Chapter 16
Economics of Land Degradation and Improvement in Kenya

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Abstract Kenya is an agricultural nation, with over 12 million people residing in areas with degraded lands. Unfortunately, the food crop productivity growth in the country has failed to exceed the population growth. The growth of agricultural output in Kenya is constrained by many challenges including soil erosion, low productivity, agro-biodiversity loss, and soil nutrient depletion. Land exploitation devoid of proper compensating investments in soil and water conservation will lead to severe land degradation. This will translate to loss of rural livelihoods, diminished water supplies and threaten the wildlife habitat. This study explores the causes, extent and impacts of land degradation in Kenya, discusses the costs of action versus inaction in rehabilitating degraded lands, and proposes policy options for promoting sustainable land management (SLM). In order to appropriately support SLM, there is a need to account for the total economic value (TEV) of land degradation, i.e. including the value of both provisioning and indirect ecosystem services of land. Using such a TEV approach, findings show that the costs of land degradation due to land use and land cover changes (LUCC) in Kenya reach the equivalent of 1.3 billion USD annually between 2001 and 2009. Moreover, the costs of rangeland degradation calculated through losses in milk and meat production, as well as in livestock live weight decreases reach about 80 million USD annually. Furthermore, the costs of "soil nutrient mining" leading to lower yields for three crops, namely wheat, maize and rice in Kenya were estimated at about 270 million USD annually. The cost of taking action

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to rehabilitate lands degraded through LUCC is found to be lower than the cost of inaction by 4 times over a 30 year period, i.e. each dollar invested in land rehabilitation is likely to yield four dollars of returns. This may strongly justify the urgent need for taking action against land degradation. Addressing land degradation involves investments in SLM. Our econometric results show that improving access to information on SLM and to the markets (input, output, financial) may likely stimulate investments into SLM by agricultural households.

Keywords Economics of land degradation · Drivers of land degradation · Sustainable land management · Cost of land degradation · Kenya

Introduction

Land degradation is a multi-faceted and complex phenomenon (Mbow et al. 2015). The United Nations Convention to Combat Desertification, (UNCCD) defines land itself as "the terrestrial bio-productive system that comprises soil, vegetation, other biota, and the ecological and hydrological processes that operate within the system." It further defines land degradation as a "reduction or loss in arid, semi-arid, and dry sub-humid areas, of the biological or economic productivity and complexity of rain-fed cropland, irrigated cropland, or range, pasture, forest, and woodlands resulting from land uses or from a process or combination of processes, including processes arising from human activities and habitation patterns, such as: (i) soil erosion caused by wind and/or water; (ii) deterioration of the physical, chemical, and biological or economic properties of soil; and (iii) long-term loss of natural vegetation" (UNCCD 2013). On the other hand, the Global Environment Facility (GEF) further describes land degradation as "any form of deterioration of the natural potential of land that affects ecosystem integrity either in terms of reducing its sustainable ecological productivity or in terms of its native biological richness and maintenance of resilience" (UNCCD 2013). Muchena et al. (2005a, b) define land degradation as a "loss in productivity of the land and its ability to provide quantitative or qualitative goods or services as a result of natural and human- induced changes in physical, chemical and biological processes". Land degradation is also defined as "reduction of the current or future capacity of land to produce" (Oluwole and Sikhalazo 2008). All these definitions imply that the costs of land degradation are manifested not only through the losses in tangible goods and services derived from land, such as food or feed, but also include the non-provisional ecosystem services, such as carbon sequestration, water purification, etc. (Nkonya et al. 2011), thus necessitating Total Economic Value approaches (Chap. 2) to comprehensively evaluate these losses.

It is widely acknowledged that land degradation remains an important problem affecting the sustainable development of many regions in the globe, especially Sub-Saharan Africa (Nkonya et al. 2011; Lal et al. 2013; von Braun et al. 2013).

Land degradation is complex and varies from place to place and over time. Thus, its exact measurements are difficult (Waswa 2012). The importance of land will remain critical in the years to come (Eswaran and Lal 2001). Moreover, land degradation is poised to diminish land productivity, especially in dry areas. Land degradation can also lead to loss of vegetation cover and thus make them susceptible to climatic hazards like droughts. Without sustainable use and management of land and soil resources, global sustainable development and environmental sustainability are unlikely to be attained (Lal et al. 2012; EAA 2005).

Land degradation is threatening the livelihoods of millions of people, who depend on land ecosystem goods and services the world over for their livelihoods, including in the dry lands of Kenya (Muia and Ndunda 2013). Kenya is an agricultural nation, with over 12 million people residing in areas with degraded lands (Bai et al. 2008; Le et al. 2014). Unfortunately, the food crop productivity growth in the country has over the last decades failed to exceed population growth (Waswa 2012). On average, the productivity of the major cereal—maize—is less than 1 metric ton per ha on most smallholder plots (Muasya and Diallo 2001; cited by Waswa 2012). Land degradation and the associated “nutrient mining” have also lead to this outcome, with significant impacts on rural livelihoods and the overall economy (Maitima et al. 2009; Henao and Baanante 2006).

The rural poor primarily depend on natural resources (especially land) for their livelihoods. Degradation of these productive resources will thus affect them disproportionately higher (Nkonya et al. 2008a, b). For example, in Kenya, the yield of most smallholder maize farmers in Kisii County was less than 2 tons/ha as compared to on-station yields of about 9 tons/ha (Nzabi et al. 2000). These low harvests are attributed to deteriorating soil fertility as a result of continuous cropping, soil erosion, non-use or inadequate use of both organic and inorganic fertilizers (Kamoni and Makhoha 2010).

Unfortunately, there exists no sufficient monitoring of land degradation issues both at national and local scales in Kenya (Waswa 2012). The growth of agricultural output in Kenya is constrained by many challenges including soil erosion, low productivity, agro-biodiversity loss, and soil nutrient depletion (GoK 2007). Land exploitation devoid of proper compensating investments in soil and water conservation will lead to severe land degradation (GoK 2013a).

This study seeks to explore the causes, extent and impacts of land degradation in Kenya, evaluate the costs of action versus inaction in rehabilitating degraded lands, and propose policy measures that can be instituted to address land degradation. In doing so, the study seeks to find answers to three research questions, namely: (1) What are the key causes of land degradation in Kenya? (2) What are the economic costs of land degradation and net benefits resulting from taking actions against land degradation? (3) What are the feasible policy and development strategies that can enable and catalyze sustainable land management (SLM)?

Literature Review

Extent of Land Degradation in Kenya

The major land degradation problems of Kenya are the loss of soil fertility through so called "soil nutrient mining", wind and water erosion of the soils, rangeland degradation, deforestation and desertification. The loss of soil by water erosion in Kenya was some time ago estimated at 72 tons per hectare per year (de Graff 1993). An even earlier study by Dregne (1990) reported a permanent reduction of soil productivity from water erosion in about 20 % of the Kenyan territory. Soil erosion is often manifest on the slopes near water streams, riparian areas, and in the marginal lands.

Salinization is believed to occur in 30 % of the irrigated lands in Kenya (Liniger et al. 2011). Resources degradation (resulting from soil and water) has both onsite and many offsite costs. It also impacts on food prices, food security and ecosystem service provision in downstream locations, beyond the source of the degradation.

