before the Swynnerton Plan defined systematic procedures for the conversion of customary tenure into individual freeholds, official policy always contemplated the ultimate disappearance of that system. The current official policy of the Kenya Government is still the extinguishment of customary tenure through systematic adjudication of rights and registration of title, and its replacement with a system akin to the English freehold (Okoth-Ogendo, 1999).

Public land

Public land comprises all land currently held as unalienated government land except such land within the Coast Province that became Government Land through the application of the Land Titles Act (Cap 282). It is administered under the government Lands Act of 1965. It also includes all land used or occupied by any ministry, department or agency of the government or a statutory corporation and all public roads and access roads as defined in the Public Roads and Roads of Access Act (Cap 399), all rivers, lakes, the territorial sea and the seabed, and the reversionary interest in all government freehold and leasehold titles.

Problems with present titling process

Although all the land ownership systems and land laws discussed above exist in Kenya today, the Registered Land Act (Cap 300) is the dominating legal instrument that governs land. All land previously held under the customary law system is being converted to registered land. Virtually all post-independence policy documents and plans have underlined the government's commitment to getting all land registered under the Registered Land Act. The acts of parliament that deal with registration of deeds in Kenya are Registration of Documents Act (Cap 285, 1902), the Land Titles Act (Cap 282, 1908) and the Government Lands Act (Cap 280). These laws have given way to the Registration of Titles Act (Cap 281) and the Registered Land Act (Cap 300) (Odhiambo and Nyangito, 2002).

Land administration and registration systems are fraught with stringent bureaucratic procedures and inefficiencies. The Registration of Titles Act, for example, has a number of problems that make its administration difficult: the Act is not foolproof and registration has occasionally been done outside the provisions of the Act. Additionally, the requirement that a *gazette* notice be issued whenever a provisional certificate of registration of title is issued defeats the purpose of *gazzettement* (Odhiambo and Nyangito, 2002). The "Njonjo Commission" report also notes that there are too many registration acts and very little attempt has been made to convert titles to the Registered Lands Act, while the same acts have been abused to deprive people of their property. The report further argues that the Land Registries staff and registrars are inefficient and there is too much corruption and too little supervision. It recommends that Government Lands Act (Cap 280), Registration of Titles Act (Cap 281), Land Titles Act (Cap 282) and Registration of Documents Act (Cap 285) registries be decentralized through converting titles to Registered Lands Act.

Furthermore, there is need to harmonize conflicting Acts. Currently, the physical planning Act of 1996 conflicts with the Government Lands Act (Cap 280) and the Land Control Act (Cap 302). Land surveys are also inhibited by poor quality staff, inaccurate and outdated maps, and high survey costs, implying a need to review the Survey Act. There is therefore clear need to review land laws and procedures in order to streamline land registration and issuance of titles in Kenya (Odhiambo and Nyangito, 2002). In addition, there is urgent need for proper coordination of various government departments dealing with land issues.

The national land policy

Kenya today, just as at independence, lacks a clearly defined or codified national land policy for adequately addressing important land issues. Land administration and management operate on the basis of an outdated legal framework (Ministry of Lands and Settlement, 2004). Odhiambo and Nyangito (2002) argue that a glaring gap in the Constitution of Kenya as far as land is concerned is the absence of guiding principles on land not classified under trust land. Issues of land tenure and management are therefore regulated by a large number of ordinary laws without a guiding constitutional philosophy. These laws have generated a multiplicity of normative, institutional and policy conflicts and have hindered the emergence of a clear land policy in Kenya.

Recognition of these problems led to the appointment of the Njonjo Commission of inquiry into existing land laws and tenure systems in 1999. The findings of the commission, together with recommendations of the Constitution of Kenya Review Commission (CKRC, 2004) have pointed to the need for a comprehensive framework for use, access and conservation of land in Kenya.

The proposed National Land Policy process is geared towards clear definition and determination of the following core issues: Insecure land tenure, poor land administration, weak and/or ineffective mechanisms for fair, timely, affordable, transparent and accessible resolution of land disputes, continued land fragmentation, and the multiplicity of tenure regimes with limited harmonization (Ministry of Lands and Settlement, 2004; Adams, 2003). In particular, the overall objective of land policy should be to establish a land administration and management system that is economically efficient, socially equitable, environmentally sustainable and operationally accountable to the Kenyan people. The Istanbul Declaration on Human Settlements and the Habitat Agenda (1996) is expected to provide the international policy and legal context for the human settlements component of the National Land Policy for Kenya.

The discussion in this section shows that the government is committed towards individualization of customary land in Kenya. This facilitates land purchases, sales and transfers. However, the system is fraught with institutional rigidities that make land marketing procedures lengthy and cumbersome. Efficiency in the land market depends on government providing an enabling framework and performing the necessary regulatory and administrative functions effectively and efficiently (Adams, 2003). The proposed national land policy is expected to reduce the bottlenecks in land marketing, quicken land transfers and thus encourage long-term investments in land improvements.

3. Study site and the socioeconomic setting

The study is based on Kajiado District, in the southern part of Rift Valley Province, Kenya. The district covers an area of 21,105 square kilometres. The rainfall pattern is bimodal, with the short rains falling between October and December and the long rains between March and May. The rainfall is quite unreliable and is influenced by altitude. Regions with a high elevation have the highest average rainfall (1,250mm), while most of the district (low elevation) records an average annual rainfall of about 500mm (Republic of Kenya, 1997). The soils are of low to moderate fertility and make the ecosystem fragile and easily degradable. The district spans a range of agro-ecological zones (based on differences in soil quality, rainfall variability, altitude and vegetation): a semi-humid climate that supports mixed agriculture, an arable semi-humid/semi-arid climate and an arid climate, favourable mainly for ranching and pastoral activities. Although the district largely supports livestock and wildlife, there is also significant crop farming in the area.

The study uses both primary and secondary panel data. The primary data were collected from a cross section of households in Kajiado district over the period March 1999 to May 2000 in three phases. The first phase corresponded with the long rains (March–May 1999), the second phase with the short rains (October–December 1999) and the third phase with the long rains (March–May 2000). The National Sample Survey and Evaluation Programme of the Central Bureau of Statistics, Ministry of Planning and National Development (Republic of Kenya, 1996), was used as the sampling frame for the field survey. A self-weighting probability sample of 570 farming households over the three time periods was chosen from the national sampling frame in Kajiado district and a detailed questionnaire used to collect the data. The questionnaire was designed to collect information regarding economic and demographic characteristics of sampled households, land conservation practices, and land use rights, among other covariates of interest. To these data we append data on population density at the cluster level from the population census.

The secondary data for the study concerning the quantity of biomass at the village level were obtained from the Department of Resource Surveys and Remote Sensing (DRSRS), Ministry of Natural Resources, Environment and Wildlife. These data are derived from satellite images and vegetation indexes collected by the National Oceanic and Atmospheric Administration (a US-government body), and translated into biomass in kilograms per acre of land in village clusters by the DRSRS. We used the data in the same form that we received them from the DRSRS.

The Maasai, settlement history and birth of privatization

Kajiado District is predominantly occupied by the Maasai as the indigenous tribe, although migration and intermarriage has increased the proportion of other tribes considerably over the last four decades. Population census reports indicate that the proportion of pure Maasai in the district declined from 69% in 1969 to 57% in 1989 (Table 1). The current proportion is not known, but one can infer from previous statistics that the Maasai population in the district is becoming increasingly smaller.[1]

Table 1: Kajiado District population by major tribe, 1969–1989

Tribe	1969		1979		1989	
	Number	**%**	**Number**	**%**	**Number**	**%**
Maasai	58,961	68.64	93,560	62.79	146,268	56.55
Kikuyu	16,258	18.93	33,630	22.57	61,446	23.76
Kamba	4,321	5.03	8,798	5.90	20,755	8.02
Luyha	1,166	1.36	2,280	1.53	5,416	2.09
Luo	1,612	1.88	3,174	2.13	8,084	3.13
Tanzanian	1,280	1.49	2,194	1.47	4,425	1.71
Other tribes	2,305	2.68	5,369	3.60	12,265	4.74
Total	85,903	100	149,005	100	258,659	100

Source: Republic of Kenya, Population and Housing Census Reports, various issues.

The Maasai are traditionally pastoral nomads who like other East African pastoralists move their livestock in response to erratic rainfall conditions to maximize herd size, milk yields and meat production for human consumption. Traditional subsistence pastoralism revolved around optimizing stock losses to drought, disease, predation and raiding. In Kenya the Maasai are concentrated in Kajiado and Narok districts of Rift Valley Province. They are bordered by agro-pastoralists to the west (Kalenjin) and agricultural Bantu tribes in most other directions.

The Maasai keep livestock breeds that are adapted to the arid savannas and vary the species mix, choosing among cattle, sheep, goats, donkeys and camels. They also selectively breed within individual species, move seasonally, and adjust daily for aging regimes and herd size to optimize foraging in response to rainfall and local pasture conditions. Flexibility and mobility of stock grazing and herding are priority, in both space and time, to reduce environmental degradation. Mobility is an effective tool for range improvement as it provides the herder flexibility to modify herds and access alternative pasture areas relative to sedentary livestock production (Kabubo-Mariara, 2003).

The Maasai experienced a period of aggressive expansion in the late nineteenth century and early twentieth century, co-existing peacefully with their agriculturally oriented neighbours with whom they engaged in trade and intermarriages. In the 1880s and 1890s, livestock diseases seriously affected livestock holdings, while at the same time a lot of

Maasai succumbed to a smallpox epidemic. These tragedies left the Maasai unusually vulnerable and they were soon compelled to sign land agreements with the British, resulting in the loss of between 50% and 70% of the land they once utilized, more so their best grazing and drought refuges (Western and Nightingale, 2002). Displaced by colonial settlers and a growing population, many moved illegally onto the wetter northern regions and settled in present day Kajiado and Narok districts (Rutten, 1992).

The lack of permanent settlements and land ownership made the Maasai easier victims of land snatches than the farming communities surrounding them (Kikuyu, Kamba and Chagga). The appropriation of wetter areas and water sources by these communities, aggravated by the loss of drought refuges to national parks (Amboseli and Chyulus), put more pressure on subsistence herders, increasing their vulnerability to ecological change and drought. In response to this predicament, privatization of land entered the Maasai consciousness and they started agitating for the same. In the early 1950s, the colonial government granted privatization rights in favour of group ranches rather than individual ownership. Privatization later received a boost from the Lawrence Report commissioned by the government to assess the potential of privatization (Lawrence at al., 1966) and also through the World Bank funding of water supply and dipping facilities (Kituyi, 1990).

Group ranches lacked ecological viability, however, because a single ranch did not have dry and wet season pasture that would ensure year-long herd survival. Lack of flexibility and mobility increased mortality of herds and lowered Maasai self-sufficiency. The concentration of livestock within fixed boundaries was also bound to increase environmental degradation (Kabubo-Mariara, 2003). The group ranch concept failed to meet its stated objectives and also jeopardized the socioeconomic and cultural welfare of the Maasai (Kituyi, 1990). Some of the ranches disintegrated into small plots unable to sustain cattle and Maasai families through dry seasons and droughts.

Because of this failure, a growing trend of privatization towards individual land titles intensified in the early 1970s. Young and educated Maasai were enthusiastic to secure land title in order to improve rangeland facilities and join the market economy through beef production. But many Maasai received land titles only to quickly sell out to Kikuyu agriculturalists and move on to look for wage employment in cities and towns. With restricted movements and further fragmentation occasioned by population growth, pastoralism has continued to be unsustainable and the Maasai can no longer rely entirely on their herds for subsistence.

Economic diversification and origins of crop farming

The unsustainability of pastoralism and the growing vulnerability of the Maasai called for flexible range practices, strong social networks and livelihood diversification strategies (Kabubo-Mariara, 2005). Arable farming, wage employment and diversification of livestock production are the main responses to environmental threat and these have increased incomes and reduced drought vulnerability. Other responses include the emergence of Maasai non-government and community-based organizations, aimed at securing rights, raising financial assistance, building local capacity and opening up new opportunities. The diversification of lifestyles and livelihoods among the more progressive Maasai and competition from more entrepreneurial immigrants creates greater hardships for those who remain rooted in subsistence pastoralism and has created deep inequalities among the Maasai (Western and Nightingale, 2002). Farming was slowly adopted from the Kikuyu, Kamba and Chagga tribes. These immigrants dominated the early phase by buying and leasing land, but the Maasai increasingly took up cultivation of their own farms in the 1980s and 1990s, more so where they border and/or inter-marry with their agro-pastoral or agricultural neighbours. As a consequence, the Maasai continue to adopt a more sedentary way of life, with a rise in permanent villages, which is evidenced by a rise in occupied manyattas, grass thatched and tin roofed houses. Seasonal migration has also become almost entirely restricted to movement of animals by male herders who leave their families behind to take care of the farm (Kabubo-Mariara, 2005).

