Cost of land degradation and improvement in Eastern Africa

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Abstract

Land degradation – defined by the Economics of Land Degradation (ELD) initiative as a “reduction in the economic value of ecosystem services and goods derived from land” – is a serious impediment to improving rural livelihoods and food security of millions of people in the Eastern Africa region. The objectives of this paper are three fold; to identify the state, extent and patterns of land degradation, to estimate the costs of land degradation, and to compares the costs of action against inaction against land degradation using the Total Economic Value approach in four countries – Ethiopia, Kenya, Malawi and Tanzania. Results show that land degradation hotspots cover about 51%, 41%, 23% and 22% of the terrestrial areas in Tanzania, Malawi, Ethiopia and Kenya respectively. Following the Total Economic Value (TEV) framework, the cost of land degradation between 2001-2009 periods is about 2 billion USD in Malawi, 11 billion USD in Kenya, 18 billion USD in Tanzania and 35 billion USD in Ethiopia. These represents about 5%, 7%, 14% and 23%, of GDP in Kenya, Malawi, Tanzania and Ethiopia respectively. Taking action against land degradation is more favorable than inaction in both short-term (6 year) and a long-term (30 year) periods. During the 30-year period, for every dollar spent on taking action against land degradation users will expect a return of about $ 4.2 in Ethiopia, $ 4.1 in Kenya, $ 3.8 in Tanzania, and $ 3.7 in Malawi.

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1. Introduction

Land degradation in the Eastern Africa region has substantial environmental, social and economic costs. Land degradation not only reduces the productive capacity of agricultural land, rangelands and forest resources but also significantly impacts on the biodiversity (Davidson & Stroud, 2006). The costs and consequences of land degradation can be direct or indirect. Direct costs may include costs such as; costs of nutrients lost by soil erosion, lost production due to nutrient and soil loss, and loss of livestock carrying capacity. On the other hand, indirect costs may include costs such as; loss of environmental services, silting of dams and river beds, reduced groundwater capacity, social and community losses due to malnutrition and poverty. Estimating these costs and the consequences of land degradation continues to be a daunting task (Bojo & Cassells, 1995; Morris, 2007; Croitoru and Sarraf, 2010 Hoffmann *et al*., 2014).

Sustainable land management is increasingly becoming an important topic in the post-2015 sustainable development agenda because land degradation poses a great challenge for sustainable development. The economic consequences of land degradation are severe among the poor and marginalized populations who usually occupying degraded land and heavily depend on natural resources. Thus, addressing land degradation is important to eradicating poverty and achieving food security for the poor agricultural-based communities. Despite the increasing need for addressing land degradation, investments in sustainable land management are low; especially in low income countries.

To date, few studies have comprehensively tackled the costs and consequences of land degradation either at the global, regional or national level using different parameters and approaches such as expert opinion, measurement of top soil losses as a result of erosion, rate of deforestation, soil fertility (nutrient balance) and vegetation index (as observed through GIS and remote sensing techniques). Land degradation has adverse effect on productive capacity of land, and thus, on food security of the farm households (Beinroth *et al.,* 1994; Nkonya *et al.,* 2011; von Braun *et al.,* 2012). Soil fertility degradation is indeed considered the most important food security constraint in SSA (Verchot, *et al.,* 2007).

Information on the exact effect of land degradation on agricultural productivity for the Eastern African region (at national, regional and plot/field level) is very scanty. Previous studies have no consensus on the exact amount of productivity losses in crop and livestock production due to land degradation in Eastern Africa. Few available country data on the economic costs land degradation show that the direct cost of loss of soil and nutrients in the case study countries are enormous. For example, an earlier study by Lal, (1995) showed up to 50% decline in productivity of some crop lands in SSA due to land degradation processes. Other studies showed yield reduction ranging from 2% to 40% – a mean of 8.2% (Eswaran, 2001). Lal (1995) estimated that past erosion in SSA had caused yield reduction of 2–40% (mean of 6.2 %), and that if present trend continued, the yield reduction would increase to 16.5% by 2020.

It is estimated that about 1 billion tons of topsoil is lost annually in Ethiopia due to soil erosion (Brown, 2006). The loss of soil by water erosion in Kenya is estimated at 72 tons per hectare per year (de Graff, 1993) and even higher in Tanzania; 105 tons/ha/year in 1960's and 224 tons/ha/year, 1980’s – 90’s). Further, salinization happened in another 30% of the irrigated land of irrigated land in Kenya and in 27 percent of irrigated land in Tanzania. An earlier study by Dregne (1990) reported permanent reduction (irreversible) soil productivity losses from water erosion in about 20% of Ethiopia and Kenya. This study is however based only on expert opinion on a few areas and extrapolated nationwide; thus they are not representative. Odelmann (1998) estimated that about 25% of cropland and 8-14% of both cropland and pasture were degraded by soil degradation. The study is also older and largely based on expert opinion and smaller areas.

In Ethiopia the annual costs of land degradation relates to soil erosion and nutrients loss from agricultural and grazing lands is estimated at about $106 million (about 3% of agricultural GDP) from a combination of soil and nutrient loss (Bojo & Cossells, 1995; Yesuf *et al*., 2008). It is further estimated that other annual losses included $23 million forest losses via deforestation and $10 million loss of livestock carrying capacity (Yesuf *et al*., 2008). All these translated to an annually total loss of about $139 million (about 4% of GDP). In Malawi, the losses may be even higher; 9.5–11% of GDP in (FAO, 2007). In Kenya, it is reported that irreversible land productivity losses due to soil erosion occurred in about 20% over the last century (Dregne 1990). Further, a high percentage 30% and 27% of high value irrigated land may have been lost due to salinization over the last century in Kenya and Tanzania respectively (Tiffen *et al*., 1994).

The objectives of this study are threefold: firstly, to identify the state, extent and patterns of land degradation; secondly, to estimate the costs of land degradation; and thirdly, to compare the costs of action verses costs of inaction against land degradation in four countries – Ethiopia, Kenya, Malawi and Tanzania. This paper contributes to the existing literature on cost of land degradation by using the Total Economic Value (TEV) approach following the comprehensive definition of land degradation proposed by Millennium Ecosystem Assessment (MEA, 2005). The rest of this paper is organized as follows; the next section describes the conceptual framework and discusses previous studies on the costs of land degradation. This is followed by a description of analytical methods and the data used in the assessments. This is followed by the discussion of the results while the last section concludes and proposes some policy implications.

2. Conceptual Framework

This study utilizes the Total Economic Value (TEV) approach – that captures the comprehensive definition of land degradation as proposed by ELD initiative (2013). TEV is broadly sub-divided into two categories; use and non-use values (**Figure 3.1**). The use value comprises of direct and indirect use. The direct use includes marketed outputs involving priced consumption (such as crop production, fisheries, tourism) as well as un-priced benefits (such as local culture and recreation value). The indirect use value consists of un-priced ecosystem functions such as water purification, carbon sequestration among others. The non–use value is divided into three categories namely; bequest, altruistic and existence values. All these three benefits are un-priced. In between these two major categories, there is the option value, which includes both marketable outputs and ecosystem services for future direct or indirect use.

Following Remoundou *et al*., 2009, Noel and Soussan, 2010, Nkonya *et al*., 2011 and ELD Initiative, 2013, the TEV framework is represented as follows: Land and its ecosystem services are naturally occurring and therefore tend to be undervalued; this is especially because ecosystem services are intangible and lack a ready market like in the case of other tangible market goods. In an ideal scenario, the ecosystem services should be regarded as capital assets or natural capital failure to which leads to higher rates of land degradation due to their omission (Daily *et al*. 2011, Barbier 2011a). Therefore, in order to foster comprehensive decision making, the economic values of ecosystem services have to be determined and included. Several methods of evaluating ecosystem services exist but attaching economic values to ecosystem services has remained a challenge due to prevalent unknowns and actual measurement limitations (Barbier *et al*. 2010, 2011a, 2011b, Nkonya *et al*. 2011).

Consequently, Daily *et al*. (2000) suggests that the assessment of natural capital should follow three steps: (i) examining of alternative options such as degrading soil ecosystem services verses their sustainable management, ii) identifying and measuring the costs and benefits of each alternate option, and iii) comparing the costs and benefits of each of the options while considering their long-term effects. However, compiling individual preferences and their attached values to ecosystem services for each alternative option is not an easy task (Daily *et al*. 2000; Barbier 2011b.) Additionally, economic values are associated to the number of (human) beneficiaries and their socioeconomic context. Therefore, these services are contingent to local or regional conditions which contribute to the variability of the values (TEEB 2010).

TEV approach is not without limitations[2.] Non-use and indirect-use values are complex and mostly non-tradable thus posing a challenge in their measurement and in assigning monetary values (Balmford *et al*., 2008). Barbier *et al* (2010) and Balmford *et al* (2008) further criticize TEV in that it has the potential of double-counting of benefits from ecosystems services – this arise from the complex nature of ecosystem services themselves.

Dasgupta (2011) reiterates that the social worth of natural resources can be decomposed into three parts: their use value, their option value, and their non-use value. These components appear in different proportions, depending on the resource. It is noteworthy that estimating the value of environmental (accounting prices) is not just to value the entire environment; rather, it is to evaluate the benefits and costs associated with changes made to the environment due to human activities. Earlier, Dasgupta (2000) contends that the links between rural poverty and the state of the local natural–resource base in poor countries can offer a possible pathway along which poverty and resource degradation is synergistic over time. This implies that the erosion of the

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[2] See a comprehensive review by Nijkamp *et al*., 2008 and Seppelt *et al*., 2011.

local natural resource base can make certain categories of people deprived even while the country's economy (GNP) increases (Dasgupta, 2000).