It is notable that no single and comprehensive approach can map patterns, the status, and quantify the extent of land degradation in Kenya (Waswa 2012). The processes of land degradation are complex process, thus a variety of approaches are needed to adequately assess it. The types of soil and land degradation often found in Kenya are soil erosion, increased sediment loading of water bodies, such as Lake Olbollosat, the Winam Gulf and lake Baringo, loss of soil fertility, salinity, reduced ground cover, and the reduced carrying capacity of pastures, such as Amboseli National Park (FAO n.d).

The estimates of the extent of land degradation in Kenya vary depending on the source and methodologies of calculation. The potential areas of land degradation, defined as "places where both net primary productivity and rain-use efficiency (the ratio of net primary productivity to precipitation)" were found to be declining, stretching to 17 % of the country and 30 % of its cropland (Bai and Dent 2006). In these areas, land degradation was especially due to the expansion of cropping into marginal lands (for example, in the drylands around Lake Turkana and marginal croplands in Eastern Province) (ibid).

Land degradation is more pronounced in the Eastern parts and North Eastern parts of Kenya (as shown in Fig. 16.1), where 12.3 % of the land suffers from severe degradation, 52 % from moderate degradation and 33 % is vulnerable to land degradation (Muchena 2008; UNEP 2009). Bai et al. (2008) depicts that in about 64 % of Kenya's total land area was subject to moderate land degradation and about 23 % to very severe degradation problems in 1997. The latter had increased to nearly 30 % in the early 2000s (Bai et al. 2008). More recently, Le et al. (2014) estimated that the total of 22 % of the Kenyan land area has degraded between 1982 and 2006, including 31 % of croplands, 46 % of forested land, 42 % of shrub lands, and 18 % of grasslands.

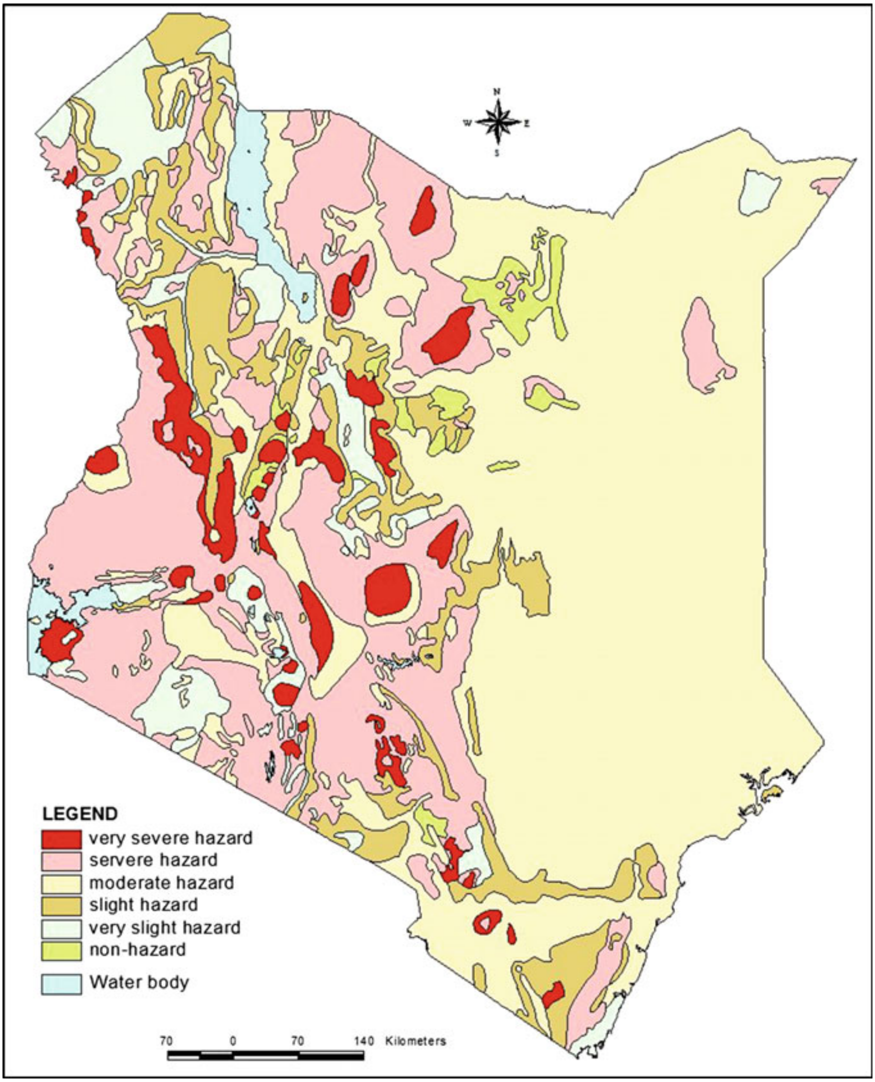

Fig. 16.1 Land degradation hazard areas in Kenya. *Source* Based on Kenya soil survey

Land Use and Cover Changes

Kenya has been undergoing dynamic land use and land cover changes over the last decade. The Moderate Resolution Imaging Spectroradiometer (MODIS) remotely sensed datasets that over the period of 2001 and 2009 present these dynamic changes for Kenya (Friedl et al. 2010) as shown in Tables 16.1 and 16.2.

Table 16.1 Land use and land cover in Kenya in 2001 (hectares)

Regions	Forests	Shrublands	Cropland	Grassland	Woodland	Barren	Water	Urban
Central	289,779	22,343	64,720	623,424	327,469	0	68	2583
Coast	131,067	2,686,984	381,133	4,677,692	467787	4947	19146	5644
Eastern	139,430	8,195,093	210,396	5,775,804	623,438	390,549	392,982	3471
Nairobi	4619	150	3362	44,823	3006	27	0	17,820
N/Eastern	60,908	9,384,587	61,413	2,879,600	212,486	15,305	55	5371
Nyanza	51,109	27,686	477,134	506,488	194,530	11,055	346,628	1804
Rift Valley	892,199	4,920,953	730,303	7,282,204	1,752,859	1,647,729	340,711	8459
Western	63,108	19,692	374,164	131,326	239,558	260	13,392	342
Total	1,632,219	25,300,000	2,302,625	21,900,000	3,821,133	2,069,873	1,112,981	45,493

Source Calculated by authors using MODIS data

Table 16.2 Land use and land cover change in Kenya between 2001 and 2009 (hectares)

Regions	Forests	Shrub-land	Cropland	Grassland	Woodland	Barren	Water	Urban
Central	−11,288	19,979	46,955	−57,095	1312	0	137	0
Coast	−28,438	−1,568,715	315,416	1,170,308	121,036	−2173	−7174	−123
Eastern	9252	−1,494,510	−67,932	1,887,028	−287,087	−27,126	−16,973	0
Nairobi	−2624	96	−1736	−492	4728	27	0	0
North-Eastern	−36,077	−2,326,594	162,238	2,175,877	37,348	−12,736	−55	0
Nyanza	−16,112	−16,002	−125,368	17,683	150,609	1462	−11,165	0
Rift Valley	−285,269	−677,471	−143,256	1,878,062	−123,510	−626,977	−19,829	0
Western	−765	−6259	−177,243	−35,052	220,604	519	−1613	0
Total	−371,322	−6,100,000	9074	7,100,000	125,040	−667,004	−56,672	−123