Settlement and the spread of small-scale farms began in the wetter elevated regions north and south of the district, and then spread along the rivers and into the swamps. Marginal farms also spread along the Loitoktok–Sultan Hamud pipeline during the 1980s and early 1990s. Most areas with arable potential had been settled by the late 1980s. Today, the main farming zones include more arable elevated areas of Ngong, Loitoktok and Magadi division and more marginal farms in Mashuru, Central and Namanga divisions. In the more arable areas, crop production has slowly evolved and ranges from traditional subsistence farming to irrigation farming and market production. Irrigation is concentrated in Loitoktok division drawing water from the slopes of Mt. Kilimanjaro, and in the Ngurumani escarpment, where there is a concentration of vegetable and fruit farming for the export market. In the more arid areas, new crop varieties that can withstand rangeland weather problems facilitate cultivation. In particular, the introduction of *katumani* maize, a drought resistant and quick-ripening variety suitable for areas with short rain seasons, has been the most important innovation. In the past, wheat and barley farming took place under commercial holding in northern Kajiado. Crop farming in the district is inhibited by ecological problems including limited soil moisture, unpredictability of rains, pressure on pasture resources and labour resources among other factors.

Given the increasing importance of crop cultivation in the district, soil and land conservation is a priority to ensure sustainability of agricultural production and the environment. This calls for urgent study of the dynamics and determinants of land conservation in the district and how changing property rights have affected land and land conservation. This study attempts to fill this research gap.

4. Literature review

This section presents a short survey of previous research on the determinants of land conservation investments. We confine the review of literature to developing countries, mostly African, but include some relatively new and relevant studies from China. First we review literature on relationships between land rights and investment in land conservation, then move to other determinants of such investments.

A small but increasing number of studies have investigated the impact of land rights on investment in environmental conservation (land improvements) in developing countries, but interest in the role of property rights only emerged in the 1980s. Prior to this, focus had been concentrated on developed countries with well specified property rights (Gebremedhin and Swinton, 2003). Place and Swallow (2000) note that such studies are complicated in several aspects. First, there are challenges in defining and measuring property rights and tenure security. Second, there are numerous difficult theoretical and empirical issues involved in such studies, particularly in defining technology, identifying key dimensions of property rights and accounting for the endogenous determination of property rights. While a number of studies have treated property rights as endogenous following Boserup's (1965) work, and attempted to control for possible endogeneity (Besley, 1995; Brasselle et al., 2002; Jacoby et al., 2002), other studies have argued that property rights could indeed be exogenous (Udry, 2003; Platteau, 1996, 2000; Goldstein and Udry, 2002; Quisumbing et al., 2001; Place and Otsuka, 2000; Kabubo-Mariara, 2005). Third, researchers have different reasons for undertaking studies of the relationship between property rights and technology adoption and each reason may have different implications for methodology.

To date, there is no consensus on the impact of tenure security on investment in land improvements. Debate on the role of property rights reveals two major schools of thought. Some studies concur that systematic land rights through land titling are not important for investments in land improvements. Where tenure security is defined in terms of bundles of transfer rights or possession of title, the correlation between security and investments has been found to be weak (Migot-Adholla, Place and Oluoch-Kosura, 1994; Migot-Adholla, Hazell, Blarel and Place, 1991; Place and Hazell, 1993; Pinckney and Kimuyu, 1994). The other strand of literature argues that land rights are important for investments. Substantial theoretical literature advocates for privatization of land on the premise that farmers' incentives to invest in technologies are inhibited by weak tenure security arising from indigenous property rights institutions and by lack of land titles, which hinders their capacity to obtain credit to make investments (Feder et al., 1988; Shiferaw and Holden, 1999). However, a few other studies suggest that highly individualized rights to land are more important for long-term than for short-term investments (Place and Otsuka, 2000; Place and Swallow, 2000; Gebremedhin and Swinton, 2003). Other studies cast doubt on any linkage between land title and agricultural investment (McCulloch et al., 1998).

We note here that part of the reason for different findings is the definition of land rights and methodological approaches used. Most studies focus on security of tenure rather than transferability. A number of authors have used binary dummies to capture security (such as having a land title, as in Feder et al., 1988; Roth et al., 1994; Pinckney and Kimuyu, 1994; Migot-Adholla et al., 1994; Shiferaw and Holden, 1999; Place and Otsuka, 2002), while other studies have taken a continuum of rights (such as right to sell, right to bequeath and so on, as in Gebremedhin and Swinton, 2003). Others have focused on the mode of land acquisition (such as purchased, borrowed or gift, a la Brasselle et al., 2002; Otsuka et al., 2003; Gavian and Fafchamps, 1996).

Place and Swallow (2000) argue that the impact of property rights on adoption of investment technologies will depend on three important dimensions of property rights: exclusivity, security and transferability. The degree of exclusivity has a positive effect on the incentive to produce, invest and adopt technology, more so those technologies that are fixed to the land. This supports Baland and Platteau (1996) who suggest that less exclusive land rights could help people to pool the risks associated with new innovations or technologies. Insecurity increases the relative price of long-term assets to land and thus reduces the capital intensity of farming. Restrictions on transferability could reduce the incentives of current residents to adopt long-term technologies, reduce the market exchange of land, and thus affect the efficiency of land allocation or even the possible use of land as collateral (Place and Swallow 2000).

Migot-Adholla, Place and Oluoch-Kosura (1994) and Migot-Adholla, Hazell, Blarel and Place (1991), after controlling for other possible effects, concluded that neither land rights nor land title were related to investment in land improvements in Kenya. Only in some regions in Rwanda and Ghana were land improvements shown to be highly associated with security of tenure. Pinckney and Kimuyu (1994) found land reform to be unimportant and indigenous tenure to be secure enough to favour increased long-term investments (coffee planting) in Kenya and Tanzania. Place and Otsuka (2000) found tenure security to be linked to land use and tree-cover change in Uganda and Malawi, although they argue that population pressure rather than tenure is the key driving force for land use change. Place and Otsuka (2002), using individual rights to give land without permission as an indicator of appropriate current land rights, decided that tenure was an insignificant determinant of coffee adoption in Uganda. Their study further shows that coffee planting enhances security of tenure, particularly under customary tenure, and that fallowing and tree planting are less common on customary land than on parcels where land rights are relatively stronger and more stable. Otsuka et al. (2003) argue that while the strength of ex ante land rights would have a positive effect on tree planting, its effect is not of overwhelming importance. Their study supports Place and Otsuka (2002) in that they also find evidence of some inefficiency of land use under customary land tenure systems.

Gavian and Fafchamps (1996) suggest that no significant differences exist in farmer's investment behaviour when land is owned individually and when the land is communally owned. Roth, Cochrane and Kisamba-Mugerwa (1994) and Roth, Unruh and Barrows (1994) determined that the effect of land title on various types of agricultural investment was insignificant in Somalia. They also found that registration in Uganda was significantly and positively related to investment in fencing, use of manure and mulching, but appeared to have little effect on long-term investments. Besley (1995) showed that better land rights facilitated investments in some regions of Ghana and not in other regions. His results seem to contradict results obtained for the same regions by Migot-Adholla, Place and Oluoch-Kosura (1994) and Migot-Adholla, Hazell, Blarel and Place (1991). Brasselle et al. (2002) indicates that controlling for the endogeneity bias between land rights and investments, increased land rights do not appear to stimulate investment.

Deininger and Jin (2002) used evidence from China to demonstrate that greater tenure security, especially if combined with transferability of land, had a positive impact on agricultural land investments. They further show that households' support for more secure property rights is increased by their access to other insurance mechanisms, suggesting that land plays an important role as a safety net. In an analysis of land rights and farmer investment incentives, Li et al. (1998) provide evidence that land tenure and associated property rights in rural China affect the production behaviour of farmers. They found that long-term use rights encourage the use of land-saving investments but do not affect the incentive of farmers to use short-term current inputs. In a study examining the risk of land expropriation as a constraint on farm investment, Jacoby et al. (2002) provide support for the view that heightened expropriation risks dampen investments in rural China. The authors conclude that although high expropriation risk reduces application of organic relative to chemical fertilizers, welfare analysis reveal that guaranteeing land tenure would yield only minimal efficiency gains.

Although studies on investment in soil management focus mostly on the impact of land rights, other factors are also investigated. For example, Somda et al. (2002) suggest that in Burkina Faso farmers' socioeconomic characteristics and agro-ecological location significantly affect their adoption decisions. The authors also found annual agricultural incomes and number of ruminants to be important. Shiferaw and Holden (1999) found lack of technology, poverty and high rates of time preference to undermine investments in land improvements. In a related study, the same authors argue that lack of low-cost technologies that would provide short-term benefits to farmers hinders investment in conservation practices (Shiferaw and Holden, 2001). Place and Otsuka (2002) find farm size, length of time since the parcel was acquired, soil fertility status, age of household head, family size and distance from a paved road to be important determinants of adoption of various land improvements. This study supports their earlier findings for Uganda and Malawi, which show that infrastructural policy (connection to markets and availability of good roads) are correlated with land improvements (Place and Otsuka, 2000). Jacoby et al. (2002) also conclude that household characteristics are important determinants of the adoption of land improving investments. This finding is supported by Deininger and Jin (2002), who say family size, especially the presence of more adults, and per capita land holding have a positive impact on investments.

Income and the number of adults in a household positively influence investments, according to Brasselle et al. (2002). The impact of family size on incentives to invest in land improvements supports Tiffen et al. (1994), who use evidence from Kenya to demonstrate that growing population, in association with market developments, generates new technologies that support increased productivity and improved conservation of land and water resources. The impact of population variables on investment is supported by Place and Otsuka (2000) using evidence from Uganda (see also Boserup, 1965), while the impact of incomes and assets is supported by Somda et al. (2002), Li et al. (1998), and Alemu (1999). McCulloch et al. (1998) argue that wealth expands households' options to acquire and use technologies, especially those that require the outlay of considerable resources, in the absence of readily available financial markets. Gebremedhin and Swinton (2003) use evidence from Ethiopia to show that the opportunity cost of labour, market access and forgone land productivity are strong determinants of level of investment in land conservation but make no significant contribution to the choice of whether to invest or not. Other factors include credit, environmental and price risks, agro-ecological conditions, and cultural factors. Access to appropriate physical, economic and information infrastructure, as well as diffusion of information are also critical determinants of conservation technology choice (McCulloch et al. 1998).

From the foregoing literature review, it is clear that there is growing research interest in the impact of land rights and tenure security on investment in environmental conservation. While a lot of work has been done in some Eastern African countries, namely Uganda and Ethiopia, there is paucity of recent work on Kenya, although a number of studies were carried out a decade ago (Tiffen et al., 1994; Migot-Adholla, Place and Oluoch-Kosura, 1994; Migot-Adholla, Hazell, Blarel and Place, 1991; Pinckney and Kimuyu, 1994). Recent studies in Ethiopia and Uganda have been made possible by the availability of data from the International Food Policy Research Institute (IFPRI) research programme. This study builds on the few existing studies in Kenya and explores the impact of land rights and other factors on adoption of land conservation practices. By bridging this research gap, this study makes an important contribution to the literature and to the database on environmental conservation practices.

5. Methodology

This study assesses the impact of land rights institutions, among other factors, on the adoption of land conservation practices. From the previous literature, we hypothesize that land rights affect investment incentives as they determine the expected returns to investments for those who actually invest (Besley, 1995). As indicated earlier, some studies have treated property rights as endogenous, following the works of Boserup (1965) and supported by empirical evidence (see Platteau, 2000). According to Boserup, as a population grows, land and other natural resources become scarcer relative to labour and access to markets improves. As a result, agricultural intensification occurs, relative prices change and food prices increase as demand for food rises. This process induces institutional innovations such as private property rights, which then facilitate adoption of better technologies that help to stave off the operation of diminishing returns in natural resource use.[2] The same premise is held by the evolutionary land rights theory (Platteau, 1996, 2000).[3] Drawing from Boserup's work, Platteau makes a convincing case that population density relative to land abundance is the place to begin to understand the evolution of property rights.

A number of econometric approaches have been used to estimate the impact of land rights on investment in land improvements. Where there are feedback effects between property rights and technology adoption, a simultaneous equation model would be appropriate for estimation. If the two variables are continuous, a three-stage least squares estimation method could be used, but this is rarely the case (Place and Swallow, 2000). For limited dependent variables, single equation models for handling endogeneity have been utilized and bootstrapping techniques employed to correct for the resulting biases in estimated errors of coefficients (Brasselle et al. 2002; Baland et al., 1999).

Owing to the paucity of exogenous variables that can be used as instruments and also because of the qualitative and sometimes unobserved nature of the land rights, it is normally difficult to apply the simultaneous equation estimation methods to land rights and adoption of land conservation technologies. For this reason, most studies estimate reduced form functions explaining the incidence of the observed technologies as a function of dummy variables representing land rights, often considered as pre-determined with respect to the adoption decision (Otsuka et al., 2003; Place and Otsuka, 2000; Place and Swallow, 2000; Goldstein and Udry, 2002).

Following this approach, we propose to use a specification where the adoption of land conservation practices (Y) is assumed to be a linear function of the expected land rights (R^e), as in Otsuka et al. (2003):

(1)

where α_0 and α_1 are parameters and Y is measured as a binary variable equal to 1 if any practice was adopted, otherwise equal to 0. We expect α_1 to be positive as stronger expected land rights increase expected future returns (Otsuka et al., 2003). The expected land rights (R^e) is not directly observable because it could be affected by land conservation technologies (Y) and the specific right held by an individual (Z) (See also Besley, 1995; Braselle et al., 2002; Jacoby et al., 2002.) The expected land rights can therefore be specified as in the following linear function:

$$R^e = \beta_o + \beta_1 Y + \beta_2 Z \tag{2}$$

where β_o refers to expected impact of land rights with no conservation technologies, β_1 represents the marginal effect of adoption of a given conservation technology on land rights, and β_2 measures the difference in specific land rights held by individuals. From available literature, it can be assumed that β_1 could be positive as land rights are shown to be increased by adoption of conservation practices. In a situation where Y has no impact on R^e, β_1 would be zero and it can be shown that land tenure institutions affect adoption of land conserving technologies through their effect on land rights (Otsuka et al., 2003).