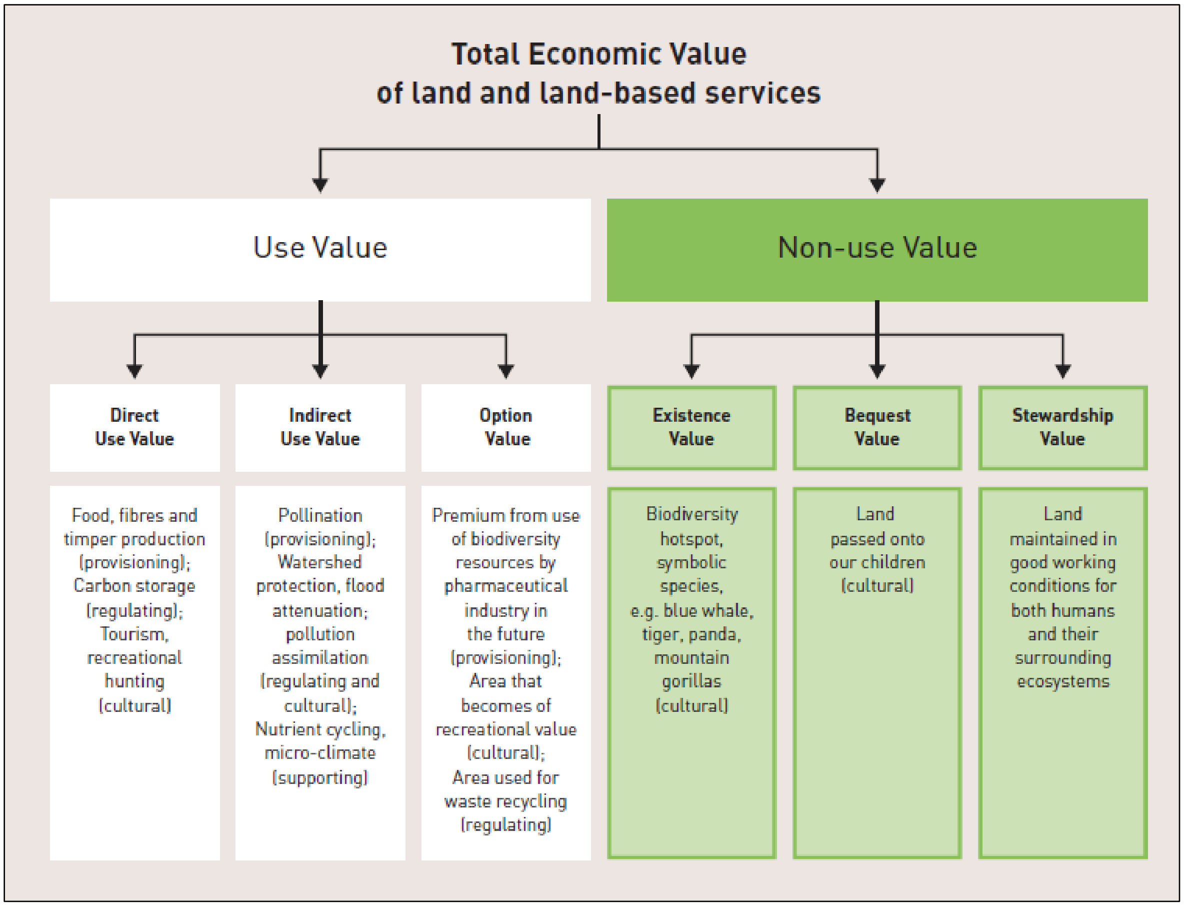

Figure 1: Total Economic Value
Source: ELD Initiative, 2013.

Some costs and consequences of land degradation documented in literature for the Eastern Africa region are presented in **Table 1**. For example, in Ethiopia the annual costs of land degradation relate to soil erosion and nutrients loss from agricultural and grazing lands is estimated at about \$106 million (about 3% of agricultural GDP) from a combination of soil and nutrient loss (Bojo & Cossells, 1995; Yesuf *et al.*, 2008). Other annual losses included \$23 million forest losses via deforestation and \$10 million loss of livestock capacity (Yesuf *et al.*, 2008). All these translated to an annually total loss of about \$139 million (about 4% of GDP). In Malawi, the losses are even higher; 9.5–11% of GDP (FAO, 2007). Further, high percentage – 30% and 27% – of high value irrigated land was lost due to salinization over the last century in Kenya and Tanzania respectively (Tiffen *et al.*, 1994).

World Bank (1992) estimated the annual yield losses for specific crops to be 4–11% in Malawi. Sonneveld (2002) modeled the impact of water erosion on food production in Ethiopia in which he concludes that the potential reduction in production would range from 10% –30% by 2030. However, other non-quantified losses in all these studies include human capital costs of drought and malnutrition, rural poverty and environmental services costs due to the impact of sedimentation of streams and rivers. The other core effect of land degradation is on food supply. Davidson and Stroud (2006) show that there is continuously decreasing cereal availability per capita in the Eastern Africa region (from 136 kg/year in the 1980s to 118 kg/year in 2000s) due to land degradation. This translates to annual economic loss from soil erosion in SSA of about USD 1.6 to 5 billion (ibid).

Table 1: Cost and consequences of land degradation in Eastern Africa

Consequence	Nature and extent of the effect
Soil nutrient loss and loss of productive land resources	- Average annual soil nutrient losses of 23 kg/ha from 1980s-1990s increased to 48 kg/ha in 2000 (FAO, 2006). - Loss of soil by water erosion estimated at 72 tons/ha/year in Kenya; and 224 tons/ha/year in 1980-2000 in Tanzania (de Graff, 1993).
Salinization	- 30% of irrigated lands lost in Kenya due to salinization; Loss of irrigated lands due to salinization in Tanzania (27% of irrigated land) (Liniger *et al.*, 2011).
Loss of Land Productivity	- The productivity loss in Africa from soil degradation estimated at 25% for cropland and 8-14 percent for both cropland and pasture (Odelmann, 1998). - Irreversible soil productivity losses of at least 20% due to erosion reported to have occurred over the last century in large parts of Ethiopia and Kenya (Dregne, 1990).
Crop Yield Losses	- Under continuous cropping without nutrient inputs; cereal grain yields declined from 2-4 tons/ha to under 1 ton/ha in SSA (Sanchez *et al.*, 1997). - Crop yield losses due to erosion ranged from 2-40% (mean of 6%) for SSA (Lal, 1995). While annual yield losses for specific crops varied from 4-11% in Malawi (World Bank, 1992).
Loss of forest resources	- Forest loss over the period 1990 – 2005 was 12.7% in Malawi. Annual forest losses of 1.1% in Ethiopia, Malawi and Tanzania; and 0.3% in Kenya , chief source of energy (at least 70%) is fuel wood and charcoal in all Eastern Africa countries (UN-Habitat, 2011).
Increased food insecurity	- In 1990-2000 cereal availability per capita in SSA decreased from 136 to 118 kg/year. - The cereal yields have stagnated over the last 60 years (Morris, 2007).
Increased poverty	- 45% of SSA's population lived below the poverty line of less than 1 USD per day; the number of rural people living below the poverty line were more than twice that of those in urban settings (Ravallion *et al.*, 2007). - 73 percent of the rural poor currently residing on marginal and degraded lands (Scherr, 2000).

Source: Kirui and Mirzabaev, 2014.

The decrease in agricultural productivity represents an on-site cost. Other socioeconomic on-site effects include the increase of production costs due to the need for more inputs to address the negative physical impacts of land degradation. The indirect effects which are more difficult to quantify include; conflicts between different land users (such as farmer and herders) as a result of forced expansion of the agricultural frontier and the migration of households and communities towards pastoral land and economic losses arising from land degradation which constrain the development of services in rural areas.

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3. Analytical Approach

This study utilizes the Total Economic Value (TEV) approach proposed by Nkonya *et al*. (2015) which assigns value to both tradable and non-tradable ecosystem services to estimate the costs of land degradation. Land degradation happens in two ways, and the cost of land degradation is computed for each of them as follows:

(i) Land degradation as a result of Land Use and land Cover Change (LUCC): the loss of ecosystem services could be due to LUCC that leads to replacement of biomes with higher ecosystem value by those with lower value (i.e. LUCC that leads to loss in the total value of ecosystem services). There are five major land use types under focus in this study namely; cropland, grassland, forest, woodland, shrub-lands and barren land.

(ii) Using land degrading management practices on a static land use (i.e. no change in land use from the baseline to end-line period). Due to data availability and time constraint, this analysis focusses on the cropland biome (maize, rice and wheat) in this study[3]. The analysis is simulated for a 40-year period.