Source Calculated by the authors using MODIS data

These changes can be summarized into four major categories at the national level:

- Deforestation, especially in the Rift valley (mainly encroachment of water towers like Mau forest/escarpment) (Baker and Miller 2013; Kiage et al. 2007).
- Massive shift from shrublands, barren lands, and in some areas, from croplands to grasslands. Studies in the country indicate an overall decline in shrublands and grasslands with subsequent increases in croplands and built-up lands (Were et al. 2013; Kioko and Okello 2011; Maitima et al. 2009; Serneels and Lambin 2001). However, the distinction between grasslands and croplands may be compounded by the fact that at different time periods, crop areas maybe left fallow for long periods and thus some parcels drifting into grasslands and vice versa (Kiage et al. 2007). This may explain the increased area under grasslands as shown using MODIS data.
- Human movement and settlement in arid ASAL areas (low lands) as population pressure mounts in the high potential highlands (Kameri-Mbote 2007).
- Considerable reductions in the cropped area in Nyanza, Rift Valley, Western and Eastern provinces and big increases in the cropped area in Coastal (new settlements), North-Eastern and Central provinces. This in support of literature on land use/land cover in the country indicating that the area under crop cultivation has more than doubled over the last few decades (Maitima et al. 2009).
- Reductions in the extent of water bodies (frequent droughts in recent past, but with increased rains the reservoirs are presently recharging) (Kiage et al. 2007).

Drivers and Impacts of Land Degradation in Kenya

The last century has seen an increase in land degradation and desertification (UNCCD 2013). As described in Chap. 2 of this volume, the causes of land degradation are grouped into two, namely; proximate (biophysical) and underlying (socioeconomic) causes. These causes interact together to determine the rates of degradation. Biophysical causes are factors relating to unsustainable agronomic practices, and land physical conditions, rainfall and pest and diseases.

The large share of the documented unsustainable management practices in Kenya in the literature relate to land use/land cover changes experienced in significant environments of the country (Kiage et al. 2007; Maitima et al. 2009). The land use/land cover changes are often associated with deforestation, loss of natural vegetation, biodiversity loss and land degradation (Kiage et al. 2007; Maitima et al. 2009). The drivers linked to the land use/land cover changes include unsustainable fuel wood extraction, logging for charcoal and commercial timber, and land clearing for purposes of agriculture (Kiage et al. 2007; Mundia and Aniya 2006; UNEP 2002; Serneels and Lambin 2001). Specific drivers of forest degradation include illegal logging for commercial timber and for domestic demand for wood and charcoal (in west Pokot, Turkana and Marakwet), illegal growing of bhang in forests (such as Mount Kenya), considerable excisions of protected forests (such as Mau and Abadares) and forest fires (as reported in Mt. Elgon). With regard to clearing native vegetation for purposes of agriculture, Serneels and Lambin (2001) identify accessibility as a key driver in some parts of the country. Accessible areas, were found to be more prone to conversions to mechanized and smallholder agriculture. Whereas the productivity of not so fertile land, such as range lands, can be improved by use of fertilizers and other modern technology, accessible areas characterized by factors such as distance to the markets and low altitude plains emerge as important factors determining whether a parcel is modified or not.

The other documented unsustainable management practices include water pollution, soil nutrient mining, overgrazing, and cultivation on steep slopes. 'Soil nutrient mining' in croplands is an important driver of cropland degradation in Kenya. According to Blum (2006) soil is a limited resource and could be considered a non-renewable resource (Bai et al. 2008). Areas with poor soil fertility and with poor management practices tend to suffer from soil nutrient depletion. Fertilizer application rates in much of Kenya remain low (Table 16.3), resulting in "soil nutrient mining", when crop producers remove more nutrients from the soils than they apply. This process is not sustainable.

The underlying drivers of land degradation are manifold. Increasing human population pressure subjects land to intense pressure leading to degradation (Maitima et al. 2009; King 2008; Kiage et al. 2007; Mundia and Aniya 2006; Serneels and Lambin 2001). High population growth rates in Kenya have increased the demand for ecosystem services. The high population pressure fuels expansion of agricultural area to meet food demands and also for economic development of the rural populations (Maitima et al. 2009).

This has led to expansion of cropland into marginal areas, pastureland and forest lands and steep slopes. The pressure on fragile ecosystems has led to increased land degradation. The growth of the pastoralist population and subsequent increase of the livestock population have also led to extension of grazing activity into semi-arid marginal lands and forests, causing severe degradation and reduced livestock productivity.

Table 16.3 Fertilizer dose rate (Kgs/acre)

Agro ecological zone	1997	2000	2004	2007
Marginal rain shadow	26.1	31.7	33.4	28.6
Central highlands	105.9	121.4	103.2	96.1
Western highlands	30.4	44.5	51.1	46.7
High potential maize zone	63.4	62.8	66.9	70.9
Western transitional	37.4	69.8	51.6	54.4
Western lowlands	59.3	42.5	9.8	18.7
Eastern lowlands	27.5	13.8	11.0	16.5
Coastal lowlands	18.1	2.3	4.5	5.6
Overall sample	64.8	72.1	64.8	63.2

Source Tegemeo survey data

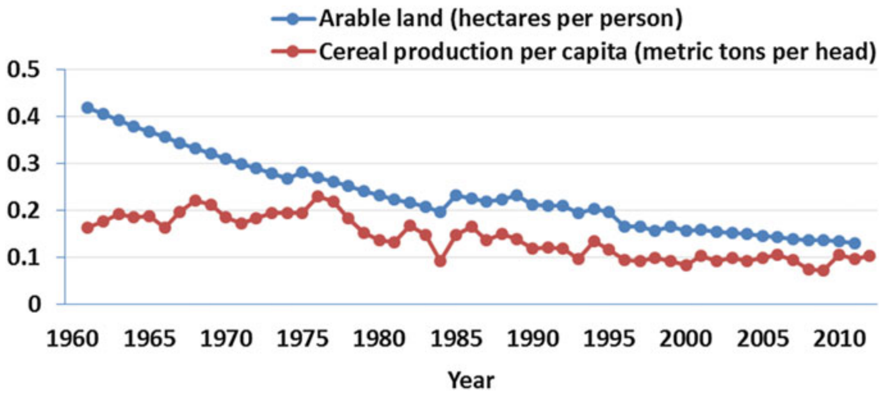

Fig. 16.2 Arable land and cereal production per capita in Kenya. *Source* The Authors

Over the period 1981–2003, the productivity declined across 40 % of croplands in the country—a critical situation in the context of a doubling of the human population over the same period in the country (Bai and Dent 2008; Fig. 16.2).

Other than modifications for agricultural purposes, unplanned growths of built-up areas are observed to be on the increase and are observed to contribute to the degradation processes (Maitima et al. 2009; Mundia and Aniya 2006; Were et al. 2013; Mireri 2005). The rising conversion of agricultural lands into industrial and residential lands especially with the increasing urbanization has also led to an increased pressure on initially productive lands. A case in point is the ongoing development of a techno-city on over 2000 acres of prime agricultural land in Machakos County, Kenya. The story is similar in other counties like Narok, Kiambu and Nakuru that are rapidly urbanizing. The construction of infrastructure such as roads on steep slopes without proper barriers, buildings without proper water drainage systems are also contributing factors to soil degradation and to making water in rivers less fit for human consumption. These developments certainly contribute to direct and indirect land degradation leading to a reduction in ecosystem balance and production of goods and services.