Substituting Equation 2 into Equation 1 and rearranging terms would yield the following reduced form function:

$$Y = \hat{o}_0 + \hat{o}_1 Z \tag{3}$$

where f_1 is the marginal effect of various land rights on the adoption of conservation technologies. If we let ε to be a vector of all other variables influencing adoption of land conservation practices, then Equation 3 becomes:

$$Y = \hat{o}_0 + \hat{o}_1 Z + \hat{\imath}\hat{o}_2 + \grave{\imath}_i \tag{4}$$

where μ_1 is a random error term.

In compact panel data form, the estimable variant of Equation 4 can be expressed as:

(5)

where j denotes the j^{th} household; t denotes the time period (t= 1,2,3), Y_{jt} is the probability that household j adopts a given land conservation measure at time t, α is a constant term and β is a vector of coefficients to be estimated. X_{jt} is a vector of determinants of adoption of conservation measures specific to household j at time t; v_j +

ε_{jt} is the residual where v_j is the household specific residual, which differs among households but is constant for any household over time; e_{jt} is white noise with the usual properties (mean zero, uncorrelated with itself, uncorrelated with *X*, uncorrelated with v_j, and homoscedastic).

Following standard practice in current literature (see, for example, Gebremedhin and Swinton 2003; Otsuka et al., 2003; Besley, 1995; Braselle et al., 2002), our empirical approach is to estimate Equation 4 using a continuum of rights (Z) as proxies for security of tenure which could be viewed as a proxy for institutional factors in investment risk. We experiment with up to five dummy variables, including right to sell land, right to bequeath land, full ownership right, land belonging to a group ranch and tenancy rights. The first three dummies are indicators of longer-term tenure security, while the last two rights are measures of short-term tenure security. We further compare models with these dummies to models with a binary variable for formal land rights.[4]

From the literature review, in addition to land rights, the adoption of conservation technologies is also a function of a vector of other determinants (ε), which include household characteristics (age, gender, marital status and level of education of the household head), prices and productivity variables. Prices are determined by relative factor endowments and market access. In the literature, prices have been captured by population density and distance to markets where actual price data are not available. On the basis of previous studies, we expect population density to encourage adoption of land conservation, owing to land scarcity. Distance to markets is taken as a proxy for return on investment factors and the impact is ambiguous because longer distance reduces both crop income and off-farm work opportunities during the dry season. Productivity is captured by the division in which a household is located, which reflects the agro-ecological zone (Gebremedhin and Swinton, 2003; Place and Otsuka, 2000, 2002; Somda et al., 2002; Deininger and Jin, 2002; Li et al., 1998; McCulloch et al., 1998). We expect farmers in more favourable agro-ecological zones to have a higher likelihood of adopting land conservation. Highland zones and villages in more elevated areas tend to suffer more erosion and thus should benefit more from soil conservation (Gebremedhin and Swinton, 2003).

Endowment of labour, land and other wealth indicators are also hypothesized to influence conservation. Family labour proxied by the number of adults would be expected to encourage investment because of the availability of workers, or the presence of more mouths to feed. Land, income and livestock (cattle and small ruminants) would be expected to have an ambiguous impact. For example, more land and livestock are indicators of more wealth and capacity and should encourage investment. On the other hand, more land could lead to extensive rather than intensive farming, while more livestock may make owners less dependent on crop farming and therefore reduce the probability of conserving the environment.

The study analyses the adoption of three different land conservation practices: blocking soil erosion outlets (commonly known as soil bunds in the literature), terracing, and planting drought resistant vegetation and trees. The three measures offer contrasts in length of investments and effectiveness of erosion abatement (Gebremedhin and Swinton, 2003). Soil bunds are more long-term measures than terracing, but the latter may require more time and inputs. Planting drought resistant vegetation and trees is labour intensive but attractive because most of the vegetation also doubles as livestock fodder.

Equation 4 can be estimated using probit or logit procedures to capture the impact of land rights and other variables on each specific conservation measure. In this paper, we estimate Equation 5 using a pooled data set. Alternatively, the multinomial logit model can be used where the three practices are assumed to be mutually exclusive and where the panel data are pooled to form cross-section data. We use panel data models as they yield better results than cross-sectional models, since the former control for unobserved heterogeneity due to farmer specific factors and are based on more informative data; they also give more variability, less collinearity among the variables and more efficient results. However, we run a series of random effects regressions and also pool the data to run a multinomial logit model of adoption of land conservation practices. We first run the regressions with a continuum of dummies for tenure security and compare the results with regressions with a binary dummy variable for tenure security.

6. Results

To ensure adequate representation and coverage of the district, information on all the six administrative divisions of the study district were collected as displayed in Table 2. The differences in sample sizes reflect differences in population density in the district. Considering variations in soil quality, rainfall, terrain and vegetation, these administrative divisions are also good proxies for the agro-ecological zones in the district (Kabubo-Mariara, 2005).

Table 2: Sample sizes by division and data collection phase

Division	Phase I	Phase II	Phase III	All phases
Loitoktok	29.12	29.47	28.36	29
Mashuru	16.19	13.28	14.01	14.54
Magadi	8.42	9.39	10.4	9.36
Ngong	21.42	23.89	22.99	22.74
Central	13.14	11.6	12.75	12.5
Namanga	11.69	12.37	11.49	11.86
Total	1,377	1,310	1,192	3,879

Source: Author's calculations from field survey data.

The key characteristics for the entire sample are presented in Table 3. We note from the table that the total number of observations amounted to 3,879 individuals from the three phases of fieldwork. The difference in number of observations is partly attributed to sample attrition over the three time periods, the prolonged drought, which led to a lot of migration, and the differences in household size. Important highlights from this table include the large household size with the largest being polygamous households. We also note that the overall mean household size in our sample (9.4) is twice as high as the mean household size for the entire district and for Kenya at 4.8 and 4.6, respectively. In the empirical analysis, we use population density rather than household size, which is arguably endogenous. Another important issue to note is illiteracy, with about half of the respondents (49%) having no schooling at all, and a very low mean (3.2) number of years in school. In the empirical implementation, we generate three dummies to capture the level of education, primary education (31%), secondary education (17%) and post secondary schooling (3%), relative to no education at all (49%).

Table 3: Key household characteristics

Variable	Phase I		Phase II		Phase III		All phases	
	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.
Age (years)	19.7	17.0	20.1	17.5	19.6	17.1	19.8	17.2
Male (percentage)	47	50	50	50	50	50	49	50
Household size (number)	9.3	5.9	9.6	6.7	9.2	5.3	9.4	6
Married (percentage)	73	44	69	47	67	47	69	46
Can read and write (percentage)	51	50	56	50	49	50	52	50
Ever attended school (percentage)	50	50	55	50	50	50	52	50
Number of years in school	3.7	4.3	3.0	4.0	2.8	4.0	3.2	4.1
Number of observations			1,377	1,310	1,192	3,879		

Source: Author's calculations from field survey data.

We base the empirical analysis on the sample of household adults aged 18 years and above, amounting to a pool of 1,600 observations.[5] A summary of the key variables used is presented in Appendix Table A1. Adoption of land conservation practices is one key variable of interest. In total about 39% of all farmers had undertaken some form of land improving investment. Of the three main types of land improving investments, 19% of all farmers planted drought resistant vegetation and trees, 8% constructed soil bunds and 8% built terraces. We note that 49% of private property holders had invested in at least one land improvement, compared with only 27% of their common property holding counterparts. The difference is statistically significant at the 5% level of significance.

Land rights are other key determinants of land conservation practices used by farmers. Broadly speaking, about 73% of all farmers in the sample held land under private property arrangements (with formal titles) and 27% under group ranches. However, we disaggregated these to measure the strength of land rights held by individual farmers. We examined the data further to check whether respondents had the right to sell land, bequeath to children or lease out to tenants, whether the land belonged to a group ranch, and last whether the respondent was a tenant. Tenancy is the weakest form of land right, followed by scheme membership. However, a respondent who can sell land (the strongest right) would also have the right to bequeath and to lease out land to tenants (Otsuka et al., 2003). Only 7% of the respondents held land under tenancy arrangements.

Household assets are proxied by a number of variables: amount of land and livestock owned, transfers received by the household, and rent incomes. Land ownership in the study district is highly unequal (Appendix Table A1). The Gini index with respect to land ownership is estimated at 0.66 compared with a Theil index of 0.81. Inequality in land ownership is highest in Ngong division with a Gini Index of 0.77 and lowest in Central with a Gini index of only 0.32. A lot of inequality is also observed in livestock ownership, with reported cattle owned yielding a mean herd size of 29 head of cattle (standard deviation of 87), and small ruminants with a mean of 60 (standard deviation of 149). Inequality measures for livestock ownership are much higher than for land ownership, with a district Gini index for total livestock units of 0.75. The index is highest for Loitoktok (0.82) and lowest in Magadi (0.56). The same trend is evident for income flows (transfers and rent incomes).

Appendix Table 1 further indicates inaccessibility of markets and water in the study district, implied by long distances to markets (12 kilometres) and to the usual sources of water (3.5 kilometres).

Population, property rights and land conservation

The population density in Kajiado District has grown steadily over time, mostly due to immigration. Results of Kenya's population census estimates that the population density has increased from 5 persons per square kilometre in 1969 to about 22 persons per square kilometre in 1999 (Table 4).[6] We note that Ngong division has consistently reported the highest population densities over time, partly due to better agro-climate conditions largely influenced by the presence of Ngong Hills and partly due to the proximity of some parts of the division to Nairobi. These two factors also account for the large variations in population density in the division.

Table 4: Population density by division: 1969-1999 (person/Km^2)

Division	1969	1979	1989	1999
Loitoktok	6	7	12	15
Mashuru	2	8	9	12
Ngong	8	13	22	41
Central	3	5	10	17
Magadi	3	3	5	8
Namanga	3	5	10	17
District total	5	8	14	22

Source: Republic of Kenya, Population and Housing Census Reports, various issues.

It is important to note that the estimates in Table 4 mask a lot of disparities in population density in the district, with more arable areas reporting very high population densities. For example, in 1969, the highest population density was estimated at 101 for Ngong location (rural), compared with 212 for the same location in 1979. As expected, the urban and peri-urban clusters reported much higher densities than this. In the same year, the highest rural population density for Loitoktok division was 101 persons per square kilometre. In 1989, the population density for Ngong location alone was estimated at 340 persons per square kilometre, but with some sub-locations reporting a density as high as 617. In the same census, some sub-locations of Loitoktok division reported population densities as high as 150 persons per square kilometre. The 1999 estimates give the same picture, with the density for Ngong location estimated at 369 persons per square kilometre, with highest reported densities of more than 3,000 persons in the peri-urban clusters. Loitoktok, the sub-location with the highest density in 1999, had an estimated 197 persons per square kilometre.

Table 5 presents an analysis of the population densities per cluster. Here we obtained the estimated population densities for sampled clusters from the census reports, so that we can tell the population density in the cluster where a household is located. For example, taking into account the division in which a household is located gives us a district mean population density of 74 persons per square kilometre with a standard deviation of 121 persons.

Table 5: Population density: 1999-2000 (Person/Km^2)

Division	Mean	Std. deviation	Min.	Max.
Loitoktok	36	20	11	76
Mashuru	11	4	4	17
Ngong	209	164	6	373
Central	20	3	17	23
Magadi	6.5	0.5	6	7
Namanga	16	2	14	18
District total	74	121	4	373

Source: Author's calculations from field survey data.

Population, conservation and property rights

The relationships among population density, land conservation and property rights are the gist of Boserup's hypothesis and the evolutionary land rights theory. To test the Boserup hypothesis, we carry out sample mean tests for differences in population densities by adoption of land conservation practices. The results (Table 6) show that other than for terracing, population density is highest for groups of farmers adopting various land conservation practices compared with their counterparts not adopting. Specifically, the mean population density among farmers adopting construction of soil bunds is 125 persons per square kilometre, while the mean among those not adopting is 70 persons. For terracing, the mean population density for non-adopters is 77 compared with a low mean of 40 for adopters. The differences in mean population densities by conservation measure are statistically significant at all conventional levels of testing.

Table 6: Population density by land conservation measure

Conservation measure adopted	Population density**		t-statistic	Pr>'t'
	Practice	No practice		
Construction of soil bunds	124.52 (12.7)	69.93 (3.1)	-5.02	0.00
Terracing	40.28 (7.6)	77.28 (3.2)	3.26	0.00
Planting vegetation and trees	94.83 (7.7)	69.79 (3.3)	-3.24	0.00
All practices	89.95 (5.5)	66.27 (3.6)	-3.49	0.00

**Standard deviations in parentheses.
Source: Author's calculations from field survey data.

Related to the Boserup hypothesis, we also test for the evolutionary land rights theory.[7] The theory can be tested through analysis of the correlation between total land owned and property rights, on the one hand, and population density and property rights, on the other. The assumption here is that as population density increases, land becomes relatively scarce and this drives evolution of property rights (Platteau, 1996, 2000). If property rights have indeed evolved endogenously in the district, then we expect that individualized property rights are found where land is relatively scarce. We therefore carry out sample mean tests to find out whether there are significant differences in total land owned under different property right regimes. The results do not seem to support the evolutionary land rights theory because it appears as though individuals own more land where there is individualized ownership (Appendix Table A2). For example, the mean number of acres owned by farmers with full ownership rights is about 110 compared with only 74 for farmers under common property resources.