3.1 Cost of degradation due to Land Use and land Cover Change (LUCC)

The cost of land degradation due to LUCC (e.g. from forest to crop) is given by:

$$\boldsymbol{C_{LUCC}} = \sum_{i}^{K}(\Delta \boldsymbol{a_1} * \boldsymbol{p_1} - \Delta \boldsymbol{a_1} * \boldsymbol{p_2}) \quad for\ i = 1,2,\dots k \qquad (\mathbf{3.1})$$

where; C_{LUCC} *= cost of land degradation due to LUCC;* a_1 *= land area of biome 1 being replaced by biome 2;* P_1 *and* P_2 *are TEV per unit of area for biome 1 & 2 respectively, and i = biome.*

By definition of land degradation, $P_1 > P_2$; this means, LUCC that does not lead to lower TEV is not regarded as land degradation but rather as land improvement or restoration. To obtain the net loss of ecosystem value, the second term in the equation nets out the value of the biome 1 replacing the high value.

3.2 Cost of land degradation due to use of land degrading management practices

The estimation of cost of land degradation due to use of land degrading management practices follows the methodology proposed by Nkonya *et al*. (2015). The provisioning services of crops are well known and they have direct influence on the rural households. The ecosystem services provided by cropland are, however, less known. Carbon sequestration services are easily measured and in this are done in this study by analyzing the carbon sequestration due to sustainable land management (SLM) and compare this with land degrading practices.

This study uses the Decision Support System for Agro-technology Transfer (DSSAT) crop simulation model to determine the impact of SLM practices on crop yield and soil carbon (Gijsman *et al*., 2002). DSSAT is one of the most popular crop modeling software packages in the world. It mathematically describes the growth of crops and its interaction with soils, climate, and management practices. DSSAT combines crop, soil, and weather databases for access by a suite of crop models enclosed under one system. The models integrate the effects of crop systems components and management options to simulate the states of all the components of the cropping system and their interaction. When calibrated to local environmental conditions, crop models can help understand the current status of farming systems and test what-if scenarios.

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[3] The focus is on anthropogenic land, but due to the lack of relevant TEV data, this study used Value Transfer approach which assigns ES values from existing studies to ES valuation in other areas with comparable ES (Desvousges *et al*., 1998; Troy & Wilson, 2006).

The DSSAT model was modified by incorporating a soil organic matter and residue from the CENTURY model. Thus, the DSSAT-CENTURY model used in this study was designed to be more suitable for simulating low-input cropping systems and conducting long-term sustainability analyses and has been has been calibrated using many experiments around the world.

Two crop simulation scenarios are used as follows:

(i) SLM practices are the combination of organic inputs and inorganic fertilizer. Integrated soil fertility management (ISFM) – combined use of organic inputs, recommended amount of chemical fertilizer and improved seeds (Vanlauwe and Giller 2006) is considered as an SLM practice.

(ii) Business as usual (BAU). The BAU scenario reflects the current management practices practiced by majority of farmers. These could be land degrading management practices:

$$\mathbf{CLD} = \left(\boldsymbol{y^c - y^d}\right)\boldsymbol{P} * (\boldsymbol{A - A^c}) + (\boldsymbol{y_1^c - y_2^c}) * \boldsymbol{A^c})\boldsymbol{P} - \boldsymbol{\tau}\Delta\boldsymbol{CO_2} \qquad (\mathbf{3.2})$$

where; CLD =cost of land degradation on cropland, y^c *= yield with ISFM,* y^d *= yield with BAU, A=total area that remained under cropland in baseline and end-line periods,* A^c *= cropland area under BAU. P = price of crop i;* y_1^c, y_2^c *are yield under ISFM in period 1 and 2 respectively;* ΔCO_2*=change in the amount of carbon sequestered under SLM and BAU and* τ *= price of* CO_2 *in the global carbon market. The net carbon sequestration was compute after considering the amount of carbon dioxide emission from nitrogen fertilization and from manure application.*

The study focuses on three major crops: maize, rice and wheat, which cover about 42% of cropland in the world (FAOSTAT, 2013) and 35% of cropland in Eastern Africa (Appendix A1). DSSAT simulated maize, rice and wheat yields at a half degree resolution (about 60 km). To capture the long-term impacts of land management practices, the model was run for 40 years. The DSSAT, like other process-based models, have a number of disadvantages as reported by Lobell and Burke (2010) and Lobell *et al*. (2011). Process-based crop models give point estimates and do not include all relevant biological processes. For example, DSSAT cannot simulate the effect of salinity, soil erosion, phosphorus, potassium, intercropping and other processes that could affect yield.

3.3 Total cost of land degradation

The total cost of land degradation was obtained by summing the costs due to LUCC and costs on static land use, as follows:

$$\boldsymbol{TCLD} = \sum(\boldsymbol{C_{LUCC}} + \boldsymbol{CLD}) \qquad (\mathbf{3.3})$$

where; TCLD = total cost of land degradation, C_{LUCC} *is cost of land degradation due to LUCC, CLD = cost of land degrading due to use of land degrading practices on a static biome.*

The annual cost of land degradation is obtained by dividing the total costs of land degradation by the total number of years (eight in this case) – assuming that the rate of land degradation follows a linear trend:

$$\boldsymbol{TCLD_a = \frac{TCLD}{T}} \qquad (\mathbf{3.4})$$

where; $TCLD_a$ *= annual cost of land degradation; T = time from baseline to end-line period. T is also required to reflect a long-term nature of land degradation.*

3.4 Cost of taking action against land degradation

The methodology for establishing the cost of action for degradation due to LUCC has to put into consideration the cost of regenerating the high value biome lost and the opportunity cost of foregone benefits derived from the lower value biome being replaced (Torres *et al*., 2010). For example, if a forest was swapped with cropland, the cost of planting trees or allowing natural regeneration (if still feasible) and the cost of maintenance of the new plantation until it reaches maturity has to be put into consideration; so should be the case for the opportunity cost of the crops being foregone to replant trees or allow natural regeneration. This means the cost of taking action against land degradation due to LUCC is given by:

$$\boldsymbol{CTA_{ia} = A_{ia}\frac{1}{\rho^t}\left\{z_i + \textstyle\sum_{t=1}^{T}(x_i + p_j x_j)\right\}} \qquad (\mathbf{3.5})$$

where; CTA_i *= cost of restoring high value biome i in agro-ecological zone a;* ρ^t *= discount factor of land user;* A_i*= area of high value biome i that was replaced by low biome value biome j;* z_i *= cost of establishing high value biome i;* x_i *= maintenance cost of high value biome i until it reaches maturity;* x_j *= productivity of low value biome j per hectare;* p_j *= price of low value biome j per unit; t = time in years and T = planning horizon of taking action against land degradation. The term* p_jx_j *represents the opportunity cost of foregoing production of the low value biome j being replaced.*

The benefits of restoring degraded land goes beyond the maturity period of biome; thus this study used the land user's planning horizon to fully capture the entailing costs and benefits. Poor farmers tend to have shorter planning horizon while better off farmers tend to have longer planning horizon (Pannell *et al* 2014). The planning horizon also depends on the type of investment. For example, tree planting requires longer planning horizon than annual cropland. For brevity however, this study assumes a 30 year planning horizon for all the biomes considered (Nkonya *et al*., 2015). This assumption implies that during this time, farmers will not change their baseline production strategies dramatically. It is important to consider the biome establishment period since it has important implications on decision making. Poor land users are less likely to invest in restoration of high value biomes that take long time to mature. Trees take about 4-6 years to reach maturity (Wheelwright and Logan 2004). Given this a six year maturity for trees was assumed. A three year maturity age for natural regeneration or planting for grasslands was assumed. Replanting is necessary if the LUCC involved excessive weeding of grass. Natural regeneration may take longer than three years but for simplicity a three natural regeneration period was assumed.

The importance of agro-ecological zones is also taken into consideration. The cost of land degradation is therefore computed for the different agro-ecological zones. For example, establishing a biome in a semi-arid area is more difficult than would be the case in humid and sub humid regions. Pender *et al*. (2009) illustrate this using the survival rate of planted trees in the Niger, which was only 50%. Other challenges also face farmers in arid and semi-arid areas (with annual average rainfall below 700 mm) when compared to land users in humid and sub humid areas (with annual precipitation above 700 mm) (IISD 1996). Hence for any given region, the cost of establishing any biome in arid and semi-arid areas was assumed to be twice the corresponding cost in the humid and sub humid regions.

3.5 Cost of inaction against land degradation

The cost of inaction will be the sum of annual losses due to land degradation, given by:

$$\boldsymbol{CI_{ia} = \sum_{t=1}^{T} C_{LUCC}} \qquad (\mathbf{3.6})$$

where CI_i *= cost of not taking action against degradation of biome i in agro-ecological zone a. Land users will take action against land degradation if* $CTA_i < CI_{ia}$ *(Nkonya et al., 2013).*

3.6 Data

a. Land use land cover change (LUCC): The land use land cover change data used in this study is sourced from the Moderate Resolution Imaging Spectroradiometer (MODIS) for the period 2001 and 2009. The changes in land area of each biome (forest, grassland, cropland, woodland, shrub-land, and bare land) between 2001 and 2009 are as reported in **Table 2**).