Investment in soil and water conservation is also incentivized by secure land tenure and land rights. There are various tenure regimes in Kenya with varying degrees of tenure security. Insecure land tenure can lead to the adoption of unsustainable land management practices.

As for the economic impacts of land degradation, IMF (2010) estimates that land degradation has huge economic costs in Kenya—about USD 390 million or (about 3 % of GDP) annually. These costs are associated to the decline in the quality of land as a result of the impact of unsustainable farming practices, the impacts of climate change, soil erosion, pollution and toxicity from agro-chemicals and alien and invasive species (such as *Ipomea kituiensils, Prosopis juliflora*, and water hyacinth).

Dregne (1990) reported that irreversible productivity losses due to soil erosion occurred in about 20 % over the last century in large parts of Ethiopia and Kenya.

Further, high percentage (27 %) of high value irrigated land was lost due to salinization over the last century in Kenya (Tiffen et al. 1994).

Land degradation in the country has been linked to increased sedimentation of water bodies from soil erosion, as it is the case in Lake Baringo, reducing their surface areas (Kiage et al. 2007). A study by Nkonya et al. (2008a, b) in Sasumua Dam Water Treatment estimated the cost of potable water production at KES 14.77 million, of which KES 9.91 million was the cost attributable to soil erosion. About 20 % of portable water supply to Nairobi city originates from the Sasumua Water Treatment Plant. The method used in the study involved comparing of estimated cost of water treatment and purification during both the wet and the dry seasons. The dry season was used as the proxy for the water treatment costs with effective control measures of soil erosion/land degradation whereas the wet/rainy season water treatment cost reflected the without effective control measures of soil erosion/land degradation scenario. The difference in costs between the two scenarios arises from the use of extra alum (aluminum sulphate), a coagulant to remove silt and other solid waste and chlorine to disinfect the water. The cost of extra use of alum and chlorine and the subsequent cost of de-silting the dam during the rainy season was estimated at KES 9.91 million.

On the other hand, deforestation is observed to decreases infiltration rates of the land, and has also led to reduced water quality and ability of catchment areas to support flow of rivers especially in the dry season (Were et al. 2013; Kiage et al. 2007).

Land use/land cover changes in rangelands has led to friction between people, livestock and wildlife over the scarce rangeland resources, with the intensity of the friction increasing over the years (Maitima et al. 2009; Campbell et al. 2003). Among the resulting effects has been the strong decline of wildlife in the rangelands (Maitima et al. 2009) which impact negatively the tourism sector of the country. Land use/land cover changes is also associated with decline in bird species, loss in plant biodiversity, and decline in soil productivity (Maitima et al. 2009).

Policy, Legal and Institutional Framework Addressing Land Degradation in Kenya

Kenya is currently having very comprehensive Sustainable Land Management (SLM) policy documents which are intended to provide guidelines on land use management and administration. The period before 2009 was characterized by land use policy scattered in bits and pieces in many national and sector policy documents (Gok 2009). The period was marred by poor coordination, lack of transparency, conflicting policies, institutions and legal framework leading to a very complicated land use management and administration system (GoK 2009). The National Land Policy (NLP) (Sessional Paper No. 3 of 2009) ensures that all land policy is unified after a thorough consultative process used in developing the policy. The vision of the policy as spelled out in the policy document is “To guide the country towards efficient, sustainable and equitable use of land for prosperity and posterity”. The vision sums up the key principles of Land Use Planning, Sustainable Production and Environmental Management used to guide the policy formulation. The most important aspects in the policy relevant to land degradation are spelled out in Chap. 3 section Improving Resource Allocation, or “L4 Actions”. The rationale is to restore the environmental integrity of land and facilitate sustainable management of land based resources. The policy proposes the following measures: Development of an incentive structure to catalyze development and adoption of technologies and methods for soil conservation; Mainstreaming use of appropriate land conservation methods; Developing and implementing measures to control land degradation associated with inappropriate land use practice and misuse of inputs; and establishing institutional mechanisms for land quality conservation for environmental preservation purposes. The main sector policy strengthening sustainable land use and conservation of natural resources is the draft National Environment Policy 2013 as provided in Chap. 4 on Management of Ecosystems and Sustainable Use of Natural Resources (GoK 2013b). Other relevant sector policies supporting the Sustainable land use policy framework in Kenya include National Water Policy 1999, National Water Management Strategy (GoK 2010a), National Climate Change Response Strategy (GoK 2010b), the Agriculture Sector Development Strategy (ASDS) (GoK 2010c), National Land Reclamation Policy (GoK 2013c) and National Environment Change Action Plan 2013–2017 (GoK 2013d).

To improve the institutional framework to implement the NLP, parliament enacted the National Land Commission Act in 2012 (GoK 2012a), which formed the National Land Commission (NLC) in 2013. The act mandates the NLC as the lead agency in land matters, functioning with the Ministry of Lands, Housing and Urban Development (MLHUD) and other regional and county institutions. Subsequently, the Commission developed a five-year National Strategic Plan to guide implementation of the NLP (GoK 2013e). The MLHUD on the other hand is responsible for policy formulation, coordination, and mobilization of resources. To support administration and management of land, the following institutions including; the local authorities, land property tribunals, district land tribunals and Land Courts play a major role. The National Environment Management Authority (NEMA), is established under the Environmental Management and Co-ordination Act No. 8 of 1999 (EMCA) as the principal instrument of Government for the implementation of all policies relating to environment. NEMA is one of the most important institutions in land management ensuring environmental capacity development and enforcement of environmental regulations. Currently many actors, both in the public and private sector play a role in land reclamation, albeit in an un-coordinated manner. The lack of a regulatory framework to drive the process and ensure consistency and quality standards indicates a responsive institutional mechanism is necessary. This is exemplified by constant turf wars between MLHUD and NLC which have ended in High Court for interpretation.

The land management and administration legal framework supportive of SLM is composed of the Constitution of Kenya, 2010. The supreme law has provisions on land; which is operationalized by the new legislations on land including the Land Act, Land Registration Act and the National Land Commission Act as well as the continuing legal reforms in the land sector. The legal framework address critical issues related to land degradation such as land administration, access to land, land use planning and environmental degradation. Environmental Management and Coordination Act (EMCA), 1999 established NEMA which has the mandate to develop the Integrated National Land Use Guidelines (INLUG).

Other sector laws supportive of SLM include; the Environment and Land Court Act, the Land Act, the Crops Act, and the Fisheries Act, the Agriculture, Fisheries And Food Authority (AFFA) Act No. 13 of 2013 the Kenya Agricultural and Livestock Research (KALR) Act No. 17 of 2013, Crop Act No. 16 of 2013 and Water Act 2002. The KALR act mandates the Kenya Agricultural and Livestock Research Organization (KALRO) to develop and promote SLM technologies and methodologies for the agricultural sector. The necessary policies and laws are largely in place. However serious cases of underfunding, political will and vested interests inhibit efficient and effective implementation of Sustainable land use policies as spelled out in the various sector and policy documents.