We also test for the evolutionary land rights theory by analysing whether there are significant differences in population densities under different property right regimes. The results for this are presented in Table 7. These results indicate that taking into account the population densities from 1969 to 1999, clusters with highest densities happen to be found where land is privatized. Furthermore, the differences are statistically significant at all conventional levels of significance, confirming that property rights in the district may be evolving endogenously as population density increases.

Table 7: Population density by property rights dummy and year

Year	Private property	Common property	t-statistic	Pr>t
1969	5.4 (2.1)	4.8 (2.2)	4.8	0.00
1979	8.6 (2.9)	7.2 (3.6)	8.2	0.00
1989	14 (5.2)	12 (6.2)	8.5	0.00
1999	23 (11.9)	18 (12.4)	4.5	0.00
1999	88 (133)	37 (68.0)	7.6	0.00
1999**	25 (17.0)	17 (17.7)	6.8	0.00

* Cluster level estimates.
** Excluding Ngong.
Source: Author's calculations from field survey data.

Breaking the property rights further into a larger continuum of tenure measures supports this conclusion somewhat, though not all differences are statistically significant (Table 8). The results indicate that the lowest population density is observed where land is still held under group ranches and thus is common property. We take note that the population density for households under tenancy rights is quite high and the results may seem surprising, or may be mistaken to imply the impact of peri-urban clusters where the population is much higher than in the pure rural clusters. We note, however, that 60% of farmers holding tenancy rights are located in Loitoktok divisions where they practice irrigation farming. The rest of the farmers holding land under tenancy are located in Ngong (34%) and Namanga (6%) divisions.

Table 8: Population density by property right regime

Land right to:	Population density**		t-statistic	Pr>t
	Has right	No right		
Sell land	78 (125)	69 (113)	1.41	0.1600
Bequeath land	84 (127)	51 (98)	4.94	0.0000
Own private land	76 (124)	71 (115)	0.84	0.4027
Scheme land	14 (21)	90 (137)	10.46	0.0000
Tenant land	103 (134)	72 (120)	2.58	0.0101

**Standard deviations in parentheses.
Source: Author's calculations from field survey data

Land conservation and land property rights

The results in Table 9 show the relationship between adoption of land practices and various land rights. The results indicate that except for soil bunds, farmers with more secure land rights are more likely to adopt soil improvements than are their counterparts with less secure rights. The differences are statistically significant at all conventional levels of significance. This conclusion is also supported by an analysis of the statistical significance of means for adoption of practices under a continuum of rights (Appendix Table A3). Table 9 shows that farmers under group ranches (schemes) and tenancy rights are less likely to construct soil bunds, although the difference for tenancy is not statistically significant. These two categories of ownership are also associated with a lower likelihood of adoption of terracing. Scheme members are also less likely to plant drought resistant vegetation and trees and to invest in any land improvement. The results therefore confirm that tenure security is important for investment in land improvements.

Table 9: Land conservation practices by property right regime

Practice	Private property**	Common property	t-statistic	Pr>t
Construction of soil bunds	8.0 (0.27)	9.1 (0.29)	0.71	0.4783
Terracing	9.4 (0.29)	2.6 (0.16)	4.62	0.0000
Planting vegetation and trees	23 (0.42)	7.9 (27.1)	6.73	0.0000
All practices	40 (0.49)	20 (0.40)	7.74	0.0000

**Standard deviations in parentheses.
Source: Author's calculations from field survey data.

Land conservation and poverty

We define the poor as those households whose mean per capita expenditures fall below the current poverty line of Ksh1,239. Although the 1997 welfare monitoring survey estimated a head-count index of only 28% for the whole district, estimates based on the

1999 population census data show a head-count index of 44% (Republic of Kenya, 2003). In this year, poverty was estimated to be highest in Magadi division (57%) and lowest in Ngong division (34%) (Table 10). The poverty gap ranged between 12% and 24%, implying that on average every poor person in the district would need between Ksh149 and Ksh297 more per month to reach the poverty line. Divisional poverty estimates are not available for 1997.

Table 10: Poverty in Kajiado District, 1999

Division	Head-count index (% of individuals below poverty line)		Poverty gap (% of poverty line) census)		Number of individuals (1999)	Estimated number of poor individuals	
	(%)	Std. error	PG	Std. error		No.	Std. error
Loitoktok	50	6.45	18	3.16	84,919	47,099	5,477
Mashuru	48	6.04	18	3.22	31,215	15,134	1,885
Ngong	34	4.99	12	2.37	96,687	33,215	4,824
Central	48	5.05	17	2.73	47,156	22,600	2,381
Magadi	57	6.56	24	4.62	18,380	10,480	1,205
Namanga	48	7.50	18	4.01	27,812	13,247	2,085
District total	44	4.08	16	2.24	306,169	136,148	12,491

Source: Republic of Kenya (2003).

The figures in the table compare fairly well with estimated poverty rates from our own data, except for some divisions. We estimate a district head count of 42%. The division with the highest head-count index is Magadi (62%), but the lowest head count is observed for Mashuru (21%). Ngong is observed to take the district average (Table 11). Our estimated poverty gap is lower than that estimated by Republic of Kenya (2003) and ranges from 7% to 22%. These estimates imply that every poor person in the district would need between only Ksh87 and Ksh273 more per month to reach the poverty line. We also analysed the level of inequality by computing Gini indexes and Theil entropy measures. The results are presented in the last two columns of Table 11. The Gini index for the whole district is much lower than the Gini index for the whole country (estimated at 0.57). Inequality is more pronounced in Loitoktok division, but least pronounced in Ngong division.

Table 11: Poverty in Kajiado District, 2000

Division	Head-count index	Poverty gap	Poverty gap squared	Gini index	Theil entropy index
Loitoktok	55	22	12	0.4	0.28
Mashuru	21	3	1	0.29	0.13
Ngong	42	13	5	0.27	0.11
Central	26	7	3	0.34	0.19
Magadi	62	20	9	0.35	0.21
Namanga	33	13	6	0.37	0.22
District total	42	15	7	0.36	0.21

Source: Author’s calculations from field survey data.

To answer the question whether the poor are able to conserve, we analyse the differences in sample means of farmers adopting various conservation practices by their poverty status. Our analysis shows that except for terracing, there is no significant difference between the likelihood of the poor and non-poor adopting land conservation measures (Table 12). This implies that the poverty status as proxied by per capita expenditure may not be an important determinant of adoption of conservation measures.

Table 12: Land conservation practices by poverty status

Practice type	Poor (%)**	Nonpoor (%)	't' Statistic	Pr>'t'
Soil bunds	10 (0.29)	7 (0.26)	1.57	0.0588
Terracing	3 (0.18)	11 (0.31)	5.73	0.0000
Planting vegetation and trees	20 (0.40)	18 (0.38)	1.18	0.2389
All practices	33 (0.47)	36 (0.49)	1.29	0.1966

**Standard deviations in parentheses.
Source: Author's calculations from field survey data.

The result illustrated in Table 12 is further supported by analysis of adoption of land conservation practices by various measures of welfare, which suggests absence of any clear pattern of adoption of land conservation practices across welfare groups. First we divide our farmers into per capita expenditure quintiles and use these groups to investigate the adoption of land conservation practices. The results, presented in Table 13, suggest that middle income families (namely second and third quintiles) are more likely to adopt conservation practices than the poorest 20% and the richest 40%.

Table 13: Land conservation by per capita income quintiles (%)

Quintiles	Soil bunds	Terracing	Planting vegetation and trees	All practices
1st	9.63 (0.29)	2.80 (0.17)	15.84 (0.37)	28.26 (0.45)
2nd	10.00 (0.30)	2.81 (0.17)	24.06 (0.43)	36.88 (0.48)
3rd	9.69 (0.29)	12.50 (0.33)	18.44 (0.39)	40.63 (0.49)
4th	7.81 (0.27)	6.25 (0.24)	18.75 (0.30)	32.81 (0.47)
5th	4.38 (0.20)	13.75 (0.34)	16.25 (0.37)	34.38 (0.48)
Lr $Chi^2(4)$	10.45 (0.00)	(51.58) (0.00)	8.80 (0.07)	12.11 (0.02)

**Standard deviations in parentheses.
Source: Author's calculations from field survey data.

To analyse the impact of assets on the adoption of land conservation, we construct a simple asset index using the principal component analysis. Owing to the paucity of asset variables in our data, we use only land, total livestock units and years of education. First, we note that the mean asset index is negative, implying that the average household in the sample is depleting its assets. The asset index also confirms wealth inequalities in the district, with a district-wide Gini index of 0.53, which ranges from a low of 0.30 in Magadi to a high of 0.53 in Namanga division. The results for the analysis of adoption of land conservation practices by asset index quintiles are presented in Table 14.

Table 14: Land conservation by asset index quintiles (%)

Quintiles	Soil bunds	Terracing	Planting vegetation and trees	All practices
1st	12.65 (0.33)	2.78 (0.16)	32.41 (0.47)	47.84 (0.50)
2nd	15.09 (0.36)	2.52 (0.15)	27.67 (0.45)	45.28 (0.49)
3rd	5.63 (0.23)	6.56 (0.25)	15.0 (0.36)	27.19 (0.45)
4th	2.81 (0.17)	14.37 (0.35)	9.69 (0.30)	26.88 (0.44)
5th	5.31 (0.22)	11.88 (0.32)	8.44 (0.28)	25.62 (0.43)
Lr $Chi^2(4)$	47.18 (0.00)	54.07 (0.00)	99.50 (0.00)	68.26 (0.00)

**Standard deviations in parentheses.
Source: Author's calculations from field survey data.

These results strongly support the conclusion from Table 13: except for soil bunds and terracing, adoption of land conservation practices declines with assets. Furthermore, the poorest 40% are more likely to plant trees and to adopt any practice than farmers with more assets. This could be explained by the fact that this index is constructed from the number of total livestock units owned and acres of land owned. Farmers with more non-income wealth are less likely to conserve their land, probably because of alternative income earning opportunities (say from herding) outside farming. The results are confirmed by further analysis based on land and total livestock unit quintiles (see tables 15 and 16).

Table 15: Land conservation by land ownership quintiles (%)

Quintiles	Soil bunds	Terracing	Planting vegetation and trees	All practices
1st	18.46 (0.39)	2.46 (0.16)	20.92 (0.41)	41.85 (0.49)
2nd	7.48 (0.26)	2.80 (0.17)	36.14 (0.48)	46.42 (0.50)
3rd	8.18 (0.27)	6.60 (0.25)	13.52 (0.34)	28.30 (0.45)
4th	2.81 (0.17)	17.19 (0.38)	15.63 (0.36)	35.63 (0.48)
5th	4.40 (0.21)	9.12 (0.29)	6.92 (0.25)	20.44 (0.40)
Lr $Chi^2(4)$	58.21 (0.00)	63.06 (0.00)	99.41 (0.00)	62.98 (0.00)

**Standard deviations in parentheses.
Source: Author's calculations from field survey data.

Table 16: Land conservation by total livestock owned quintiles (%)

Quintiles	Soil bunds	Terracing	Planting vegetation and trees	All practices
1st	10.7 (0.31)	3.06 (0.17)	29.66 (0.46)	43.43 (0.50)
2nd	17.3 (0.38)	5.35 (0.23)	26.73 (0.44)	49.37 (0.50)
3rd	4.33 (0.20)	8.36 (0.28	16.72 (0.37)	29.41 (0.46)
4th	5.41 (0.23)	9.55 (0.29)	10.83 (0.31)	25.80 (0.44)
5th	3.75 (0.19)	11.88 (0.32)	9.06 (0.29)	24.69 (0.43)
Lr $Chi^2(4)$	51.36 (0.00)	23.81 (0.00)	73.79 (0.00)	70.00 (0.00)

**Standard deviations in parentheses.
Source: Author's calculations from field survey data.

The likelihood test ratio results presented in the last row of tables 13–16 indicate statistical independence and significant differences in the probability of adoption of land conservation practices across wealth categories. Unfortunately, we cannot test empirically the impact of each of these individual assets on adoption of land conservation because these assets are arguably endogenous and our data set lacks appropriate instrumental variables to control for this.

The foregoing descriptive analysis suggests that there is clear correlation between property rights and population density. In other words, our descriptive analysis indicates that our data support Boserup's hypothesis and the evolutionary land rights theory. Further, security of tenure is important for adoption of land conservation practices. The analysis does not, however, uncover a clear relationship between the status of poverty and the adoption of conservation methods. We test the robustness of these results using multivariate econometric analysis in the next section.

Regression results

The regression results from a random effects discrete choice model of land conservation practices are reported in tables 17 and 18. The results suggest that the panel-level variance is important (rho is not equal to zero [Wooldridge, 2002; STATA Corp, 1999]). In all regressions, the null hypothesis that rho = 0 is rejected at 1% level of significance. We therefore base our discussion on the random effects results (Tables 17 and 18). The multinomial logit results support the random effects probit regression results. To save on space these results are not presented but are available from the author upon request.