Table 2: Change in land area of terrestrial biomes between 2001- 2009 (*in Ha and %)*

Country	Forest	Cropland	Grassland	Woodland	Bare land	Water
Ethiopia	-1412899 (-25.8%)	2783381 (32.7%)	-3035811 (-10.7%)	-333918 (-1.8%)	-696317 (-12.3%)	-49838 (-7.8%)
Kenya	-456636 (-22.5%)	955321 (27.7%)	10500000 (29.2%)	488149 (9.3%)	-673523 (-32.3%)	-78195 (-6.7%)
Malawi	30597 (7.7%)	-52749 (-33.5%)	1042056 (18.3%)	-959338 (-30.9%)	6341 (56.9%)	-1544 (-0.1%)
Tanzania	-1479437 (-23.1%)	-1724502 (-36.9%)	6125137 (9.7%)	-2066826 (-5.5%)	26265 (29.3%)	-164233 (-2.8%)

Note: Change in area = $Area_{2009} – Area_{2001}$.
Source: Authors compilation

b. **Total Economic Value (TEV):** The **total economic value data** is derived from The Economics of Ecosystems and Biodiversity (TEEB) database, which is based on more than 300 case studies – reporting more than 1350 Ecosystem Services values (De Groot *et al* 2012). The spatial distribution of the terrestrial biome studies is shown in **Figure 2**. Due to a large variation of the data source and methods used, data were standardized[4] to ensure that the reported values are comparable. The data were converted to 2007 US$ to allow value comparison across time. Nkonya *et al*. (2015) describes in detail the criteria used for including studies in the database and the weakness of the ecosystem service values included in the database.

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[4] For details of standardization methods used, see de Groot *et al* (2010).

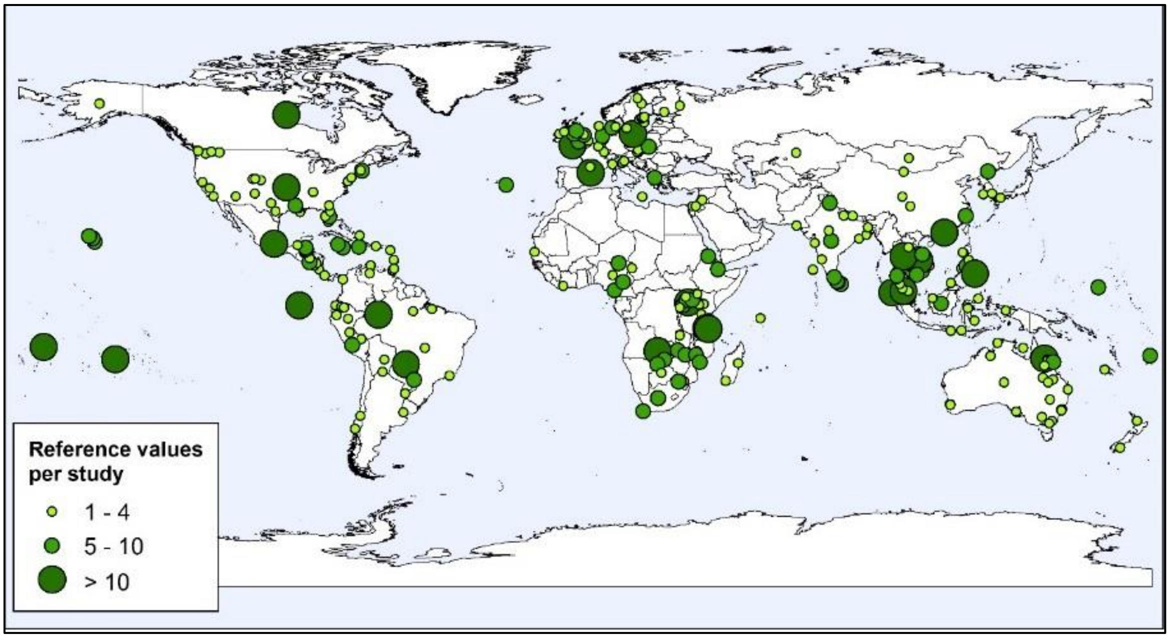

Figure 2: Location of TEEB database of terrestrial ecosystem service valuation studies

Source: Nkonya *et al*. (2015).

c. **The Gross Domestic Product (GDP):** The Gross Domestic Product was obtained from the World Bank database.

d. **Crop yields:** The Crop yields for the ten-year baseline period (2001-2010) were sourced from the Food and Agriculture Organization Corporate Statistical (FAOSTAT) database

e. **Crop simulation – Decision Support System for Agrotechnology Transfer (DSSAT):** Crop yields simulation is done for two management scenarios: the integrated soil fertility management (ISFM) which is the land improvement scenario, and the business-as-usual (BAU) which is the land degrading management scenario. Secondary data from household surveys and literature review is used to determine adoption rate of ISFM. Corroborating data on conservation agriculture was obtained from AQUASTAT website. The DSSAT simulations are then estimated at each pixel (half degree resolution) to determine the yield under ISFM and BAU scenarios. The yield differences are then used to estimate the costs of land degradation on a 'static cropland biome'.

f. **Cost of Action and Cost of Inaction:** The data used to estimate the cost of action and the cost of inaction are derived from Nkonya *et al*. (2015). Cost of action data includes data on cost of establishing high value biome, cost of maintenance of the high value biome and the opportunity cost of foregoing production of the low value biome (being replaced by high value biome).

4. Results and discussions

4.1 Cost of Land Degradation due to Land Use Cover Change

As noted in the methodology section, the analysis of the costs of land degradation follows the comprehensive TEV framework. Description of the results therefore begin with the presentation of the total **terrestrial ecosystem value** for each of the countries followed by the costs of land degradation – loss of ecosystems values due to LUCC. The GDP, TEV, and costs of land degradation due to LUCC are all reported in **Table 2**. These values have been converted to 2007 USD to allow for fair comparisons. The total TEV includes the value of provisioning, regulating, habitat and cultural ecosystem services. Results show that annual TEV ranged from $ 24.98 billion in Malawi, $ 127.7 billion in Kenya, $ 206.4 billion in Ethiopia, to $ 223.1 billion in Tanzania. The GDP values for 2007 ranged from $ 3.6 billion in Malawi, $16.8 billion in Tanzania, $19.3 billion in Ethiopia, to $ 27.2 billion in Kenya.

The cost of land degradation due to LUCC in the four countries (**Table 2** and **Figure 3**) ranged from US$ 1.98 billion in Malawi, $10.65 billion in Kenya, $18.47 billion in Tanzania, to US$ 34.82 billion in Ethiopia. The average annual costs of land degradation in the four countries are also presented. This is the average of the costs of land degradation per year assuming a linear trend. These costs ranged from $ 0.25 billion in Malawi, $1.33 billion in Kenya, $2.31 billion in Tanzania, to $4.35 billion in Ethiopia. The results of costs of land degradation due to LUCC are further presented in per hectare basis. They range from $38 in Ethiopia and $25 in Tanzania to $23 in Kenya and $21 in Malawi.

To provide a better visibility, the average annual costs of land degradation and further present these annual costs as a percentage of both GDP and TEV present in **Table 2**. The cost the cost of land degradation as a percentage of GDP was the highest in Ethiopia (23%) and Tanzania (14%). Kenya and Malawi experienced the smallest loss of ecosystem services values as a percentage of GDP (5% and 7% respectively). The costs of land degradation as percentage of TEV is the lowest Malawi (0.9%), followed by Kenya and Tanzania (both reported at 1%) but highest in Ethiopia (2.1%). These costs at regional/district level are presented in the subsequent subsection.

Table 3: Terrestrial ecosystem value and cost of land degradation due to LUCC

Country	GDP	TEV	Costs of land degradation due to LUCC (2001-2009)	Annual costs of land degradation due to LUCC	Cost of LD as % of 2007 GDP	Cost of LD as % of TEV	Annual costs of land degradation due to LUCC (per ha)
			US$ billion		%	%	US$/ha
Ethiopia	19.346	206.41	34.825	4.353	22.5%	2.11%	38.49
Kenya	27.236	127.74	10.645	1.331	4.9%	1.04%	22.88
Malawi	3.647	24.98	1.980	0.248	6.8%	0.94%	21.01
Tanzania	16.825	223.10	18.474	2.309	13.7%	1.03%	24.53

Source: TEV and Land Degradation –Author's compilation; GDP – World Bank data.

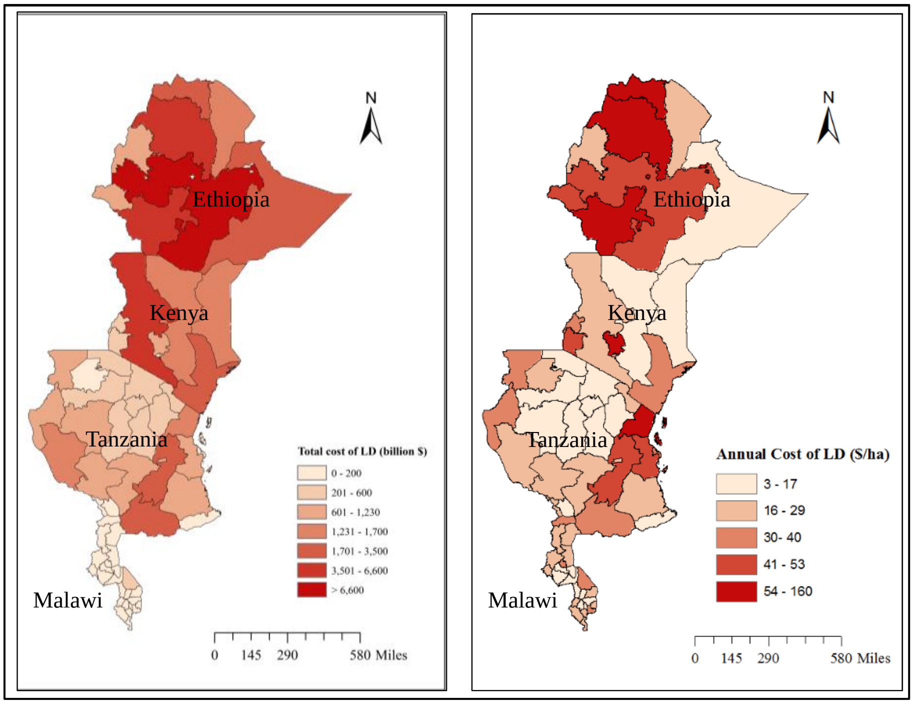

Figure 3: Cost of land degradation due to LUCC (for 2001-2009).
Source: Author's compilation.