Methods and Data

Conceptual Framework

The conceptual framework applied in this study follows the ELD framework presented in Nkonya et al. (2014) and elaborated in Chap. 2 of this volume. The framework groups the causes of land degradation in two categories; proximate biophysical causes and underlying causes. These two categories act together hence resulting in different levels of land degradation—which in turn determines the effects (on-site or off-site), on the ecosystem services and the benefits humans derive from those services. Actors could take action to control the causes, levels and effects of land degradation. For a further comprehensive discussion on the conceptual framework, refer to Chap. 2 of this volume.

Empirical Strategy

The empirical approaches used to estimate the determinants of SLM adoption and the number of SLM technologies adopted are discussed in detail in this section. These methods are based on the methodological Chap. 2, and are consistently applied throughout several case studies in this volume, including in Chaps. 14 and 20. The variables used in these chapters are measured in exactly the same way but for different countries.

Drivers of Number of Sustainable Land Management Practices Adopted

Land degradation usually occurs due to lack of use of sustainable land management practices. Those factors preventing households from adopting SLM practices are also likely to lead land degradation. Therefore, analyzing the drivers of SLM is similar in its implications as analyzing the drivers of land degradation. The number of SLM technologies adopted by agricultural households is a count variable (ranging from 0 to 12 in our case). Thus the assessment of the determinants of the number of SLM technologies adopted needs to be conducted by Poisson regression model (Xiang and Lee 2005; Greene 2003). Poisson regression model (PRM) is normally the first step for most count data analyses. Thus in this study, we apply PRM to the following reduced form econometric model using nationally representative agricultural household survey data from Kenya.

$$A = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_4 + \beta_5 z_i + \varepsilon_i \qquad (16.1)$$

where A = number of SLM technologies; x_1 = a vector of biophysical factors (e.g. climate conditions, agro-ecological zones, etc.); x_2 = a vector of policy-related and institutional factors (e.g. market access, land tenure, etc.); x_3 = a vector of variables representing access to rural services (e.g. access to extension); x_4 = vector of variables representing rural household level capital endowment, level of education, household size, dependency ratio, etc.; and z_i = vector of country fixed effects.

Costs of Action and Inaction Against Land Degradation Due to LUCC

The approach for determining the for degradation due to LUCC considers the cost of reestablishing the high value biome lost and the opportunity cost of foregoing the benefits drawn from the lower value biome that is being replaced (Chap. 6). The cost of inaction on the other hand is the sum of annual losses due to land degradation. In this study, two time horizons are presumed; 6 year period—a planning horizon typical for small holder farmers in cropland biomes, and 30 year period—a typical planning horizon for afforestation program in forests, woodlands, and shrub-lands biomes. The rational land user will take action against land degradation if costs of taking action are less than the costs of inaction (Chap. 6).

Refer to Chaps. 2 and 6 of this volume for an in-depth and comprehensive discussion on the methods, formulae and datasets used to estimate the costs of land degradation and also the empirical strategy to estimate the costs of taking action (versus inaction) against land degradation.

Cost of Land Degradation Due to Use of Land Degrading Management Practices

We use Decision Support System for Agro-technology Transfer (DSSAT) crop simulation model to determine the impact of SLM practices on crop yield and soil carbon. DSSAT combines crop, soil, and weather databases for access by a suite of crop models enclosed under one system. Two crop simulation scenarios are considered, namely; (i) Integrated soil fertility management (ISFM)—combined use of organic inputs, recommended amount of chemical fertilizer and improved seeds, and (ii) Business as usual (BAU)—reflecting the current management practices practiced by majority of farmers. Refer to Chap. 6 of this volume for a comprehensive description of DSSAT simulation model.

Cost of Land Degradation on Static Rangelands (Grasslands)

Static rangeland (grazing land) degradation is analyzed for the entire rangelands at pixel level. The total costs of static rangeland degradation are divided into three: costs due to loss of milk production, costs due to loss of meat production, and costs due to loss of live weight of livestock not slaughtered or sold. An elaborate presentation and explanation of the analytical approach used to estimate static rangeland degradation provided for in Chap. 8 of this volume. Some aspects not captured in this methodology due to data limitations include the costs associated to land degradation on livestock health, parturition, and mortality rates. Also some other costs such as loss of carbon sequestration and the loss of other ecosystem services provided by grasslands are not included.

Data

The Kenya case study is based on spatial GIS data and existing household surveys (Agricultural Sector Development Support Programme (ASDSP)). The ASDSP national survey covered all the 47 counties, with the overall sample consisting of 12,651 agricultural households. The sample size for each county was determined using the proportionate to population size (PPS) sampling technique, based on total number of farming households in each county. Additional data sources include: The Economics of Ecosystems and Biodiversity (TEEB) database on the value of ecosystem services, MODIS LUCC datasets (cf. Chap. 6 for more details), Tegemeo Panel data: 2000–2004, 2011; and secondary statistics at district level.

Results and Discussion

Drivers of Sustainable Land Management: Adoption of Improved SLM-Friendly Technologies

The analysis of the 2013 country wide ASDSP baseline survey data shows that only about 40 % of surveyed households have applied some practices that could be considered as SLM practices. The most common SLM practices include: cutoff drains and drainage trenches, terraces planted with fodder species such as Napier grass, contour ploughing, use of stone bounds and trash lines, and tree planting, use of manure, inorganic fertilizer and compost and agricultural lime. The remaining 60 % households having no adoption of any improved technologies (Fig. 16.3).

The major source of knowledge and extension on these technologies came from agro-dealers, followed by government extension offices, and then private companies. The role of local and international NGOs was relatively low (Fig. 16.4).

The most important constraint against using these technologies were cited to be their high costs and lack of information and expertise in their proper application (Fig. 16.5).

The distribution of the number of SLM technologies used is quite dispersed, ranging from 0 to 12 (Fig. 16.4). Moreover, if we analyze by county, the conditional variance of the distribution is higher in all cases than the conditional mean. Furthermore, our dependent variable on the number of SLM technologies used is a counting variable. Such a nature of the dependent variable requires the application of negative binomial regression, which is a generalization of Poisson regression for a count dependent variable with dispersed distribution.