The Chi-square test statistic for the estimated models with 27 and 24 degrees of freedom ranges from 66 to 258. The null hypothesis that the non-intercept coefficients are jointly equal to zero is rejected at 0.01% levels for adoption of all practices (both individual and combined practices). This implies that the underlying empirical probit models are highly significant in explaining choice of particular land use practices, and confirms the stability of the estimated models.

The results show that household investment in soil bunds, terracing and planting of drought resistant vegetation and trees is influenced by a wide range of factors. However, the likelihood of adoption of various practices is quite modest. The predicted probability of adoption of soil bunds is estimated at only 5%, the probability of terracing at 2%, and of planting drought resistant vegetation and trees at 10%. We note that the determinants of adoption of land conservation practices tend to differ from one practice to another. Physical assets, a proxy for household capacity to invest, land tenure security and socio-institutional factors have different impacts on adoption of the three different practices. For example, most of the factors favouring soil bunds have either insignificant or reverse impacts on terracing. A similar conclusion appears to be the case for planting drought resistant vegetation and trees and terracing. This finding is not uncommon in the literature (see for example, Gebremedhin and Swinton, 2003).

Table 17: Determinants of choice of land conservation practices (with continuum of rights)

Variable	Construction of soil bunds		Terracing		Planting drought resistant vegetation/trees		All conservation practices	
	Coefficient	z-stat.	Coefficient	z-stat.	Coefficient	z-stat.	Coefficient	z-stat.
Land rights								
Has right to bequeath land	1.47***	(2.36)	-0.86	-(0.66)	0.90*	(1.63)	0.82**	(1.88)
Has land in Scheme	-0.36	-(1.19)	-0.24	-(0.23)	-0.39	-(1.32)	-0.17	-(0.62)
Has own plot	1.77***	(2.48)	-1.56	-(1.15)	-0.35	-(0.63)	0.36	(0.78)
Has tenancy right	0.65	(1.16)	2.87**	(1.90)	-0.26	-(0.65)	0.49	(1.29)
Household assets								
Log number of adults	0.28	(1.09)	-1.75**	-(2.21)	-0.53***	-(2.34)	-0.50**	-(2.21)
Log rent income	0.04***	(3.08)	0.22***	(4.44)	-0.02**	-(2.27)	0.02*	(1.67)
Log transfer income received	0.02	(0.60)	-0.13*	-(1.77)	-0.08***	-(3.20)	0.02	(0.63)
Log value of farm equipment	0.10	(1.43)	0.06	(0.32)	0.64***	(6.48)	0.39***	(5.26)
Log biomass per acre	-1.34**	-(1.85)	-0.99	-(0.66)	1.85***	(3.77)	2.12***	(3.82)
Household characteristics								
Log age of household head	0.35	(0.99)	0.20	(0.31)	0.04	(0.14)	0.14	(0.52)
Sex	-0.10	-(0.50)	-0.19	-(0.53)	0.05	(0.34)	-0.02	-(0.16)
Marital status (1=married)	-0.23	-(0.83)	0.47	(0.76)	-0.06	-(0.26)	0.15	(0.67)
Has primary school education (relative to no education)	0.15	(0.54)	0.46	(0.71)	0.01	(0.04)	0.11	(0.51)
Has secondary school education	-0.17	-(0.48)	0.10	(0.15)	0.06	(0.24)	0.27	(1.05)
Has Post secondary education	1.46***	(6.42)	7.19***	(7.19)	2.43***	(11.68)	5.20***	(15.41)
Market characteristics								
Log price per head of cattle	-1.28***	-(3.65)	1.07**	(1.83)	-0.71***	-(2.68)	-0.88***	-(3.19)
Log price per goat	-0.62**	-(1.85)	-6.81***	-(5.65)	0.80***	(2.89)	-0.66***	-(2.50)
Log price per kilo of maize	-0.91	-(1.10)	-2.58	-(1.41)	5.78***	(7.13)	3.68***	(5.46)
Log price per kilo of beans	4.69***	(6.16)	2.84**	(1.85)	-4.76***	-(6.35)	-1.77***	-(3.26)
Log distance to market	-0.79***	-(3.01)	0.43	(1.03)	0.08	(0.42)	-0.04	-(0.24)
Distance to source of water	0.15	(0.74)	1.19***	(2.60)	-0.16	-(0.74)	0.06	(0.35)
Log population density	0.51	(1.23)	-1.41	-(1.43)	1.29***	(3.17)	0.09	(0.26)
Agro-ecological zones								
Mashuru	-5.46***	-(4.95)	13.58***	(4.58)	-2.00***	-(3.16)	-2.46***	-(4.18)
Ngong	-0.87	-(1.19)	8.41***	(3.96)	-4.56***	-(6.79)	-4.10***	-(7.19)
Central	-3.67***	-(4.21)	11.92***	(4.81)	-2.67***	-(5.14)	-2.48***	-(4.55)
Magadi	-4.23***	-(4.04)	6.82***	(2.70)	-1.03	-(1.21)	-3.52***	-(3.39)
Namanga	-7.22***	-(5.06)	12.46***	(4.68)	-4.21***	-(7.00)	-3.84***	-(6.15)
Constant	4.57	(0.60)	25.43	(1.76)	-20.44	-(3.92)	-11.55	-(2.17)
Number of observations	1600	1600	1600	1600				
Wald chi^2(27)	128.02***		69.12***		231.28***		258.37***	
Log likelihood	-241.03		-122.60		-361.26		-361.64	
Rho	0.91		0.96		0.85		0.78	
Likelihood ratio test of rho=0: chibar^2 (01)	181.02		229.21		266.99		262.55	

***,**,*: Significant at 1%, 5% and 10% level, respectively.

Land rights and adoption of land conservation practices

The results indicate that, generally, land tenure system variables are important for adoption of land conservation practices. Specifically, soil bunds are likely to be constructed where land rights are more secure and not under common property resources. The same result is implied by results for planting drought resistant vegetation and trees. Bequest right is also important for planting drought resistant vegetation and adoption of all conservation practices. Except for soil bunds, results with property rights as a binary variable confirm that secure land rights act as an incentive for farmers to invest in land conservation practices (Table 18). This is consistent with our a priori expectations of the sign of α_1 and τ_1 in equations 1 and 4, respectively, and supports literature arguing that private landowners are more likely to conserve land as they are assured of retaining the long-term gains from investments in conservation. Furthermore, this supports results of our statistical analysis (tables 9 and A3), which show that security of tenure is important for adoption of land conservation practices. These results are also consistent with previous literature (see, for example, Place and Otsuka, 2002, 2000; Place and Swallow, 2000; Gebremedhin and Swinton, 2003; Deininger and Jin, 2002; Jacoby et al., 2002). Results for adoption of soil bunds support findings by Otsuka et al. (2003), who find that traditional land tenure institutions are not inefficient with respect to the decision to plant trees.

Household characteristics, markets and location factors

Our results do not uncover any important impact of household characteristics on adoption of land conservation practices except for higher education, where farmers with more education are more likely to adopt land conservation practices than their uneducated counterparts. In general, household characteristics increase the likelihood of adopting all land conservation practices combined, though this impact is insignificant, the results support earlier findings by Place and Otsuka (2002), Jacoby et al. (2002), and Deininger and Jin (2002). Experimenting with years of education rather than educational dummies yields the same conclusion as for the dummies and so we retain the latter.

Market factors are observed to have different impacts on adoption of land conservation practices relative to non-adoption. Livestock prices discourage adoption of all conservation practices except for planting of drought resistant vegetation/trees. This result is interesting given that most resistant vegetation is used as fodder for livestock. The results here support the expectation that better livestock prices may bias production decisions towards livestock rather than farming. Maize prices are an important factor for planting of drought resistant vegetation/trees and all practices combined, while the price of beans is important for soil bunds and terracing. Distance to markets is associated with lower probabilities of adoption of soil bunds and all practices combined, but has unexpectedly insignificant impacts on the other practices. Distance to a source of water also turns out to have the unexpected positive signs on the continuum of rights models, except for planting of drought resistant vegetation/trees, implying that distance may not be an important determinant of adoption of any land conservation practice. However, this variable has the expected and significant impact for soil bunds and terracing in the property right dummy model.

Divisional dummies indicate that farmers located in all other divisions are less likely to invest in land improvements relative to those located in Loitoktok division. The results are consistent across all models and imply that farmers in better agro-ecological and climate zones are more likely to invest in land improvements than their counterparts in unfavourable zones.[8] The reverse is observed for terracing, however, where results imply that farmers in Loitoktok are less likely to adopt terracing than those located in other divisions, probably because of differences in terrain/topography, which our study is unable to control for due to lack of adequate data. Our expectation was that soils are more likely to erode (and thus a higher probability of adoption of conservation practices) in Ngong division, where slopes are steeper than in other regions. That the magnitude of the coefficient for all practices combined for the division is larger than coefficients for other divisional dummies in both models (with continuum of rights and dummy for rights) supports this expectation.

These empirical results are supported by the data. Descriptive statistics indicate, for example, that only 1% of households in Loitoktok division invested in terracing and this was the division with the lowest proportion adopting this practice. Ngong division topped in adoption of terraces (31%). Farmers in Loitoktok were also found to be more likely to invest in drought resistant vegetation (31%) than all other divisions. In Central division, adoption of soil bunds and drought resistant vegetation (15% each) were relatively more important than in other divisions.

Though divisional dummies are used as proxies for agro-ecological zones, they could also be taken as proxies for community controls, which are also captured by population density and prices. Models without regional dummies would control for population densities across regions, while including regional dummies helps us to look at the impact of determinants of conservation practices within regions. To test for the impact of various covariates on conservation and land rights across regions, we re-run all regression models without divisional dummies in order to test the impact of population density and prices on conservation and land rights. The results show little change in the signs and magnitudes of the retained variables, implying that the divisional dummies are important on their own in influencing conservation (see Appendix Table A7[9]).

Assets and land conservation

The coefficients for asset variables show mixed results. Rent income[10] is associated with a higher probability of adopting all land use practices, except terracing. Number of adults in a household and transfers are inversely related to adoption of some land conservation practices. These results imply less reliance on agriculture for households with more adults and higher transfers. As expected, increased investment in physical capital (fixed technology) favours land conservation relative to non-conservation. This is portrayed by the positive impact of the value of farm equipment on adoption of all practices. Amount of biomass available at the village level exerts a positive impact on planting of drought resistant vegetation/trees and adoption of all practices combined, but a negative impact on soil bunds and terracing. These results are collaborated by the regressions with a binary variable for property rights (Table 18).

Although there are mixed results for some practices, overall the regression results show that poverty in assets could hinder adoption of land conservation practices. Specifically, rent incomes, investment in farm equipment and availability of biomass are important assets favouring adoption of all land conservation practices. Comparing these results with the results of the statistical analysis, we conclude that although the status of poverty (derived from actual expenditures) may not be an important determinant of adoption of land conservation practices, poverty in assets is a crucial factor (Reardon and Vosti, 1995).

Table 18: Determinants of choice of land conservation practices (with property rights dummy)

Variable	Construction of soil bunds		Terracing		Planting drought resistant vegetation/trees		All conservation practices	
	Coefficient	z-stat.	Coefficient	z-stat.	Coefficient	z-stat.	Coefficient	z-stat.
Land rights								
Property right regime (1=private, 0= common)	-0.60**	-(1.84)	1.86***	(2.78)	1.55***	(4.08)	1.40***	(5.13)
Household assets								
Log number of adults	0.09	(0.36)	-1.84***	-(2.92)	-0.29	-(1.24)	-0.36	-(1.51)
Log rent income	0.02**	(1.86)	0.19***	(4.32)	-0.02**	-(2.08)	0.01	(1.14)
Log transfer income received	0.01	(0.23)	-0.11	-(1.52)	-0.09***	-(3.24)	0.01	(0.49)
Log value of farm equipment	0.03	(0.41)	0.36**	(1.89)	0.56***	(6.38)	0.48***	(5.33)
Log biomass per acre	-1.38	-(1.90)	-0.30	-(0.24)	1.54***	(3.12)	1.52***	(2.69)
Household characteristics								
Log age of household head	0.16	(0.42)	0.03	(0.05)	0.21	(0.75)	0.09	(0.33)
Sex	-0.10	-(0.50)	-0.09	-(0.26)	0.03	(0.18)	0.00	-(0.01)
Marital status (1=married)	0.01	(0.04)	0.15	(0.26)	-0.15	-(0.69)	0.26	(1.15)
Has primary school education (relative to no education)	0.01	(0.04)	0.34	(0.57)	-0.03	-(0.12)	0.11	(0.49)
Has secondary school education	0.01	(0.03)	0.05	(0.08)	0.05	(0.20)	0.37	(1.40)
Has post secondary education	1.22***	(5.02)	6.85***	(6.68)	2.57***	(11.66)	5.60***	(14.79)
Market characteristics								
Log price per cattle	-1.24***	-(3.48)	1.45***	(2.65)	-0.51**	-(2.02)	-0.90***	-(3.05)
Log price per goat	-0.57*	-(1.67)	-8.49***	-(5.97)	0.42	(1.48)	-0.99***	-(3.56)
Log price per kilo of maize	4.43***	(6.14)	1.33	(0.67)	-4.29***	-(5.93)	-0.88	-(1.47)
Log price per kilo of beans	-1.32***	-(3.85)	1.48***	(3.42)	-0.05	-(0.24)	0.04	(0.22)
Log distance to market	0.02	(0.08)	-0.55	-(1.11)	-0.03	-(0.18)	-0.02	-(0.14)
Distance to source of water	-1.62***	-(3.86)	-1.92**	-(1.85)	1.23***	(2.66)	0.05	(0.16)
Log population density	1.24***	(3.48)	1.45***	(2.65)	-0.51**	-(2.02)	-0.90***	-(3.05)
Agro-ecological zones								
Mashuru	-6.83***	-(6.03)	8.79***	(4.40)	-2.76***	-(3.96)	-3.01***	-(5.08)
Ngong	-1.84***	-(2.58)	7.68***	(3.74)	-4.34***	-(5.56)	-4.15***	-(6.97)
Central	-4.14***	-(5.34)	16.28***	(5.53)	-2.85***	-(5.29)	-2.30***	-(4.25)
Magadi	-5.71***	-(4.99)	7.24***	(3.28)	-0.98	-(1.18)	-2.75***	-(2.58)
Namanga	-4.41***	-(4.74)	14.78***	(5.16)	-3.96***	-(6.85)	-4.20***	-(6.60)
Constant	11.28	(1.56)	23.18	(1.57)	-21.12***	-(3.88)	-7.60	-(1.41)
Number of observations	1600		1600		1600		1600	
Wald chi^2(24)	131.72		220.51		65.71		233.73	
Log Likelihood	-241.89		-358.38		-124.14		-351.66	
Rho	0.93		0.98		0.84		0.79	
Likelihood ratio test of rho=0: chibar^2(01)	223.06		-358.38		241.27		*256.88*	