The cost of land degradation due to LUCC can be presented in terms of loss of provisional ecosystem services or loss of other ecosystem services (regulating, habitat and cultural services). Provisioning ecosystem services are services with direct impact on land users while regulating, habitat and cultural services are indirect local and/or global benefits. Loss of the regulating, habitat and cultural services is regarded as costs of land degradation borne by the international community – outside the district or region of analysis.

Figure 4 shows that loss of provisioning services account for about 65% and 60% of the cost of land degradation in Malawi and Tanzania respectively while the loss of regulating, habitat and cultural services in these two countries accounted only for 35% and 40% of the total costs respectively. The losses in provisioning services were reported at 57% and 52% in Kenya and Ethiopia respectively. This results suggests that the costs of and degradation borne 'outside' community is substantially high.

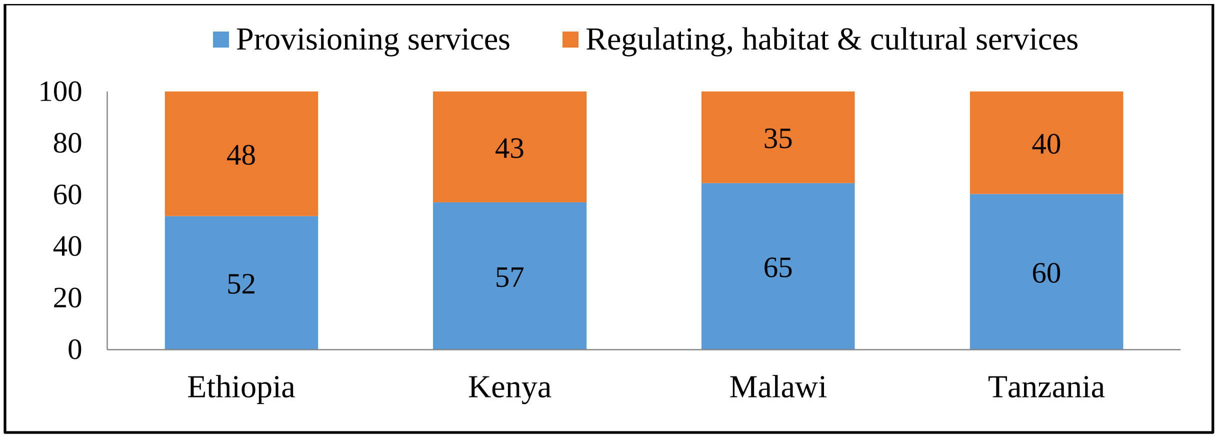

Figure 4: Provisioning verses other components of cost of land degradation
Source: Author's compilation.

4.2 Cost of land degradation due to use of land degrading practices on cropland

As described in the methods section, three crops (maize, wheat and rice) that constitute the bulk of production were considered for analysis. Data availability also contributed to the choice of these crops. The simulated results of the yields of rain-fed maize and wheat and irrigated rice yields under BAU and ISFM scenarios for a period of forty years are presented in **Table 3**. The results are structured in to two time periods; base-line and end-line. The base-line period refers to the first 10 years while the end-line refers to the last 10 years of the simulation period.

The base-line maize yields in the BAU scenario is 2.4 tons/ha in both Ethiopia and Malawi, 2.1 tons/ha in Tanzania and 1.6 tons/ha in Kenya. In the end-line period, maize yields declined to 1.8 tons/ha in Ethiopia, 1.6 tons/ha in both Malawi and Tanzania and 1.4 tons/ha in Kenya. This implies a decline of 34% in Malawi, 27% in Tanzania, 25% in Ethiopia and 17% in Kenya compared to yield in the past 30 years. Results further show that average maize yields are higher under ISFM scenario as compared to the BAU scenario. During the base-line period, the yield of ISFM maize yield ranged from 2.8 tons/ha in Ethiopia, 2.5 tons/ha in Malawi, 2.3 tons/ha in Tanzania to 1.8 tons/ha in Kenya. However, the yield declines to 2.4 tons/ha in Ethiopia, 1.9 tons/ha in both Malawi and Tanzania and 1.8 tons/ha in Kenya in the end-line period. These represent declines of about 23% in Malawi, 16% in Tanzania 12% in Ethiopia and 3% in Kenya.

The net effect of use of land degrading management practices on maize yields is presented in the last column of **Table 3**. This is obtained by comparing the simulated end-line yields for both the ISFM and BAU scenarios. Results show that the yield decline due to land degradation is high in Ethiopia (36%) and Kenya (32%) followed by Malawi (22%) and Tanzania (22%). The inverse of the yield decline may also be interpreted as benefits of using ISFM. Thus the use of ISFM leads to increase in maize yields by about 36% in Ethiopia, 32% in Kenya, 22% in Malawi and Tanzania.

The base-line rice yields in the BAU scenario is 6.1 tons/ha in Malawi, 5.9 tons/ha in Tanzania and 3.6 tons/ha in Kenya. In the end-line period of the BAU, rice yields declined to 4.2 tons/ha in

Tanzania, 4.0 tons/ha in Malawi and 3.2 tons/ha in Kenya. This implies a decline of 33% in Malawi, 29% in Tanzania, and 9% in Kenya compared to yield in the past 30 years. Results further show that average rice yields are higher under ISFM scenario as compared to the BAU scenario. During the base-line period, the yield of rice under ISFM ranged from 6.6 tons/ha in Malawi, 6.2 tons/ha in Tanzania to 4.4 tons/ha in Kenya. However, in the end-line period of the ISFM scenario, the yield declines to 4.7 tons/ha in Malawi, 4.5 tons/ha in Tanzania, and 4.2 tons/ha in Kenya. These represent declines of about 32% in Kenya, 16% in Malawi, and 8% in Tanzania as a result of use of land degrading management practices on irrigated rice.

Table 4: Change in maize, rice and wheat yields under BAU and ISFM scenarios

	BAU		ISFM		Yield Change (%)		Change due to land degradation
	Baseline (y_1^d)	End-line (y_2^d)	Baseline (y_1^c)	End-line (y_2^c)	BAU	ISFM	Percent
Country	Yield (tons/ha)		Yield (tons/ha)		$\%\Delta y = \frac{y_2 - y_1}{y_1} * 100$		$\%D = \frac{y_2^c - y_2^d}{y_2^d} * 100$
Maize							
Ethiopia	2.39	1.79	2.79	2.44	-25.1	-12.6	36.0
Kenya	1.63	1.35	1.84	1.79	-17.1	-2.5	32.4
Malawi	2.37	1.57	2.51	1.92	-33.5	-23.3	22.0
Tanzania	2.14	1.57	2.29	1.92	-26.6	-16.0	22.3
Rice							
Kenya	3.55	3.21	4.36	4.23	-9.4	-3.0	31.6
Malawi	6.06	4.04	6.61	4.68	-33.3	-29.2	15.9
Tanzania	5.88	4.17	6.16	4.51	-29.0	-26.8	8.0
Wheat							
Ethiopia	1.67	1.33	1.80	1.66	-20.4	-7.9	24.7
Kenya	2.77	2.34	3.09	3.08	-15.6	-0.3	32.0
Malawi	0.55	0.52	0.53	0.52	-6.4	-2.1	0.2
Tanzania	0.66	0.64	0.67	0.68	-3.5	0.6	5.9

Note: y_1 = Baseline yield (average first 10 years); y_2 = Yield end-line period (average last 10 years).

Source: Author's compilation.

The base-line wheat yields in the BAU scenario is 2.8 tons/ha in Kenya, 1.7 tons/ha in Ethiopia, 0.7 tons/ha in Tanzania, and 0.6 tons/ha in Malawi. In the end-line period of the BAU scenario, wheat yields declined to 2.3 tons/ha in Kenya, 1.3 tons/ha in Ethiopia, 0.6 tons/ha in Tanzania, and 0.5 tons/ha in Malawi. This implies a decline of 20% in Ethiopia, 17% in Kenya, 6% in Malawi, and 4% in Tanzania compared to yield in the past 30 years. Results further show that average wheat yields are higher under ISFM scenario as compared to the BAU scenario. During the base-line period, the yield of wheat under ISFM ranged from 3.1 tons/ha in Kenya and 1.8 tons/ha in Ethiopia to 0.7 tons/ha in Tanzania and 0.5 tons/ha in Malawi. The end-line period, the yield remain largely unchanged in Kenya, Malawi and Tanzania but declines to 1.7 tons/ha in Ethiopia. These wheat yield declines in the ISFM scenario are marginal – ranging from about 0.3 % in Kenya and 0.6% in Tanzania, to 2 % in Malawi and 8% in Ethiopia. Consequently, the analysis show that yield decline on rain-fed wheat as a result of the use of land degrading management practices are high in Kenya (32%) and Ethiopia (25%) but lower in Tanzania (6%) and least in Malawi (0.2%).