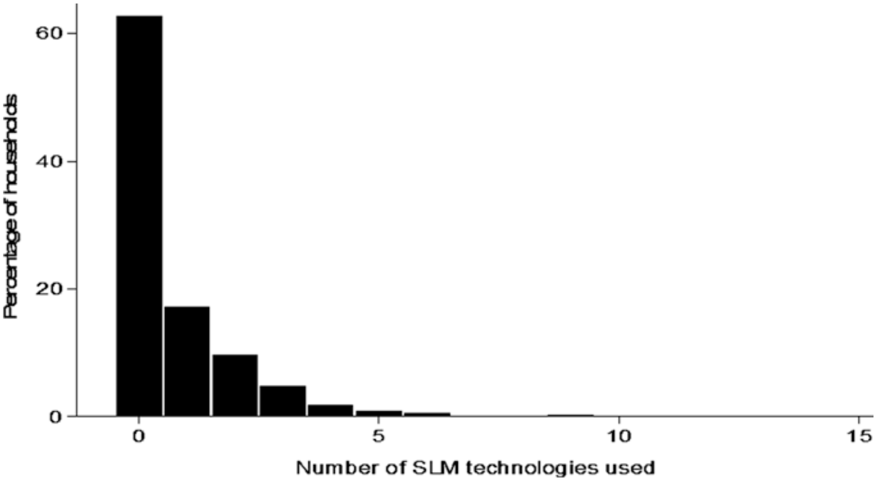

Fig. 16.3 Adoption of improved SLM-friendly technologies. *Source* Calculated by authors using initial data from ASDSP household survey data

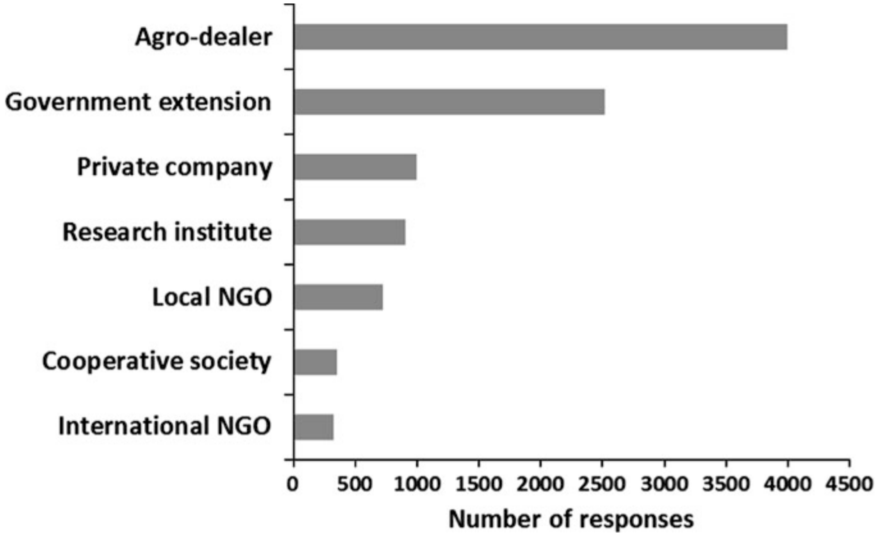

Fig. 16.4 The role of different organizations in catalyzing adoption of SLM practices. *Source* Authors' compilation

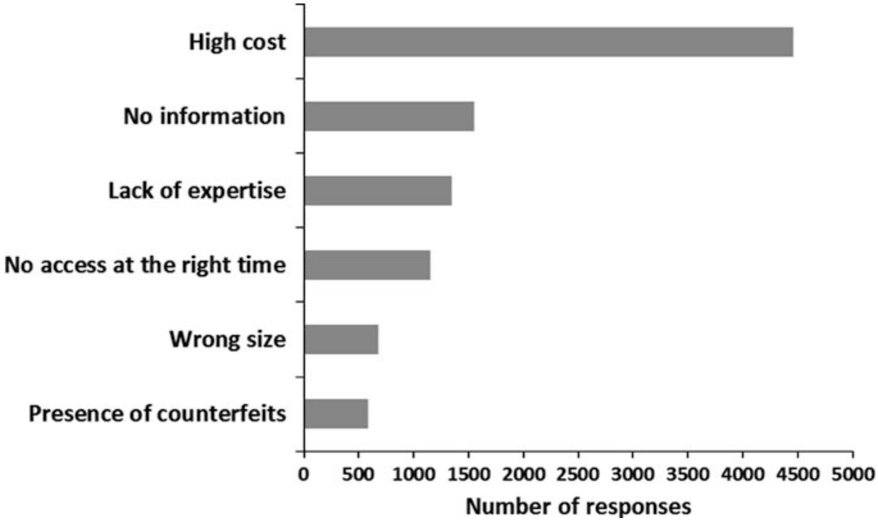

Fig. 16.5 Constraints in using the SLM technologies. *Source* Authors' compilation

The results of the regression on the determinants of the number of SLM technologies used by households are given in Table 16.4. The overall test of model fit shows that the model is statistically significant at 1 % (LR chi^2 (84) = 10,901.84, Prob > $\text{chi}^2 = 0.0000$, and Pseudo $R^2 = 0.359$). The likelihood ratio test comparing this negative binomial model to the Poisson model is statistically significant at 1 %, suggesting that the negative binomial model fits the data better than the Poisson model.

Robust checks on the model show no evidence of multicollinearity, heteroscedasticity and omitted variables. Ramsey RESET test (ovitest) was not significant; showing no evidence of omitted variables while the Breusch-Pagan/Cook-Weisberg test (hettest) showed no evidence of heteroscedasticity. We however, report robust standard errors. Further, the VIF test was less than 10 showing no evidence of multicollinearity.

The regression results point at several variables which have statistically significant relationships with the number of SLM technologies adopted by households. Particularly, access to information through various means (including extension officers, research institution, cooperatives and local NGOs) increased the log count of the number of SLM technologies adopted. For example, farmers with access to government extension officers increased the log count of the number of SLM technologies adopted by 43.7 % while those with access to agricultural cooperatives increased the log count of the number of SLM technologies adopted by 21.5 %, ceteris paribus. Similar to previous studies (such as Nhemachena and Hassan 2007; Teklewold et al. 2013) this finding points to the importance of agricultural extension services when making farm decisions and in influencing farmers' technology adoption behavior.

Access to market information, agricultural dealers and access to credit facilities facilitates the adoption of more SLM technologies. Farmers with access to market information increased the log count of the number of SLM technologies adopted by 12.3 %, holding other factors constant. Agricultural dealers play an important role in delivering information on various and emerging SLM technologies besides supplying some of the SLM (such as seed and fertilizers). Where government extension services are scarce, the local NGOs serve as focal points for information and technology dissemination among the rural population. Access to a local NGO increased the log count of the number of SLM technologies adopted by 33.2 % ceteris paribus. This corroborates earlier studies on the important role played by the NGOs in disseminating agricultural information in rural agricultural communities (Amr and Richiedei 2000; Wattenbach et al. 2005; Molua 2014; Schipper et al. 2014).

Further, access to markets (input and output) significantly influences the number of SLM technologies adopted. Increase in distance to these markets reduces the the log count of the number of SLM technologies adopted by about 5.5 % holding other factors constant. This finding may suggests that proximity to markets represents reductions in transaction costs related to access to both inputs and outputs, increased availability of information, financial and credit organizations, and technology accessibility. All these factors are important in enhancing technology adoption decisions. (Pender et al. 2006; von Braun et al. 2012).