***,**,*: Significant at 1%, 5% and 10% level, respectively.

The foregoing conclusion finds support in further analysis with assets. Land and total livestock owned (cattle and small ruminants) are not included in the estimating model because they are arguably endogenous to conservation. As a sensitivity analysis, however, we run regression models with the asset index derived from these assets to investigate their impact on the adoption of conservation practices. The results are presented in Appendix Tables A4 and A5. Other than for differences in signs and magnitude of the coefficients of some of the other variables, the results are consistent with earlier regression results and also the descriptive analysis results for terracing in Table 14. Specifically, the asset index has significant positive impacts on adoption of soil bunds and terracing, but a negative impact on planting drought resistant vegetation/trees and adoption of all practices combined. The findings for soil bunds and terracing therefore confirm that poverty in assets will discourage adoption of soil bunds and terracing, which supports findings in earlier studies (Somda et al., 2002; Shiferaw and Holden, 1999, 2001; Li et al., 1998; Alemu, 1999).

The Boserup hypothesis and the evolutionary land rights theory

Table 17 shows that population density is associated with higher probability of adoption of all practices except for terracing. The same result is observed for soil bunds and terracing in Table 18. These results confirm that population density increases the need for conservation and intensification (Boserup, 1965; Tiffen et al., 1994; Place and Otsuka, 2000).

To further test the Boserup hypothesis, we run a different version of model 1a where we test the impact of population density on land conservation without controlling for property rights. The results are presented in Table A6. The empirical results support our descriptive results and also earlier regression findings (Table 17), i.e., our results confirm the Boserup hypothesis. Furthermore, the results show that holding land rights constant, population density has a significant positive impact on the adoption of land conservation practices, specifically adoption of soil bunds and planting of drought resistant vegetation.

We also test for the evolutionary land rights theory by analysing empirically the impact of population density on different land rights. The results are presented in Table 19. They confirm that large population densities are associated with individual land rights. This is shown by the positive significant coefficient for population density with respect to the right to bequeath, full ownership rights and tenancy rights. Further, we note that the impact of population density on tenancy rights is much less than the impact on bequest and full ownership rights. Finally, the impact of population density on common property rights is negative and significant, implying that common property arrangements are likely to be found in areas of low population densities; thus confirming the evolutionary land rights theory.[11]

The same table investigates impact of household assets, household characteristics and market factors on land rights. There seems to be no clear pattern of the impact of each of these groups of factors on different land rights. Number of adults and rent income seem to be important for bequest and full ownership rights, but not for tenancy and common property rights. All other assets tend to be unimportant except investment in farm equipment, which is important for full ownership rights. Education seems to matter only for bequest and tenancy rights, while market factors do not seem to matter. We do not include locational dummies in this model because there is little or no variation in some land rights among the sample taken from some divisions.

Table 19: Determinants of land rights

Variable	Right to bequeath		Full ownership rights		Tenancy rights		Common property rights	
	Coefficient	z-stat.	Coefficient	z-stat.	Coefficient	z-stat.	Coefficient	z-stat.
Household assets								
Log number of adults	0.55***	(2.96)	0.12	(0.78)	-1.40***	-(3.81)	-0.12	-(0.66)
Log rent income	0.03**	(2.12)	0.01	(0.61)	-0.02*	-(1.77)	-0.03	-(1.29)
Log transfer income received	-0.02	-(0.70)	-0.005	-(0.23)	-0.01	-(0.12)	-0.002	-(0.08)
Log value of farm equipment	-0.06	-(1.14)	0.10**	(2.02)	-0.29***	-(2.95)	-0.03	-(0.57)
Log biomass per acre	-0.77***	-(3.16)	-1.09***	-(4.04)	-2.14***	-(2.62)	0.50**	(1.83)
Household characteristics								
Log age of household head	0.12	(0.47)	0.07	(0.31)	0.29	(0.55)	-0.08	-(0.28)
Sex	0.18	(1.10)	0.07	(0.51)	-0.34	-(1.17)	-0.05	-(0.28)
Marital status (1=married)	-0.11	-(0.52)	-0.34*	-(1.70)	-0.89***	-(2.25)	0.16	(0.63)
Has primary school education (relative to no education)	0.14	(0.58)	-0.18	-(0.85)	2.85***	(4.33)	-0.03	-(0.11)
Has secondary school education	0.25	(0.87)	-0.25	-(1.00)	3.03***	(4.72)	0.16	(0.56)
Has post secondary education	-0.86*	-(1.70)	-0.52	-(1.38)	3.61***	(4.42)	0.73	(1.32)
Market factors								
Log price per cattle	0.29	(1.57)	0.17	(0.97)	-1.26***	-(2.56)	-0.07	-(0.31)
Log price per goat	0.06	(0.23)	-0.08	-(0.37)	0.87	(1.56)	-0.23	-(0.82)
Log price per kilo of maize	-0.22	-(0.43)	-0.29	-(0.64)	-1.24	-(0.89)	0.03	(0.04)
Log price per kilo of beans	-0.48	-(1.04)	0.02	(0.05)	-1.42	-(1.37)	-0.53	-(0.96)
Log distance to market	0.02	(0.16)	0.09	(0.69)	0.38	(1.41)	0.10	(0.86)
Distance to source of water	0.75***	(5.17)	0.86***	(5.62)	-0.06	-(0.21)	-0.63***	-(5.92)
Log population density	2.68***	(9.85)	2.20***	(7.09)	1.20**	(2.15)	-4.86***	-(7.98)
Number of observations	1600	1600	1600	1600				
Wald chi^2(18)	132.70	121.65	58.44	132.52				
Log Likelihood	-377.70	-462.20	-142.68	-308.45				
Rho	0.89	0.86	0.93	0.89				
Likelihood ratio test of rho=0: chibar^2(01)	657.67	820.90	*285.76*	470.78				

Policy simulations

We use our empirical results to simulate the ceteris paribus effects of various policies on adoption of land conservation practices. The simulations are based on the coefficients of Model 1 (Table 17) and the means of the variables (Appendix Table A1). The results are presented in Table 20. The table details sample proportions (actual percentages of farmers adopting a given practice), and the predicted (base) probability of adopting each practice. Our random effects model has not been able to predict perfectly the adoption of each practice and so the actual sample proportions and the predicted proportions differ. The sample proportions indicate that only 8.3%, 7.06% and 18.7% of all farmers adopted blocking soil erosion outlets, land terracing and planting of drought resistant vegetation, respectively, as land conservation strategies. Our model over predicts adoption of all land conservation practices. The results also imply that on average all farmers adopted at least one practice. For example, the predictions imply that 29% of all farmers would adopt construction of soil bunds, 61% would plant drought resistant vegetation and trees, and 15% would adopt land terracing.

The results are interpreted as follows: For the first policy option, increasing the proportion of farmers with individual rights by 10% would increase the probability of adoption of soil bunds from 0.291 to 0.298.

Table 20: Policy simulations

		Probability of adopting		
		Soil bunds	**Terracing**	**Plant vegetation /trees**
Sample proportions		**0.083**	**0.076**	**0.187**
Base probability		**0.291**	**0.611**	**0.148**
Policy	**Policy outcomes**			
1). Increase proportion of farmers with individual ownership rights by 10%*	New probability	0.298	0.607	0.151
	Absolute change	0.007	-0.004	0.003
	Relative change	2.51	-0.60	1.86
2). Increase proportion of farmers under common property rights by 10%	New probability	0.290	0.610	0.147
	Absolute change	-0.001	-0.001	-0.001
	Relative change	-0.39	-0.12	-0.82
3). Increase assets (rent incomes, transfers and equipment) by 10%	New probability	0.296	0.617	0.171
	Absolute change	0.005	0.006	0.023
	Relative change	1.68	0.97	15.68
4). Increase all levels of education by 10%	New probability	0.292	0.620	0.151
	Absolute change	0.0018	0.0090	0.003
	Relative change	0.61	1.48	1.93
5). Increase biomass by 10%	New probability	0.240	0.574	0.218
	Absolute change	-0.051	-0.037	0.070
	Relative change	-17.48	-6.13	47.46
6). Increase livestock prices by 10%	New probability	0.212	0.414	0.145
	Absolute change	-0.078	-0.197	-0.003
	Relative change	-26.94	-32.26	-1.78
7). Increase crop prices by 10%	New probability	0.364	0.625	0.147
	Absolute change	0.073	0.014	-0.002
	Relative change	25.04	2.29	-1.03
8). Reduce distance to source of water and markets by 10%	New probability	0.298	0.602	0.148
	Absolute change	0.008	-0.009	0.000
	Relative change	2.62	-1.48	-0.16
9). Increase population growth by 10%	New probability	0.294	0.601	0.157
	Absolute change	0.004	-0.010	0.009
	Relative change	1.28	-1.66	6.28

* Refers to right to bequeath, own right and tenancy right.

That is, the share of farmers adopting construction of soil bunds would increase from 29% of all farmers to 30%, an absolute increase of 0.007 points or 2.51 percentage points. Such a policy would reduce the probabilities of land terracing by only 0.6%, but increase the probability of planting drought resistant vegetation by 1.861%. This means that other things held constant, secure land rights will encourage adoption of land conservation practices in the study district. This conclusion is confirmed by simulation results for farmers holding land under group ranches (common property). Holding other factors constant, increasing the proportion of farmers holding land under schemes by 10% would reduce the proportion of farmers adopting all conservation practiced, though the elasticities are quite low.

Household assets have the effect of raising the probability of adopting all land conservation practices. Specifically, a policy of increasing rent incomes, transfer incomes and budgets for farm capital by 10% would increase the proportion of farmers adopting construction of soil bunds, land terracing and planting of resistant vegetation and trees by 1.7%, 0.97% and 15.68%, respectively. There are therefore notable differences in the elasticities of adoption of land conservation practices with respect to assets. These results imply the need to alleviate asset poverty in the study region in order to encourage adoption of land conservation practices. This policy option also indicates the need for long-term policies that could facilitate diversion of non-farm incomes and remittances into investments in land conservation.

The elasticities of adoption with respect to changes in education are quite modest. Improving education in the district would have a stronger impact on planting drought resistant vegetation/trees than construction of soil bunds and terracing. For example, if the mean education level were to increase by 10%, the probability of adoption of construction of soil bunds would increase by only 0.61%. The same change would increase the probability of planting drought resistant vegetation by 1.93%, but decrease the probability of terracing by 1.48%. Overall, the results imply that although most coefficients of education dummies are insignificant in our regression models, increasing the level of education would encourage adoption of land conservation practices.

Simulation results for biomass, livestock and crop prices give mixed results. A 10% increase in biomass per acre, for example, would reduce the probability of adopting soil bunds and terracing by 17.48% and 6.13%, respectively. A similar policy change would have an enormous positive impact on planting of trees and drought resistant vegetation. Increasing livestock prices by 10% would discourage adoption of all conservation measures. Crop prices seem to be much more important for construction of soil bunds than adoption of other practices. A 10% increase in crop prices would lead to a 25.04% increase in probability of adoption of soil bunds, compared with a modest 2.29% increase in probability of terracing and a 1.03% fall in probability of adoption of drought resistant vegetation. Reducing the distance to a source of water and markets by 10% would increase the probability of construction of soil bunds by 2.62%, but reduce the probability of adoption of the other two practices by 1.48% and 0.16%, respectively.

The last policy simulation assesses the impact of a 10% population growth. Holding all other factors constant, a 10% population growth would have a net effect of increasing the adoption of land conservation practices. Specifically, increasing population growth by 10% would increase the probability of constructing soil bunds and planting resistant vegetation/trees by 1.28% and 6.28%, respectively. This result supports our earlier descriptive and regression results and also the literature (Boserup, 1965; Tiffen et al., 1994). However, such a change would have the effect of reducing the probability of terracing by -1.66%, which is also consistent with our descriptive and regression results.