Ensuing the simulation of the yields for the forty years period, is the estimation of the costs of land degradation on the static cropland for the three crops. Results (**Table 4**) show that the total annual costs of land degradation associated with use of land degradation practices were about US$ 305 million in Ethiopia, US$ 270 million in Kenya, US$ 162 million in Tanzania, and US$ 114 million in Malawi. When these losses are expressed as percent of GDP, Malawi is the most severely affected by cropland degradation – loses about 3% of its GDP annually. Similarly, Ethiopia loses about 2%, while Tanzania and Kenya each lose about 1% of GDP. Statistics show that the three crops (maize, rice and wheat) account for about 42% of the cropland globally. Assuming that the overall levels of degradation in all cropland is comparable to that occurring on the three major crops, then these costs range from 2.3% in Tanzania, 2.4% in Kenya, 3.8% in Ethiopia to 7.5% in Malawi. The annual costs on static maize, wheat, and rice biomes are also presented as a percentage of the total cropland area to enhance comparison across countries. The annual costs per hectare ranged from as high as US$ 194 in Malawi and US$ 117 in Kenya to as low as US$ 90 in Tanzania and just US$ 27 in Ethiopia. It is noteworthy that the costs of land degradation due soil fertility mining as reported in **Table 4** are conservative. Other aspects of land degradation on a static cropland biome including soil erosion and salinity, and offside costs of pesticide use are not considered because of lack of data.

Table 5: Annual Cost of land degradation on static cropland – DSSAT results

Country	Annual cost of maize, wheat, rice degradation	Annual cost of maize, wheat, rice degradation	Annual cost of total cropland degradation	Annual cost of land degradation (per ha)
	2007 US$ million	(% GDP)	(% GDP)	US$/ha
Ethiopia	304.96	1.58	3.75	27.02
Kenya	269.77	0.99	2.36	116.70
Malawi	114.09	3.13	7.45	194.18
Tanzania	161.94	0.96	2.29	89.63

Source: Author's compilation.

4.3 Total Cost of land degradation

Table 5 presents the total annual costs of land degradation – sum of costs due to LUCC and costs due to use of land degrading practices on a static cropland biome. These costs are also presented as a percent of GDP. The total annual cost of land degradation ranged from US$ 361 million in Malawi and US$ 1600 million in Kenya to US$ 2471 million in Tanzania and US$ 4658 million in Ethiopia. When expressed as a percent of GDP, total costs of land degradation are the highest in Ethiopia (24%) and Tanzania (15%) followed by Malawi (10%) and the least in Kenya (6%). For a better comparison between countries, the total annual costs of land degradation are converted to per hectare basis. Results show that annually, the total costs of land degradation are highest in Ethiopia ($ 41) and Malawi ($ 31) followed by Kenya ($ 28) but least in Tanzania ($ 26).

Table 6: Annual total cost of land degradation (costs on static cropland and LUCC costs)

Country	Cost of land degradation on static biome (cropland)	Annual Cost of land degradation due to LUCC	Total Annual Cost of land degradation	Total cost of land degradation as % of GDP	Total Annual Cost of land degradation
	2007 US$ million			%	US$/ha
Ethiopia	305.0	4353.1	4658.1	24.1	41.2
Kenya	269.8	1330.6	1600.4	5.9	27.5
Malawi	114.1	247.5	361.6	9.9	30.7
Tanzania	161.9	2309.3	2471.2	14.7	26.2

Source: Author's compilation.

4.4 Costs of action versus inaction against land degradation

This section presents the results of the assessment of the costs of action against land degradation which help in determining whether the action against land degradation could be justified economically. Nkonya *et al* (2013) notes that land users will take action against land degradation if the cost of inaction is greater than the cost of action. To completely rehabilitate degraded land due to LUCC in a period of six years, a total of about $ 54 billion in Ethiopia, $ 37 billion in Tanzania, $ 18 billion in Kenya, and $ 4 billion in Malawi (**Table 6 and Figure 5**). But if no action is taken to rehabilitate degraded lands over the same period, it would lead to a loss of about $ 169 billion in Ethiopia, $ 103 billion in Tanzania, $ 55 billion in Kenya, and $ 12 billion in Malawi. The cost of action as a percent of cost of inaction in a 6-year time period represents just about 32% in Ethiopia, 33% in Kenya, 37% in Malawi and 36% in Tanzania. Consequently, during the first six years, for every dollar spent on taking action against land degradation users will expect a return of about $ 3.1 in both Ethiopia and Kenya, $ 2.7 in Malawi and $ 2.8 in Tanzania.

Table 7: Cost of action & inaction against LUCC-related land degradation (US$ billion)

Country	Cost of Action	Cost of Inaction	Cost of Action as % cost of Inaction	Returns from action	Cost of Action	Cost of Inaction	Cost of Action as % cost of Inaction	Returns from action
	First 6 years				30–years horizon			
Ethiopia	54.05	168.67	32.0	3.1	54.17	228.32	23.7	4.2
Kenya	18.03	55.33	32.6	3.1	18.07	74.89	24.1	4.1
Malawi	4.24	11.52	36.8	2.7	4.25	15.60	27.3	3.7
Tanzania	36.56	102.56	35.6	2.8	36.63	138.83	26.4	3.8

[a] The inverse of the corresponding percent is the returns to investment

Source: Author's compilation based on MODIS data.

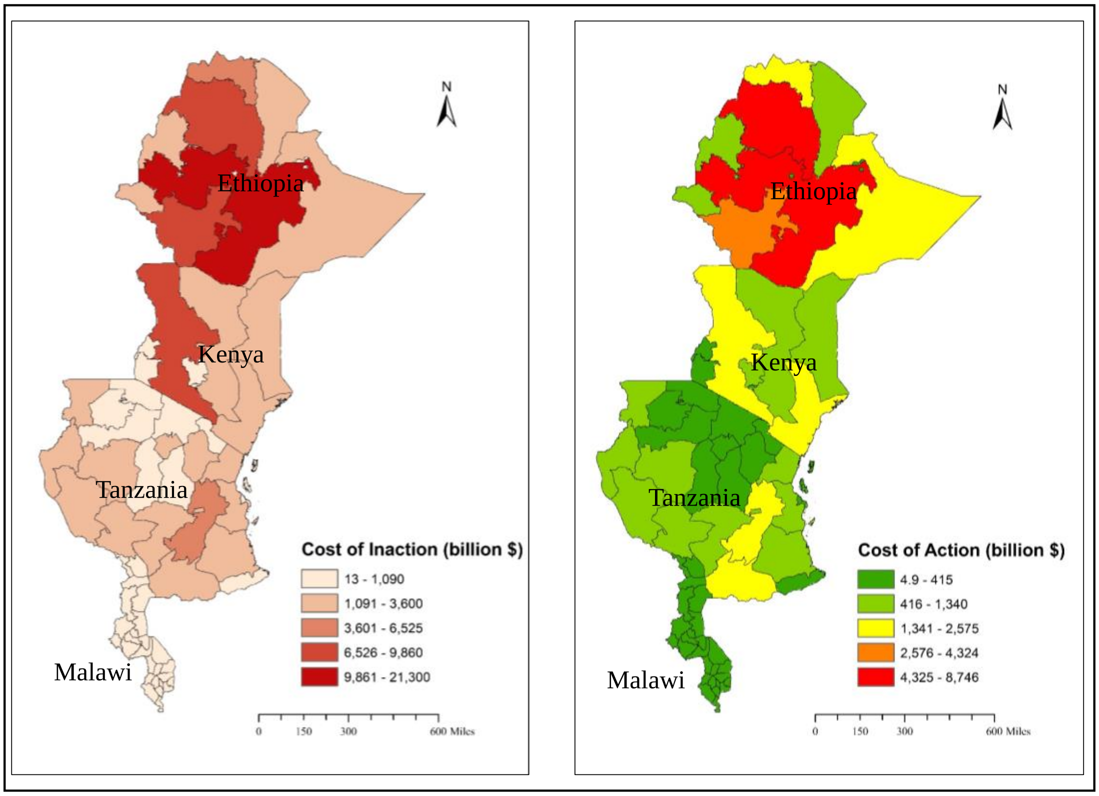

Figure 5: Cost of action & inaction against LUCC-related land degradation
Source: Author's compilation.

During the entire 30-year planning horizon, the cost of action is about $ 54.2 billion in Ethiopia, $ 36.6 billion in Tanzania, $ 18.1 billion in Kenya, and $ 4.3 billion in Malawi. However, if no action is taken to address land degradation over the 30-year period, it would lead to a loss of about $ 228 billion in Ethiopia, $ 139 billion in Tanzania, $ 75 billion in Kenya, and $ 16 billion in Malawi. These imply that the cost of action as a percent of cost of inaction represented about 24% in Ethiopia and Kenya, 26% in Malawi and Tanzania. Consequently, during the 30-year period, for every dollar spent on taking action against land degradation users will expect a return of about $ 4.2 in Ethiopia, $ 4.1 in Kenya, $ 3.8 in Tanzania, and $ 3.7 in Malawi.