Household characteristics, such as gender, education, and age of the household head, household size, and dependency ratio are not significant in the sample. Similarly capacity and socio-economic variables such as total cultivated land,

Table 16.4 The drivers of number of SLM technologies adopted in Kenya

Variables	Coefficient	Standard error	z-value	Confidence interval (lower, upper)
Extension (dummy)	0.052*	0.029	1.799	−0.005, 0.108
Distance to extension	−0.001	0.001	−1.036	−0.003, 0.001
Extension by agrodealers	0.771***	0.028	27.695	0.717, 0.826
Extension by research orgs	0.250***	0.037	6.715	0.177, 0.323
Extension by Govt org	0.437***	0.033	13.165	0.372, 0.502
Extension by cooperatives	0.215***	0.052	4.174	0.114, 0.317
Extension by local NGO	0.332***	0.041	8.042	0.251, 0.413
No. of SLM extension sources	0.418***	0.010	41.245	0.398, 0.438
Education some schooling	0.009	0.028	0.304	−0.047, 0.064
Education completed school	0.033	0.063	0.530	−0.090, 0.157
Education university	0.025	0.047	0.543	−0.066, 0.117
Land tenure—owns, but no title	0.010	0.026	0.399	−0.041, 0.062
Land tenure—lease-rented in	−0.106	0.101	−1.052	−0.304, 0.091
Land tenure—communal rights	0.008	0.062	0.123	−0.114, 0.129
Land tenure-squats	−0.081	0.097	−0.830	−0.272, 0.110
Distance to road	−0.001	0.001	−0.849	−0.002, 0.001
Access to weather information	0.033	0.032	1.045	−0.029, 0.096
Savings	0.000	0.000	0.178	−0.000, 0.000
Amount borrowed	−0.000*	0.000	−1.684	−0.000, 0.000
Savings#Amout borrowed	0.000***	0.000	2.938	0.000, 0.000
Input#output market distances	−0.055**	0.027	−2.064	−0.107, −0.003
Access to market information	0.123***	0.026	4.769	0.072, 0.173
Gender of household head	−0.024	0.033	−0.722	−0.087, 0.040
Age of household head	0.002	0.005	0.478	−0.007, 0.012
Age of household head, sq.	0.000	0.000	−0.376	−0.000, 0.000
Family size	−0.006	0.005	−1.242	−0.016, 0.004
Dependency ratio	0.001	0.014	0.063	−0.027, 0.029
Total cropped area	0.000	0.000	−0.264	−0.000, 0.000
Perception of land degradation	−0.027	0.024	−1.132	−0.074, 0.020
Total assets value	−0.000**	0.000	−2.555	−0.000, −0.000
Membership in association	0.004	0.031	0.133	−0.056, 0.064
Agricultural income	0.000	0.000	0.134	−0.000, 0.000
Off-farm income	0.000	0.000	−0.342	−0.000, 0.000
Livestock value	0.000	0.000	0.410	−0.000, 0.000
County dummies (47)	Yes	Yes	Yes	Yes
Constant	−1.438***	0.167	−8.628	−1.764, −1.111
lnalpha_constant	−2.522***	0.109	−23.187	−2.736, −2.309
Model characteristics	No. of obs. = 12,651		Chi^2 = 10,901.84	
	p-value = 0.000		Pseudo R^2 = 0.359	

Source Authors' compilation
***, **, and * denotes significance at 1%, 5% and 10% significance level respectively

income, land tenure, and value of livestock are not significant in influencing the adoption of SLM technologies. However, contrary to expectations, the value of total household assets showed a negative relationship with the number of the number of SLM technologies adopted. This is contrary to the expectation that wealthier households are deemed able to adopt several SLM technologies because of their ability to better access such technologies as improved seeds, inorganic fertilizers, irrigation equipment and soil and water conservation measures (McCarthy 2011).

Costs of Action and Inaction Against Land Degradation Due to LUCC

The results show that the costs of land degradation, using land use change as a measure and the Total Economic Values framework accounting for the losses of ecosystem services, were about 10.6 billion USD for the period 2001–2009 (expressed in constant 2007 USD). This translated to about 1.3 billion USD annually, or about a 4.9 % equivalent of the Kenyan GDP (Table 16.5). The biggest losses in terms of magnitudes have occurred in the Rift Valley (452 million USD), the Coastal (290 million USD) and Eastern (214 million USD) provinces.

In terms of per capita costs of land degradation, the biggest negative impacts have occurred in the Coastal ($680) and North-Eastern ($640) provinces, followed by the Rift Valley ($352). These losses are mostly related to deforestation. The areas with net improvements are the Rift Valley, North-Eastern, Coastal, Eastern and Western province. The major driver of this improvement was the massive shift from shrub lands and barren lands to grasslands in these provinces.

Table 16.5 The costs of land degradation in Kenya through land use change (LUCC)

Regions	Cost of land degradation between 2001 and 2009 (million USD)	Annual cost of land degradation expressed in 2007 constant USD (million USD)	Annual cost of land degradation per capita, in USD
Central	647.4	80.9	144
Coast	2321.5	290.2	680
Eastern	1713.7	214.2	296
Nairobi	18.5	2.3	8
North-Eastern	1502.8	187.8	640
Nyanza	577.1	72.1	104
Rift Valley	3616.6	452.1	352
Western	247.7	31.0	56
Total	10,645.2	1330.6	272

Source Calculated by the authors

Table 16.6 Total economic value (TEV) of land ecosystems and GDP in Kenya, $ billion

Region	TEV/GDP ratio	Annual TEV 2001	Annual TEV 2009	TEV per capita 2009
Central	1.1	4	4	857
Coast	8.1	20	21	6200
Eastern	8.6	35	37	6582
Nairobi	0.1	0	0	48
North-Eastern	14.9	24	26	11,426
Nyanza	1.3	5	5	983
Rift Valley	5.5	40	42	4208
Western	0.5	1	2	367
Total	4.72	129	137	3343

Source Calculated by the authors

However, there have also been improvements in land use of about 19 billion USD equivalent, making the net change in the Total Economic Value of land ecosystems in the country positive by about 8 billion USD in 2009 as compared to 2001 (Table 16.6).

The results on costs of taking action verses inaction against land degradation are presented in Table 16.7. Results show that the costs of action against land degradation are lower than the costs of inaction in Kenya by about 4 times over the 30 year horizon. The costs of action were found to equal about 18 billion USD over a 30-year horizon, whereas if nothing is done, the resulting losses may equal to almost 75 billion USD during the same period. The implications is that each dollar spent on addressing land degradation is likely to have about 4 dollars of returns. This is a very strong economic justification favoring action as opposed to taking no action.

Table 16.7 Costs of action verses inaction in Kenya

Provinces	GDP 2007	Annual costs of land degradation	Annual costs in terms of provisional ecosystem services	Cost of action (6 years)	Cost of action (30 years)	Cost of inaction (6 years)	Cost of inaction (30 years)	Ratio of cost of action: inaction 30 years
	Billion	Million		Billion				%
Central	3.37	80.9	35.691	1.08	1.08	3.24	4.38	25
Coast	2.55	290.2	128.895	3.34	3.35	11.28	15.27	22
Eastern	4.35	214.2	125.718	2.99	3.00	9.35	12.66	24
Nairobi	2.41	2.3	1.050	0.04	0.04	0.10	0.13	28
N/Eastern	1.77	187.8	110.820	2.81	2.82	8.37	11.33	25
Nyanza	4.18	72.1	30.206	0.81	0.82	2.75	3.73	22
R/Valley	7.69	452.1	219.726	6.53	6.55	18.96	25.66	26
Western	3.33	31.0	14.043	0.41	0.42	1.27	1.72	24
Total	29.65	1330.6	666.15	18.03	18.07	55.33	74.89	24