Most of the policy options considered in Table 20 can be achieved, some in the short run and others in the long run. For example, security of tenure could be enhanced through deliberate government efforts: privatization of common property resources could be quickened if the government was to waive survey fees for land subdivision, as transaction costs are a major setback to subdivision. For the third policy option, government targeting programmes and other policies that reduce poverty would equip farmers with assets that would encourage adoption of land conservation practices.

Improving access to education would also increase the probability of adoption. In the short term, informal education through extension services would have the effect of increasing adoption, while formal education would have the same impact but is a more long-term policy option. Increasing the availability of biomass may not be possible in the short term because it depends mostly on agro-climate conditions and land use practices. However, farmer education on biomass conservation would increase the amount of biomass at the village level. In the long term, irrigation would have the same impact. To encourage adoption of land conservation practices, the government can also facilitate improvements in product prices and access to markets and water. The latter can also be through local community mobilization, where communities can access water through self-help groups.

7. Concluding remarks

Using survey data, this paper has empirically examined the impact of property rights and assets, among other covariates, on the adoption of land conservation practices. The study sought to address a number of issues: the main land conservation practices adopted by farmers in fragile ecological environments; the relationship between population density and property rights; whether the poor are able to conserve; and the major policy issues for sustainable environmental conservation. The key hypothesis tested in the paper is that security of land tenure affects land conservation incentives as it determines the expected returns to conservation for those who actually adopt conservation measures.

The descriptive analysis shows that security of tenure is indeed important for the adoption of land conservation practices. The results also show a clear correlation between property rights and population density. This confirms the evolutionary land rights theory (Platteau, 2000). Empirical results and policy simulations corroborate these finding. Individual ownership rights favour adoption of soil bunds and planting of vegetation and trees, but not terracing. Traditional tenure systems (proxied by group ranches/schemes) favour planting of vegetation and trees but not the other two practices. We also find that assets, more so rent incomes and farm capital, are important determinants of adoption of land conservation practices, a confirmation that the poor will be less likely to conserve than the rich. The results further show that other than for terracing, population density increases the likelihood of adoption of land conservation practices, thus confirming the Boserup hypothesis. Education, biomass availability, market development and location of the farm are also found to be important determinants of adoption.

Our study calls for a combination of short-term and long-term policy measures that offer incentives for land conservation. These include enhanced security of tenure, government targeting programmes and other policies that reduce household poverty, improved access to education both formal and informal, and improvements in product prices and access to markets and water. These policy options could be pursued through government initiatives and/or local community mobilization.

Lastly, we acknowledge a number of shortcomings of the study, owing mostly to constraints associated with the available data. These include the inability to:

- Explore the determinants of the level of land conservation;
- Analyse conservation decisions at the plot level;
- Extend measurement of land rights to perceptions/continuum such as mode of acquisition;
- Take into account the cost of land conservation measures, and

- Take into account the underlying soil conditions/quality prior to the adoption of land conservation practices.

Another shortcoming is the limitation of the short period of the panel used in this study. While superior to cross sectional data, a longer time period would be better suited to analyse conservation investment decisions made in the past. Both Boserup's and the evolutionary theory of land rights hypotheses are also more of a long-term historical process and would therefore be best analysed using a longer time panel. Nevertheless, in the absence of such data, this paper makes an important contribution to understanding the interplay of land rights, population density and decisions to invest in land conservation. These data limitations call for a different/new study design, which could yield richer insights for informing policy. We recommend further research in this direction.

Notes

1. The issue of tribe and ethnicity has become quite controversial because of political differences and so current government surveys do not touch on the issue of ethnicity. In the 1999 census, data were collected on district of birth and district of residence rather than tribe living in district x. This information is not directly comparable with information in Table 1 and is therefore excluded.

2. Although Boserup's hypothesis has been found to be consistent with certain empirical evidence from developing countries (Tiffen et al., 1994, among other studies), we note that it has also been contradicted by some studies. Instead, the latter studies show that population growth is associated with increased environmental degradation and declining productivity (Place and Otsuka, 2000; Mäler, 1997; Pinstrup-Anderson and Pandya-Lorch, 1994; Reardon and Vosti, 1995).

3. The evolutionary land rights theory contends that as land scarcity increases, people demand more land tenure security. As a result, private property rights in land tend to emerge and once established, to evolve towards greater measures of individualization and formalization.

4. Although an increasing number of studies have used a continuum/perception of rights, these are often not variables over which policy makers have direct influence. The impact of issuance of formal titles to land, which has been tested by several studies, can be addressed much more easily through legal instruments rather than other measures of tenure security (Place and Swallow, 2000).

5. The data represent an unbalanced panel with 37%, 33% and 30% observations in the three time periods, respectively. However, since the variations in the sample are not systematic, we assumed that sample attrition does not bias our results. The software used (Stata) also takes care of unbalanced panels automatically.

6. We caution that owing to changes in structure of population and also administrative boundaries, the clusters may not be directly comparable between 1969 and 1999. In cases where it was difficult to tell the actual cluster, location and division estimates were used. We believe that this still gives us a good picture of the population density in time and space.

7. It can be argued that both Boserup's and the evolutionary theory of land rights hypotheses are about a long-term historical process. In the absence of a long time-series for our panel data, we believe that the short panel utilized in this study still provides important inferences about these two hypotheses. Second, one may expect that land conservation practices are long-term options and may not change within a short period. But the temporal patterns of the adoption decisions show that they changed between the three time periods and still a short panel is superior to cross sectional data to analyse the adoption decisions. Third, it may be expected that government policy may have played an important role in the evolution of land rights but this is something of the distant past (1960s and 1970s). From the 1980s, group ranches have the freedom to subdivide the schemes (see Kabubo-Mariara, 2005, for a detailed discussion of the historical developments in government land programmes).

8. Land values also vary by agro-ecological zones. From general investment theory, it is expected that conservation practices follow land values. In the absence of data on land values, agro-ecological zones capture the impact of land values on conservation. Our results therefore imply that higher value land (in Loitoktok division) attracts a higher probability, and diversified forms, of investment than lower value land.

9. Other regression results are not presented to save space but are available from the author on request.

10. Rent income here refers to non-farm rent incomes such as housing rent, which is exogenous to conservation.

11. Although this confirms Platteau's argument that land arrangements and practices are evolving autonomously under increased land scarcity with significant shifts towards increased individualization of tenure, we caution that we do not really test the theory through actual titling and central registration, which he warns presents serious difficulties to the evolutionary theory of land rights (Platteau, 2000: 179).

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Appendix

Table A1: Definition and measurement of variables, N=1600

Variable	Mean	Std. dev.
1) *Land conservation practices*		
Farmer adopted at least one practice	0.39	0.48
Farmer constructed soil bunds (1 = yes, 0 = no)	0.08	0.27
Farmer engaged in land terracing (1 = yes, 0 = no)	0.08	0.27
Farmer planted vegetation/trees (1 = yes, 0 = no)	0.19	0.39
2) *Land rights factors*		
Right to bequeath (1 = yes, 0 = no)	0.73	0.45
Own plot (right to sell) (1 = yes, 0 = no)	0.63	0.48
Right to lease (1 = yes, 0 = no)	0.73	0.45
Land belongs to Scheme (group ranch) (1 = yes, 0 = no)	0.27	0.40
Tenant (1 = yes, 0 = no)	0.07	0.25
3) *Assets*		
Total land owned (acres)	22.08	14.54
Rent incomes (Ksh ’000)	11.26	37.53
Transfers incomes (Ksh ’000)	2.14	10.01
Value of farm equipment (Ksh ’000)	6.35	11.16
Number of cattle owned	29.39	86.74
Number of small ruminants (sheep & goats) owned	59.78	148.60
Asset index	-2E-09	0.82
Per capita expenditure	1737.36	122.83
4) *Household characteristics*		
Number of adults	4.42	3.45
Age of household head	35.16	13.22
Sex (1 = male, 0 = female)	0.49	0.50
Marital status (1 = married, 0 = not married)	0.69	0.46
Primary school education (1 = yes, 0 = no)	0.31	0.46
Secondary school education (1 = yes, 0 = no)	0.17	0.38
Post secondary education (1 = yes, 0 = no)	0.23	0.42
5) *Market characteristics*		
Price of maize (Ksh/kg)	20.77	6.36
Price of beans (Ksh/kg)	42.59	13.18
Distance to market (km)	11.73	9.65
Distance to source of water (km)	3.45	4.58
6) *Agro-ecological zones (Division where household is located)*		
Loitoktok (1 = yes, 0 = no)	0.30	0.46
Mashuru (1 = yes, 0 = no)	0.13	0.33
Ngong (1 = yes, 0 = no)	0.28	0.45
Central (1 = yes, 0 = no)	0.10	0.30
Magadi (1 = yes, 0 = no)	0.08	0.28
Namanga (1 = yes, 0 = no)	0.11	0.31

Table A2: Total land owned by property right regime

Land right	Total land owned**		t-statistic	Pr>t
	Has right	No right		
Sell	108.5 (155)	81.7 (128)	-3.61	0.1600
Bequeath	107.3 (160)	74.5 (95)	-4.09	0.0000
Own	110.2 (151)	77.5 (127)	-4.38	0.4027
Scheme	73.7 (82.1)	104.4 (160)	3.43	0.0000
Tenant	38.3 (97.1)	102.4 (147)	4.48	0.0101

**Standard deviations in parentheses.
Source: Author's calculations from field survey data.

Table A3: Land conservation practices by land security measure

Right \Practice	Sell			Bequeath			Own			Scheme			Tenant		
	Yes	No	"t"	Yes	No	"t"	Yes	No	"t"	Yes	No	"t"	Yes	No	"t"
Soil bunds	0.01	0.08	2.67	0.09	0.07	-0.91	0.07	0.11	3.11	0.08	0.08	0.50	0.08	0.08	0.02
Terracing	0.10	0.04	-4.94	0.09	0.04	-3.45	0.01	0.04	-4.77	0.02	0.09	4.45	0.08	0.04	1.61
Vegetation & trees	0.21	0.15	-3.18	0.22	0.12	-5.22	0.21	0.14	-3.47	0.09	0.21	4.83	0.23	0.18	-1.89
All practices	0.38	0.29	-3.80	0.40	0.22	-6.78	0.39	0.29	-3.68	0.19	0.39	6.79	0.35	0.34	-0.06

Source: Author's calculations from field survey data.

Table A4: Determinants of choice of land conservation practices (continuum of rights and asset index)

Variable	Construction of soil bunds		Terracing		Planting drought resistant vegetation/trees		All conservation practices	
	Coefficient	z-stat.	Coefficient	z-stat.	Coefficient	z-stat.	Coefficient	z-stat.
Land rights								
Has right to bequeath land	1.39**	(2.10)	-1.00	-(1.27)	1.02*	(1.80)	0.81*	(1.84)
Has land in scheme	-0.44	-(1.44)	-0.06	-(0.10)	0.12	(0.40)	-0.16	-(0.58)
Has own plot	1.54**	(1.99)	-2.47***	-(2.85)	-0.50	-(0.80)	0.35	(0.75)
Has tenancy right	0.65	(1.13)	1.37	(1.52)	0.19	(0.42)	0.47	(1.22)
Household assets								
Log number of adults	0.34	(1.33)	-2.39***	-(5.55)	-0.03	-(0.12)	-0.48**	-(2.07)
Log rent income	0.04***	(3.27)	0.16***	(5.63)	-0.02**	-(2.00)	0.02*	(1.64)
Log transfer income received	0.02	(0.57)	0.02	(0.66)	-0.10***	-(3.37)	0.02	(0.58)
Log value of farm equipment	0.12*	(1.67)	0.43***	(4.08)	0.55***	(6.15)	0.39***	(5.24)
Asset index	0.47**	(2.10)	0.41***	(2.48)	-1.08***	-(4.66)	-0.09	-(0.55)
Log biomass per acre	-1.45**	-(2.02)	-0.75	-(1.25)	1.95***	(3.57)	2.10***	(3.78)
Household characteristics								
Log age of household head	0.42	(1.19)	-0.08	-(0.24)	0.10	(0.35)	0.14	(0.52)
Sex	-0.10	-(0.50)	0.00	(0.02)	0.01	(0.07)	-0.02	-(0.13)
Marital status (1=married)	-0.32	-(1.18)	0.74**	(2.16)	0.00	(0.00)	0.15	(0.68)
Has primary school education (relative to no education)	0.10	(0.36)	0.15	(0.44)	0.07	(0.31)	0.10	(0.44)
Has secondary school education	-0.21	-(0.58)	-0.07	-(0.17)	0.14	(0.52)	0.25	(0.96)
Has post secondary education	1.42***	(6.25)	0.25	(0.44)	2.51**	(11.32)	5.19***	(15.37)
Market characteristics								
Log price per cattle	-1.30***	-(3.70)	0.70***	(2.38)	-0.54**	-(2.01)	-0.87***	-(3.16)
Log price per goat	-0.60*	-(1.74)	-3.21***	-(5.57)	0.38	(1.34)	-0.66***	-(2.50)
Log price per kilo of maize	-0.87	-(1.01)	0.04	(0.04)	6.64***	(6.92)	3.67***	(5.46)
Log price per kilo of beans	4.62***	(6.09)	-0.68	-(0.90)	-4.90***	-(6.75)	-1.75***	-(3.22)
Log distance to market	-0.78***	-(3.00)	0.52***	(3.23)	0.11	(0.53)	-0.04	-(0.22)
Distance to source of water	0.29	(1.41)	0.88**8	(3.28)	-0.52**	-(2.21)	0.05	(0.33)
Log population density	1.03**	(2.29)	-1.32***	-(2.39)	0.59	(1.51)	0.06	(0.18)
Agro-ecological zones								
Mashuru	-3.07*	-(3.64)	7.20***	(6.93)	-2.32***	-(3.15)	-2.40***	-(4.00)
Ngong	-1.19***	-(1.63)	2.44***	(2.61)	-4.80***	-(6.28)	-4.04***	-(6.98)
Central	-3.97*	-(4.57)	9.17***	(7.54)	-2.51***	-(4.30)	-2.43***	-(4.44)
Magadi	-4.08*	-(3.86)	5.09***	(3.85)	-1.78*	-(1.76)	-3.51***	-(3.36)
Namanga	-3.01*	-(2.94)	10.27***	(6.98)	-3.56***	-(5.43)	-3.74***	-(5.74)
Constant	4.48	(0.60)	14.66	(2.37)	-21.60	-(3.73)	-11.56	-(2.17)
Number of observations	1600		1600		1600		1600	
Wald $chi^2(28)$	132.07		88.97		217.52		259.37	
Log Likelihood	-238.53		-203.4		-355.08		-361.49	
Rho	0.92		0.94		0.86		0.78	
Likelihood ratio test of rho=0: $chibar^2(01)$	255.56		224.96		262.48		185.54	