The costs of action and inaction against LUCC land degradation for the six-year and thirty-year periods are also computed on per ha basis as presented in **Table 7**. Analysis show that during the six-year period the costs of action per ha ranged from as high as $ 477 in Ethiopia and $ 384 in Tanzania to as low as $ 343 in Malawi and $ 310 in Kenya. However, the costs of inaction over the same period is about $ 1491 in Ethiopia, $ 1090 in Tanzania, $ 978 in Malawi and $ 951 in Kenya. During a 30-year period the costs of action per ha is about $ 478 in Ethiopia, $ 385 in Tanzania, $ 344 in Malawi and $ 311 in Kenya. However the costs of inaction increase to about $ 2019 in Ethiopia, $ 1475 in Tanzania, $ 1323 in Malawi, and $ 1287 in Kenya.

Table 8: Cost of action & inaction against LUCC-related land degradation per hectare

Country	Cost of Action	Cost of Inaction	Cost of Action	Cost of Inaction
	(6 years)		(30 years)	
Ethiopia	476.6	1491.4	477.7	2018.7
Kenya	309.9	951.1	310.6	1287.4
Malawi	343.0	977.7	343.7	1323.4
Tanzania	384.3	1089.5	385.1	1474.7

Source: Author's compilation based on MODIS data.

The results at district/regional levels for the four countries are varied. In Ethiopia, results show that the annual cost of land degradation is about $4.1 billion (**Table 8**). Only about $1.7 billion (42%) of this cost of land degradation represent the loss of provisional ecosystem services. The other 58% represents the loss of supporting and regulatory and cultural ecosystem services. The annual costs of land degradation were higher in Southern Nations ($1.6 billion), Dire Dawa ($822 million) and Afar ($654 million) regions but least in Somali ($4 million), Addis Ababa ($4 million) and Harari ($8 million) regions.

The results further show the costs of action were about $54.1 million in a six-year period and about $54.2 million over a 30-year horizon whereas the costs of inaction in six-year period were about $169 million and about $228 million in a 30-year period. This implies that the costs of action against land degradation are lower than the costs of inaction by about 4.2 times over the 30 year horizon; i.e. the ratio of action to cost of inaction is 24.8%. This implies that each dollar spent on addressing land degradation is likely to have about 4.1 dollars of returns. The ratio of costs of action to cost of inaction in the 30-year period was high in Oromia (27.2%), Harari (26.7%), Gambela (26.7%), and Amhara (25.2%) regions. The returns from action were the highest in Tigray ($5.8), Somali ($4.4), and Dire Dawa ($ 4.4) regions and lowest in Oromia ($ 3.7), Harari ($3.8) and Gambela ($3.8) regions.

Table 9: Cost of action and inaction against land degradation in Ethiopia (million USD)

Region	Annual costs of Land Degradation	Annual costs of land degradation in terms of provisional ES only	Cost of Action (6 years)	Cost of Inaction (6 years)	Cost of Action (30 years)	Cost of Inaction (30 years)	Ratio of Cost of action: cost of Inaction (30 years)	Returns from action (30 years)
	Million USD						%	$
Addis Ababa	3.564	0.396	0.045	0.135	0.045	0.182	24.8%	4.04
Afar	654.287	270.585	8.578	26.331	8.595	35.641	24.1%	4.15
Amhara	296.628	140.036	4.504	13.234	4.514	17.913	25.2%	3.97
Benshangul	197.078	106.565	2.685	8.588	2.693	11.625	23.2%	4.32
Dire Dawa	822.324	176.375	9.836	31.973	9.863	43.278	22.8%	4.39
Gambela	107.765	76.750	1.870	5.189	1.873	7.024	26.7%	3.75

Harari	8.268	6.218	0.151	0.419	0.151	0.567	26.7%	3.75
Oromia	128.042	96.575	2.381	6.489	2.385	8.783	27.2%	3.68
Somali	4.200	1.552	0.051	0.168	0.052	0.227	22.7%	4.41
Southern	1569.461	686.605	21.256	64.619	21.301	87.468	24.4%	4.11
Tigray	303.782	138.263	2.691	11.532	2.702	15.609	17.3%	5.78
Total	**4095.40**	**1699.92**	**54.05**	**168.67**	**54.17**	**228.32**	**24.8%**	**4.21**

Source: Author's compilation based on MODIS data.

In Kenya, results show that the annual cost of land degradation is about $ 1.3 billion (**Table 9**). About 51% of this cost (or $ 666 million) represent the loss of provisional ecosystem services. The other half represents the loss of supporting and regulatory and cultural ecosystem services. The annual costs of land degradation were higher in Rift valley ($445 million), Coast ($283 million) and Eastern ($209 million) provinces but least in Nairobi ($2 million), Western ($30 million) and Nyanza ($70 million) provinces. The results further show the costs of action were about $18 million in a six-year period and about $18.1 million over a 30-year horizon whereas the costs of inaction in six-year period were about $55 million and about $75 million in a 30-year period.

This implies that the costs of action against land degradation are lower than the costs of inaction by about 4.1 times over the 30 year horizon; i.e. the ratio of action to cost of inaction is 24%. This implies that each dollar spent on addressing land degradation is likely to have about 4.1 dollars of returns. The ratio of costs of action to cost of inaction in the 30-year period was high in Nairobi (28%), Rif Valley (26%), North Eastern (25%), and Central (25%) provinces. The returns from action were the highest in Coast ($4.6), Nyanza ($4.5), and Western ($ 4.1) provinces and lowest in Nairobi ($ 3.6) and Rift Valley ($3.9) provinces.

Table 10: Cost of action and inaction against land degradation in Kenya (million USD)

Region	Annual costs of Land Degradation	Annual costs of land degradation in terms of provisional ES only	Cost of Action (6 years)	Cost of Inaction (6 years)	Cost of Action (30 years)	Cost of Inaction (30 years)	Ratio of Cost of action: cost of Inaction (30 years)	Returns from action (30 years)
	Million USD						%	$
Central	79.634	35.691	1.085	3.239	1.087	4.384	24.8%	4.034
Coast	282.672	128.895	3.337	11.283	3.346	15.272	21.9%	4.565
Eastern	208.807	125.718	2.993	9.353	3.001	12.660	23.7%	4.219

Nairobi	2.289	1.050	0.036	0.097	0.036	0.131	27.8%	3.602
North Eastern	185.088	110.820	2.815	8.369	2.821	11.328	24.9%	4.016
Nyanza	70.324	30.206	0.818	2.753	0.820	3.727	22.0%	4.544
Rift Valley	444.969	219.726	6.533	18.959	6.546	25.663	25.5%	3.920
Western	30.251	14.043	0.417	1.273	0.418	1.724	24.2%	4.127
Total	**1304.03**	**666.15**	**18.03**	**55.33**	**18.07**	**74.89**	**24.1%**	**4.14**

Source: Author’s compilation based on MODIS data.

In Malawi, results show that the annual cost of land degradation is about $244 million (**Table 10**). Only about $153 million (62%) of this cost of land degradation represent the loss of provisional ecosystem services. The other (about 38%) represents the loss of supporting and regulatory and cultural ecosystem services. The annual costs of land degradation were higher in Mangochi ($27 million), Nkhata Bay ($24 million), Nkhotakota ($20 million), and Rumphi ($20 million) districts but least in Balaka ($0.8 million), Chiradzulu ($0.9 million) and Blantyre ($2 million) districts.

The results also show that the costs of action were about $4 million in a six-year period and about $4.3 million over a 30-year horizon whereas the costs of inaction in six-year period were about $12 million and about $17 million in a 30-year period. This implies that the costs of action against land degradation are lower than the costs of inaction by about 3.7 times over the 30 year horizon; i.e. the ratio of action to cost of inaction is 27.3%. This implies that each dollar spent on addressing land degradation is likely to have about 3.7 dollars of returns. The ratio of costs of action to cost of inaction in the 30-year period was high in Nkhata Bay (29.8%), Mzimba (28.3%), Ntcheu (28.3%), and Nsanje (28.1%) districts. The returns from action were the highest in Salima ($4.1), Mangochi ($3.9), Balaka ($ 3.8) and Karonga ($ 3.8) districts. The lowest returns from action were reported in Nkhata Bay ($ 3.4), Ntcheu ($3.5) and Mzimba ($3.5) districts.