Source Calculated by the authors

Cost of Land Degradation Due to Use of Land Degrading Practices

We present the simulated results of rain-fed maize yield under business-as-usual (BAU) and integrated soil fertility management (ISFM) scenarios for a period of forty years in Kenya in Table 16.8. The average maize yields are higher under ISFM—1.84 tons/ha (baseline) and 1.79 tons/ha (end-line) as compared with the BAU scenario—1.63 tons/ha (baseline) and 1.35 tons/ha (end-line) periods. However, there is a yield decline between the end-line and baseline periods for both ISFM and BAU scenarios. Under ISFM, yield end-line yield declined by about 2.5 % while under BAU scenario, yield declined by about 17.1 %. Overall, the yield decline due to use of land management practices in maize plots is about 32 %. Similarly, simulation analysis show that the use of land degrading management practices on rain-fed wheat leads to a decline of about 32 % as compared to yield in the previous 40 years. Under ISFM, yield declined is negligible (about 0.3 %) while under BAU yield declined by about 15.6 %. Similarly, the use of land degrading management practices on irrigated rice leads to a decline of about 31.6 % as compared to yield in the previous 40 years. Under ISFM, yield declined by about 3 % while under BAU yield declined by about 9.4 %.

The cost of land degradation for the three crops is about $270 million. When these losses are expressed as percent of GDP, Kenya loses about 1 % of the GDP annually as a result of cropland (maize, wheat and rice) degradation. Statistics show that the three crops (maize, wheat and rice) account for about 40 % of the cropland globally. Assuming that the levels of degradation is comparable to that occurring on the two major crops, then the total cost of land degradation on cropland is about 2.4 % of GDP in Kenya. On per hectare basis, use of degrading practices on cropland leads to losses amounting to about $117 annually in Kenya (Table 16.9).

Table 16.8 Change in maize and wheat yields under BAU and ISFM in Kenya

Crop	BAU		ISFM		Yield change (%)		Change due to land degradation
	Baseline	End-line	Baseline	End-line	BAU	ISFM	
	Yield (tons/ha)		Yield (tons/ha)		Percent		
Maize	1.63	1.35	1.84	1.79	−17.1	−2.5	32.4
Wheat	2.77	2.34	3.09	3.08	−15.6	−0.3	32.0
Rice	3.55	3.21	4.36	4.23	−9.4	−3.0	31.6

Source Kirui O.K. (Unpublished Ph.D. Thesis)

Table 16.9 Cost of soil fertility mining on maize, rice and wheat cropland in Kenya

Cost of land degradation (soil fertility mining)	Cost as % of GDP	Cost of cropland degradation as % GDP	Annual cost of land degradation (per ha)
2007 US$ million	(%)	(%)	(US$/ha)
269.77	0.99	2.36	116.70

Source Authors' compilation

Land Degradation on Static Grasslands

Livestock production is mainly concentrated in the arid and semi-arid lands (ASALs) parts of the country which cover above 80 % of total land area and supports approximately 70 % of the country's livestock (GoK 2012a). Livestock production plays a crucial role not only in sustaining livelihoods but plays a significant role in national development by contributing about $4.54 billion US dollars to agricultural GDP (GoK 2012b; Behnke and Muthami 2011). Livestock production is however hampered by reduced grazing biomass productivity brought about by degraded lands, translating to high costs to the nation as a whole.

Table 16.10 shows the simulated results of costs of loss of milk, meat, and costs associated with weight loss of animals not slaughtered or sold due to land degradation in grazing biomass. A detailed methodological approach is presented in Chap. 6 of this volume. Results show that land degradation in grazing biomass had a huge impact on milk production in Kenya. The total costs of milk and meat production losses were about $49.5 million and $8.7 million respectively. The bigger proportion of milk and meat losses is experienced in warm arid ($24 million), warm semi-arid ($16 million) and cool sub-humid ($10 million) agro-ecologies.

Table 16.10 Cost of loss of milk and meat production due to land degradation of grazing biomass

Agro-ecological zones	Milk	Meat	Total loss (milk and meat)	Total gross loss—includes weight loss of animals not slaughtered/sold
	2007 US$ million			
Tropic-cool semi-arid	4.056	0.874	4.930	6.383
Tropic-cool arid	1.152	0.095	1.247	1.813
Tropic-cool humid	0.820	0.069	0.889	1.291
Tropic-cool sub-humid	9.027	1.109	10.137	14.207
Tropic-warm semi-arid	13.393	2.666	16.059	21.078
Tropic-warm arid	20.551	3.873	24.424	32.343
Tropic-warm sub-humid	0.508	0.036	0.544	0.799
Total	49.507	8.723	58.23	77.914

Source Authors' compilation

The total gross loss—cost of milk, meat and cost of weight loss of animals not slaughtered or sold—in Kenya was about \$78 million. The bigger proportion of the total gross losses is consequently experienced in warm arid (\$32 million), warm semi-arid (\$21 million) and cool sub-humid (\$14 million) agro-ecologies.

Conclusion

This study investigated the causes, extent and impacts of land degradation in Kenya It also evaluated the costs of action versus inaction in rehabilitating degraded lands, and proposed policy measures that can be instituted to address land degradation. Our results indicate that land degradation is a serious problem in Kenya especially in the ASALs. About 30 % of the Kenya's landmass is subject to severe land degradation. This trend of land use changes is expected to become more serious as population pressure increases.

The analysis of nationally representative data showed that access to information through various means (including extension officers, research institution, cooperatives and local NGOs) facilitated the adoption of SLM technologies. Agricultural dealers play an important role in delivering information on various and emerging SLM technologies besides supplying some of the SLM sources (such as seed and fertilizers). Where government extension services are scarce, the local NGOs serve as focal points for information and technology dissemination among the rural population. Policies and strategies relating to agricultural extension, information and market access could be prioritized to boost SLM adoption and thus address land degradation, especially in croplands. Equipping the agro-dealers with relevant and credible SLM information will enhance their capacity to disseminate timely and important information to benefit the farmers.

Using the Total Economic Values framework, it was estimated that the economic costs emanating from land degradation due to land use and land cover change at the national scale amount to about out 1.3 billion USD annually, or about a 4.9 % equivalent of the Kenyan GDP in 2007. The annual costs of land degradation on static cropland amounted to 270 million USD while the annual costs of rangeland (static) degradation amounted to 80 million USD. This estimate is significantly higher than the previous estimate of land degradation by IMF (2010) of USD 390 million. Further analysis indicated that the cost of taking action against land degradation is lower than the cost of inaction both in a shorter term of six years and a longer term of 30 years. The returns to investment in action against land degradation are about four times the costs of inaction in the first six years. This provides a justification for taking action against land degradation.

Recommendations

To reverse the trends in land degradation, actions on land rehabilitation and reclamation are recommended. First, increased support for research and extension to increase crop yields is crucial to meeting the needs of a growing human population for food, biomass energy, fiber, and timber. Secondly, there is a need to increase support to biodiversity preservation by alleviating pressure to convert remaining natural habitat to croplands. This can be achieved partly by establishing linkages to carbon markets to make the cost benefit ratios favorable for adoption SLM practices. And third, there is a need for more public investments to support SLM to slow land degradation and reclamation of already degraded lands. Land is often a limiting factor of economic output, and thus its degradation may further undermine the prospects of economic growth in the poor areas of Kenya.

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