***; **; *: Significant at 1%, 5% and 10% level, respectively.

Table A5: Determinants of choice of land conservation practices (rights dummy and asset index)

Variable	Construction of soil bunds		Terracing		Planting drought resistant vegetation/trees		All conservation practices	
	Coefficient	z-stat.	Coefficient	z-stat.	Coefficient	z-stat.	Coefficient	z-stat.
Land rights								
Property right regime (1=private, 0= common)	-0.31	-(1.06)	0.97	(1.50)	1.71***	(4.21)	1.44***	(5.06)
Household assets								
Log number of adults	0.48**	(2.03)	-2.45***	-(3.41)	-0.15	-(0.60)	-0.40*	-(1.65)
Log rent income	0.05***	(3.73)	0.18***	(3.59)	-0.01	-(1.27)	0.004	(0.31)
Log transfer income received	0.03	(0.86)	-0.01	-(0.07)	-0.09***	-(3.30)	0.02	(0.78)
Log value of farm equipment	0.08	(1.18)	-0.07	-(0.30)	0.55***	(6.29)	0.47***	(4.93)
Asset index	0.47**	(2.16)	0.38	(0.76)	-1.14***	-(4.85)	-0.18	-(1.02)
Log biomass per acre	-1.10	-(1.57)	-3.84**	-(2.24)	1.73***	(3.33)	1.75***	(3.14)
Household characteristics								
Log age of household head	0.34	(0.96)	-0.07	-(0.11)	0.31	(1.01)	0.14	(0.50)
Sex	-0.05	-(0.25)	-0.16	-(0.47)	0.04	(0.23)	0.01	(0.05)
Marital status (1=married)	-0.22	-(0.84)	0.34	(0.57)	-0.25	-(1.04)	0.20	(0.89)
Has primary school education (relative to no education)	0.18	(0.68)	0.04	(0.06)	0.15	(0.62)	0.07	(0.30)
Has secondary school education	-0.28	-(0.79)	0.32	(0.49)	0.30	(1.14)	0.28	(1.05)
Has post secondary education	1.33***	(5.66)	7.51***	(5.69)	2.57***	(11.74)	5.64***	(14.51)
Market characteristics								
Log price per cattle	-1.22***	-(3.53)	0.85	(1.53)	-0.29	-(1.14)	-0.77***	-(2.75)
Log price per goat	-0.55*	-(1.64)	-7.19***	-(4.51)	0.06	(0.19)	-1.06***	-(3.77)
Log price per kilo of maize	-0.50	-(0.55)	-2.31	-(1.37)	7.07***	(7.33)	2.97***	(4.43)
Log price per kilo of beans	4.55***	(5.94)	2.08	(1.18)	-4.49***	-(6.32)	-0.80	-(1.33)
Log distance to market	-0.84***	-(2.97)	0.12	(0.22)	-0.04	-(0.17)	-0.06	-(0.31)
Distance to source of water	0.27	(1.51)	0.15	(0.33)	-0.10	-(0.48)	-0.02	-(0.16)
Log population density	1.17***	(2.78)	-4.25***	-(3.23)	-0.70	-(1.47)	-0.14	-(0.41)
Agro-ecological zones								
Mashuru	-3.58***	-(4.32)	7.32***	(3.34)	-3.30***	-(4.39)	-3.01***	-(4.55)
Ngong	-1.77***	-(2.45)	8.37***	(2.95)	-3.78***	-(4.61)	-4.23***	-(6.33)
Central	-4.80***	-(5.74)	10.96***	(3.82)	-3.00***	-(5.48)	-3.11***	-(5.20)
Magadi	-4.68***	-(4.31)	4.71	(1.60)	-3.19***	-(3.51)	-2.96***	-(2.95)
Namanga	-6.07***	-(4.88)	14.31***	(4.48)	-3.80***	-(6.20)	-4.14***	-(5.64)
Constant	1.58	(0.21)	61.65	(3.06)	-21.33	-(3.79)	-9.08	-(1.71)
Number of observations	1600		1600		1600		1600	
Wald $chi^2(25)$	126.65		56.50		221.90		241.36	
Log Likelihood	-241.17		-120.79		-351.92		-349.22	
Rho	0.93		0.97		0.85		0.78	
Likelihood ratio test of rho=0: $chibar^2(01)$	224.05		243.90		245.76		252.43	

***, **, *: Significant at 1%, 5% and 10% level, respectively.

Table A6: Impact of population density on land conservation±

Variable	Construction of soil bunds		Terracing		Planting drought resistant vegetation/trees		All conservation practices	
	Coefficient	z-stat.	Coefficient	z-stat.	Coefficient	z-stat.	Coefficient	z-stat.
Household assets								
Log number of adults	0.24	(0.92)	-2.41***	-(2.36)	-0.41*	-(1.76)	-0.37*	-(1.61)
Log rent income	0.02*	(1.79)	0.24***	(4.43)	-0.01	-(1.62)	0.02**	(2.07)
Log transfer income received	-0.003	-(0.11)	-0.07	-(0.97)	-0.09***	-(3.26)	0.01	(0.48)
Log value of farm equipment	0.07	(0.96)	-0.30	-(1.48)	0.62***	(6.57)	0.42***	(5.22)
Log biomass per acre	-1.53**	-(2.27)	-5.01***	-(2.74)	1.71***	(3.41)	1.75***	(3.23)
Household Characteristics								
Log age of household head	0.13	(0.35)	-0.01	-(0.02)	0.01	(0.02)	0.09	(0.33)
Sex	-0.06	-(0.30)	-0.09	-(0.23)	0.06	(0.43)	-0.01	-(0.07)
Marital status (1=married)	0.03	(0.11)	0.89	(1.28)	-0.02	-(0.09)	0.18	(0.81)
Has primary school education (relative to no education)	-0.02	-(0.08)	0.60	(0.88)	0.00	-(0.02)	0.15	(0.69)
Has secondary school education	-0.10	-(0.31)	0.40	(0.61)	-0.05	-(0.19)	0.28	(1.11)
Has Post secondary education	1.43***	(5.97)	7.13***	(6.81)	2.46***	(11.86)	5.13***	(15.13)
Market characteristics								
Log price per cattle	-1.36***	-(4.06)	0.85	(1.63)	-0.57***	-(2.35)	-0.95***	-(3.44)
Log price per goat	-0.55*	-(1.66)	-7.04***	-(5.58)	0.66***	(2.54)	-0.61**	-(2.31)
Log price per kilo of maize	-1.32*	-(1.63)	-2.34	-(1.40)	5.66***	(7.26)	3.74***	(5.48)
Log price per kilo of beans	4.44***	(6.10)	1.91	(1.11)	-4.41***	-(6.54)	-1.64***	-(3.03)
Log distance to market	-0.74***	-(2.53)	-1.67***	-(3.40)	0.04	(0.23)	-0.06	-(0.39)
Distance to source of water	-0.17	-(0.95)	1.95***	(3.02)	-0.05	-(0.30)	0.18	(1.27)
Log population density	**-1.32*** **	**-(3.28)**	**-2.23** **	**-(2.28)**	**1.44*** **	**(3.74)**	**0.30**	**(0.89)**
Agro-ecological zones								
Mashuru	-5.64***	-(5.75)	13.27***	(4.36)	-2.28***	-(3.57)	-2.55***	-(4.30)
Ngong	-1.23**	-(1.85)	12.26***	(4.14)	-4.51***	-(6.40)	-4.01***	-(6.97)
Central	-3.90***	-(5.09)	17.41***	(4.43)	-2.78***	-(5.46)	-1.70***	-(3.16)
Magadi	-4.56***	-(4.61)	6.94***	(2.59)	-1.81***	-(2.54)	-3.49***	-(3.13)
Namanga	-3.85***	-(4.23)	19.07***	(4.68)	-3.98***	-(7.10)	-3.63***	-(5.93)
Constant	13.73	(1.91)	66.96	(3.63)	-20.40	-(3.80)	-9.15	-(1.77)
Number of observations	1600		1600		1600		1600	
Wald chi2(25)	132.15		58.67		225.50		252.26	
Log Likelihood	-243.59		-121.33		-366.53		-366.58	
Rho	0.90		0.97		0.85		0.78	
Likelihood ratio test of rho=0: chibar2(01)	220.22		250.03		275.76		271.77	

± Without controlling for land rights.
***,**,*: Significant at 1%, 5% and 10% level, respectively.

Table A7: Determinants of choice of land conservation practices (model with no divisional dummies)

Variable	Construction of soil bunds		Terracing		Planting drought resistant vegetation/trees		All conservation practices	
	Coefficient	z-stat.	Coefficient	z-stat.	Coefficient	z-stat.	Coefficient	z-stat.
Land rights								
Has right to bequeath land	2.05***	3.28	-0.31	-0.27	0.75	1.48	1.12***	2.34
Has land in Scheme	-0.98***	-3.62	0.04	0.05	0.09	0.3	-0.53*	-1.88
Has own plot	1.01	1.49	-2.11	-1.57	0.10	0.22	0.68	1.44
Has tenancy right	1.36***	2.58	-0.03	-0.03	0.27	0.72	0.55	1.04
Household assets								
Log number of adults	-0.15	-0.66	-1.05*	-1.93	-0.34*	-1.8	0.10	0.46
Log rent income	0.04***	3.42	0.10***	3.06	0.00	-0.04	0.02***	2.26
Log transfer income received	-0.04	-1.31	0.03	0.70	-0.07***	-2.67	0.01	0.36
Log value of farm equipment	0.10	1.4	0.17	0.99	0.47***	5.53	0.36***	4.93
Log biomass per acre	-0.63	-1.33	0.77	1.15	0.16	0.45	0.18	0.50
Household Characteristics†								
Log age of household head	0.34	1.07	-0.22	-0.40	0.31	1.19	0.46*	1.73
Sex	-0.16	-0.9	0.06	0.21	0.02	0.15	-0.10	-0.71
Marital status (1=married)	-0.29	-1.15	0.21	0.41	-0.30	-1.43	-0.20	-1.00
Has primary school education (relative to no education)	0.17	0.71	0.22	0.47	0.37*	1.72	0.41*	1.75
Has Secondary school education	0.16	0.54	-0.09	-0.17	0.34	1.47	0.49*	1.78
Has Post secondary education	1.45***	6.73	5.35***	7.95	2.43***	11.98	4.86***	15.11
Market characteristics								
Log price per head of cattle	-1.13***	-3.62	-0.20	-0.41	-1.12***	-4.58	-1.07***	-4.17
Log price per goat	-0.61**	-1.94	-2.98***	-4.39	0.85***	3.45	-0.53**	-2.10
Log price per kilo of maize	-2.46***	-3.99	-1.50	-0.57	4.77***	7.98	2.10***	4.11
Log price per kilo of beans	3.80***	6.08	3.06	1.92	-5.81***	-8.61	-2.45***	-4.73
Log distance to market	-0.52***	-2.82	0.37	0.55	0.05	0.38	-0.08	-0.50
Distance to source of water	0.51***	2.59	-0.57	-0.51	0.09	0.57	0.18	0.89
Log population density	0.96***	2.84	-3.30***	-3.37	0.36	1.48	0.42	1.43
Constant	4.61	1.14	8.23	.	0.67	0.22	6.79	1.97
Number of observations	1600		1600		1600		1600	
Wald chi2(27)	133.67		1164.99		216.58		255.50	
Log Likelihood	-256.67		-157.47		-385.98		-386.09	
Rho	0.95		0.95		0.85		0.75	
Likelihood ratio test of rho=0: chibar2(01)	186.40		230.51		291.47		258.97	

***,**,*: Significant at 1%, 5% and 10% level, respectively.

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