Table 11: Cost of action and inaction against land degradation in Malawi (million USD)

Region	Annual costs of Land Degradation	Annual costs of land degradation in terms of provisional ES only	Cost of Action (6 years)	Cost of Inaction (6 years)	Cost of Action (30 years)	Cost of Inaction (30 years)	Ratio of Cost of action: cost of Inaction (30 years)	Returns from action (30 years)
	Million USD						%	$
Balaka	0.750	0.501	0.013	0.036	0.013	0.049	26.0%	3.84
Lilongwe	9.972	7.022	0.176	0.485	0.176	0.657	26.8%	3.73

Machinga	11.027	7.081	0.197	0.525	0.197	0.710	27.7%	3.61
Mangochi	27.302	14.968	0.403	1.169	0.403	1.583	25.5%	3.92
Mchinji	5.594	4.297	0.104	0.284	0.104	0.384	27.2%	3.68
Mulanje	6.605	4.021	0.112	0.308	0.112	0.416	26.9%	3.72
Mwanza	6.245	4.267	0.111	0.301	0.111	0.408	27.3%	3.66
Mzimba	19.635	13.027	0.367	0.961	0.368	1.301	28.3%	3.54
Nkhata Bay	24.379	9.222	0.415	1.031	0.416	1.395	29.8%	3.36
Nkhotakota	19.988	11.710	0.337	0.916	0.338	1.240	27.2%	3.67
Nsanje	4.219	2.865	0.079	0.210	0.080	0.284	28.1%	3.57
Blantyre	1.934	1.276	0.035	0.095	0.035	0.128	27.3%	3.66
Ntcheu	4.381	3.128	0.086	0.224	0.086	0.303	28.3%	3.53
Ntchisi	5.559	4.002	0.102	0.275	0.103	0.373	27.5%	3.63
Phalombe	3.948	2.739	0.072	0.195	0.072	0.264	27.3%	3.67
Rumphi	19.568	12.281	0.331	0.908	0.331	1.229	26.9%	3.71
Salima	5.023	2.826	0.076	0.227	0.076	0.307	24.7%	4.05
Thyolo	4.655	3.054	0.081	0.226	0.081	0.306	26.6%	3.76
Zomba	4.668	2.744	0.083	0.222	0.083	0.301	27.7%	3.61
Chikwawa	8.780	6.034	0.155	0.428	0.155	0.580	26.7%	3.74
Chiradzulu	0.874	0.587	0.016	0.043	0.016	0.058	26.8%	3.73
Chitipa	9.246	6.722	0.173	0.469	0.174	0.634	27.4%	3.65
Dedza	7.436	5.233	0.135	0.369	0.135	0.499	27.0%	3.70
Dowa	4.889	3.393	0.086	0.242	0.086	0.328	26.4%	3.79
Karonga	12.394	7.899	0.205	0.579	0.206	0.784	26.3%	3.81
Kasungu	15.321	12.205	0.295	0.797	0.296	1.079	27.4%	3.65
Total	**244.39**	**153.11**	**4.24**	**11.52**	**4.25**	**15.60**	**27.3**	**3.67**

Source: Author’s compilation based on MODIS data.

In Tanzania, results show that the annual cost of land degradation is about $2.3 billion (**Table 11**). Only about $1.3 billion (57%) of this cost of land degradation represent the loss of provisional ecosystem services. The other (about 43%) represents the supporting and regulatory and cultural ecosystem services. The annual costs of land degradation were higher in Morogoro ($297 million), Ruvuma ($214 million), and Rukwa ($193 million) districts but least in Zanzibar West ($3 million), Dar-Es-Salaam ($6 million) and Unguja North ($7 million) districts.

Moreover, results show that the costs of action were about $36.5 million in a six-year period and about $36.6 million over a 30-year horizon. However, the costs of inaction in six-year period were about $103 million and about $139 million in a 30-year period. This implies that the costs of action against land degradation are lower than the costs of inaction by about 3.8 times over the 30 year horizon; i.e. the ratio of action to cost of inaction is 26.4%. This implies that each dollar spent on addressing land degradation is likely to have about 3.8 dollars of returns. The ratio of costs of action to cost of inaction in the 30-year period were high in Singida (29.5%), Lindi (29.4%), and Morogoro (28.2%) regions but lowest in Pemba South (15.3%), Mwanza (17.1%) and Pemba North (17.4%) regions. The returns from action were the highest in Pemba South ($6.5), Mwanza ($ 5.9) and Pemba North ($ 5.8) regions. The lowest returns from action were reported in Singida ($ 3.4), and Lindi ($3.4) districts.

Table 12: Cost of action and inaction against land degradation in Tanzania (million USD)

Region	Annual costs of Land Degradation	Annual costs of land degradation in terms of provisional ES only	Cost of Action (6 years)	Cost of Inaction (6 years)	Cost of Action (30 years)	Cost of Inaction (30 years)	Ratio of Cost of action: cost of Inaction (30 years)	Returns from action (30 years)
	Million USD						%	$
Arusha	56.032	30.290	0.880	2.479	0.882	3.356	26.3%	3.81
Pemba South	7.337	2.032	0.046	0.223	0.046	0.302	15.3%	6.53
Lindi	122.851	69.604	2.360	5.935	2.364	8.033	29.4%	3.40
Manyara	60.588	41.192	1.108	2.987	1.111	4.044	27.5%	3.64
Mara	42.107	14.759	0.417	1.523	0.418	2.061	20.3%	4.93
Mbeya	160.688	116.777	2.918	8.003	2.924	10.833	27.0%	3.70
Morogoro	297.369	171.086	5.195	13.621	5.204	18.438	28.2%	3.54
Mtwara	15.219	6.292	0.181	0.596	0.182	0.807	22.5%	4.45
Mwanza	70.762	23.992	0.551	2.387	0.552	3.231	17.1%	5.85
Pwani	129.504	62.931	2.139	5.711	2.142	7.731	27.7%	3.61
Rukwa	192.746	122.226	3.083	8.790	3.089	11.898	26.0%	3.85
Dar-Es-Salaam	6.371	2.661	0.070	0.246	0.070	0.333	21.0%	4.76
Ruvuma	214.386	144.504	3.592	10.002	3.599	13.539	26.6%	3.76
Shinyanga	44.896	20.818	0.504	1.737	0.506	2.352	21.5%	4.65
Singida,	55.587	29.423	1.055	2.644	1.056	3.578	29.5%	3.39
Tabora	100.566	73.526	1.839	5.037	1.842	6.817	27.0%	3.70
Tanga	161.926	88.442	2.541	7.113	2.545	9.628	26.4%	3.78
Zanzibar South	9.159	3.047	0.124	0.347	0.124	0.470	26.3%	3.80
Zanzibar West	3.225	0.903	0.038	0.116	0.038	0.157	24.2%	4.14
Dodoma	32.033	18.172	0.475	1.419	0.476	1.920	24.8%	4.03
Iringa	144.596	85.781	2.452	6.631	2.456	8.976	27.4%	3.65
Kagera	157.460	85.285	2.251	6.736	2.256	9.117	24.7%	4.04
Pemba North	8.569	2.397	0.064	0.273	0.064	0.369	17.4%	5.75
Unguja North	6.737	2.120	0.068	0.233	0.068	0.316	21.5%	4.65
Kigoma	157.616	79.468	2.014	6.140	2.017	8.311	24.3%	4.12
Kilimanjaro	36.721	20.272	0.598	1.634	0.599	2.212	27.1%	3.70
Total	**2295.05**	**1318.00**	**36.56**	**102.56**	**36.63**	**138.83**	**26.4%**	**3.79**

Source: Author’s compilation based on MODIS data.

5. Conclusions

Land degradation is increasingly becoming an important subject due to the increasing number of causes as well as its effects. Recent assessments show that land degradation affected 51%, 41%, 23% and 22% of the terrestrial areas in Tanzania, Malawi, Ethiopia and Kenya respectively. This paper demonstrates that the consequences and losses due to land degradation are enormous. Based on TEV framework, the costs of land degradation due to LUCC between 2001-2009 periods were $1.98 billion in Malawi, $10.65 billion in Kenya, $18.47 billion in Tanzania, to US$ 34.82 billion in Ethiopia. This represents about 5%, 7%, 14% and 23% of GDP in Kenya, Malawi, Tanzania and Ethiopia respectively. When these costs are converted to per hectare basis, they range from $38 in Ethiopia, $25 in Tanzania, $23 in Kenya and $21 in Malawi annually. The total annual costs of land degradation associated with use of land degradation practices in maize, wheat and rice croplands were about $305 million in Ethiopia, $270 million in Kenya, $162 million in Tanzania, and $114 million in Malawi. These costs on static cropland degradation are, however, conservative. Only three crops were considered, other aspects of land degradation common on a static biome (cropland) including soil erosion and salinity, and offside costs of pesticide use are not considered because of lack of data.

It is worthwhile to take action against land degradation. As expected, the TEV computation shows that the costs of action are lower as compared to costs of inaction against land degradation in all the countries both in a 6-year and a 30-year cycle. During the entire 30-year planning horizon, the cost of action is about $ 54.2 billion in Ethiopia, $ 36.6 billion in Tanzania, $ 18.1 billion in Kenya, and $ 4.3 billion in Malawi. However, if no action is taken to address land degradation over the 30-year period, it would lead to a loss of about $ 228 billion in Ethiopia, $ 139 billion in Tanzania, $ 75 billion in Kenya, and $ 16 billion in Malawi. These imply that the cost of action as a percent of cost of inaction represented about 24% in Ethiopia and Kenya, 26% in Malawi and Tanzania. Consequently, during the 30-year period, returns to investment in action against land degradation are at least four folds. Specifically, for every dollar spent on taking action against land degradation land users will expect a return of about $4.2 in Ethiopia, $4.1 in Kenya, $3.8 in Tanzania, and $3.7 in Malawi.

Policies and strategies that incentivize better sustainable land management and discourage deforestations ought to be emboldened so as to achieve UNCCD's target of zero net land degradation by year 2030. The costs of land degradation due to LUCC constitute the biggest proportion of the total costs of land degradation. Therefore, strategies and mechanisms must be developed to address LUCC such as payment for ecosystem services (PES) and participatory management of community resources such as forests and grazing lands.

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