Costs of land degradation in Eastern Africa

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Abstract:

Land degradation is a serious impediment to improving rural livelihoods in eastern Africa. This paper identifies land degradation patterns based on Land Use Cover Change and Normalized Difference Vegetation Index decline, 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. The cost of land degradation between 2001-2009 periods is about US$2 billion in Malawi, US$11 billion in Kenya, US$18 billion in Tanzania and US$35 billion in Malawi. These represent about 5%, 7%, 14% and 23%, of GDP in Kenya, Malawi, Tanzania and Ethiopia respectively. The costs of action as compared to the costs of inaction represented only about 23.7%, 24.1%, 26.0% and 26.2% in Ethiopia, Kenya, Malawi and Tanzania.

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 & Strout, 2004). 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).

The economic consequences of land degradation are severe in Eastern Africa because about 65% of the population is rural; with the main livelihood of about 90% of these rural populations is agricultural-based. 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 productivity for the Eastern African region (and at national level and plot/field level) is very scanty. Previous studies have no consensus on the exact amount of productivity losses 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 (MoFED 2010). 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 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). It is further estimated that 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 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 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 Strout (2004) 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).

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. The objectives of this study are twofold: firstly, to estimate the extent of land degradation, and secondly to determine the cost of land degradation in Eastern Africa. The study makes new contributions to literature by adopting the Millennium Ecosystem Assessment (MEA, 2005) definition of land degradation and using the Total Economic Value (TEV) approach to determine the value of land degradation.

2. Relevant Literature

The total population of Sub-Saharan Africa (SSA) is currently estimated at 750 million people (UNDP, 2005), but this is projected to grow past the one billion mark by 2020 (ibid). The region is the poorest in the world, with an estimated one in every three people living below the poverty line. The demand for food is putting greater pressures on the natural resource base. Assessments of land degradation in the region vary in methodology and outcome (Stoosnijder, 2007; Lal & Stewart, 2013; Zucca et al., 2014). The GLASOD survey, based on expert opinion, concluded that in the early 1980s about 16.7% of SSA experienced serious human-induced land degradation (Middleton & Thomas, 1992; Yalew, 2014). Using standardized criteria and expert judgment, Oldeman (1994) revealed that about 20% of SSA was affected by slight to extreme land degradation in 1990. These assessments were done based on 'experts' opinion and in varying time periods.

The data from the FAO TERRASTAT maps 67% (16.1 million km^2) of the total land area of SSA as degraded (FAO, 2000; **Table 1**), with country-to-country variations. These differences are quite large: Ethiopia is the most seriously affected (25% of territory degraded) while Kenya and Tanzania records 15% and 13%, respectively. Malawi is the least affected (9%). These figure for Tanzania (13%) is quite low compared to a later study (Assey et al., 2007) based on expert opinion that showed about 61% of the territory affected by land degradation. The TERRASTAT dataset allows the further classification of the degraded lands by the relative degree of severity of degradation. Thus the out of the 67% degraded land in SSA, the four sub-categories exist, namely; light (24%), moderate (18%), severe (15%), and very severe (10%). In contrast, the GLASOD data shows that about 25%, 14% and 13% of land area is degraded in Ethiopia, Kenya and Tanzania respectively. However, the main weakness of these studies is that it is based on subjective expert judgment and must be approached with caution. Following Vlek et al., (2010), the land degradation 'hotspots' map shows that Ethiopia, Kenya, Tanzania and Malawi are the most affected in the Eastern Africa region, thus we select them as our case studies countries.

<<**Table 1** >>

GLASOD global survey (Nachtergaele, 2006) and FAO`s global forest resource assessment (2005) identified six main types of land degradation predominant across SSA countries (**Table 2**). Among them, water and wind erosion are undoubtedly the most widespread type of land degradation (46% and 38% respectively), followed by chemical and physical deterioration of soils (16%). The other types of land degradation include salinization and water logging, decline in soil fertility, and loss of habitat (especially forest and woodland). Previous studies have not been successful in quantifying the extent and severity of these types of land degradation in East Africa. However, it is notable that water erosion, declining soil fertility and nutrient depletion are important in all the four countries. While salinization (especially of irrigated land) is severe in Kenya (30%) and Tanzania (27%), loss of forest and woodland in these countries is estimated at 0.7% per annum. In terms of population affected, available statistics show that declining soil fertility (with varying degree) affects almost every individual (100%), while water and soil erosion affects 97% and 18% of the total population respectively (ibid).

<<**Table 2** >>

The use of satellite–based imagery and remote sensing techniques to identify the magnitude and processes of land degradation at different levels has increased recently. This involves the use of Normalized Difference Vegetation Index (NDVI) derived from Advanced Very High-Resolution Radiometer (AVHRR) data. This approach was previously used by Evans & Geerken (2004), Bai et al. (2008), Hellden & Tottrup (2008), and Vlek et al. (2010). Using this technique, Bai et al., (2008) estimated that about 26% of Ethiopian territory was experiencing land degradation processes between the periods 1981-2003; affecting about 30% of the population over the same period.

Unlike this GLASOD and TERRASTAT assessment, Bai et al., (2008) estimated that about 24% of the global land area has been degrading in 25 years. Much of the areas they identify do not overlap with those indicated in the GLASSOD survey. However, Sub Saharan Africa region remains the most affected. Country estimates (**Table 3**) show that Tanzania was the most affected country; 41% of its land territory degraded. Ethiopia and Malawi both had 26% of their territories degraded while about 18% of Kenya land area was degraded in the same period. In terms of populations affected; about 40% and 36% of people in Tanzania and Kenya were directly affected by land degradation. Similarly, about 30% and 20% of the Ethiopian and Malawian population was affected by land degradation over the same period. It is however notable that these estimates do not take into account the effect of atmospheric fertilization, the rainfall factor and the effect of soil moisture in sparse vegetative areas.

<<Table 3 >>

Some costs and consequences of land degradation documented in literature for the Eastern Africa region are presented in **Table 4**. 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). It is further estimated that 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 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

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3. Conceptual framework and Empirical strategy

This study utilizes the Total Economic Value (TEV) approach–that captures the comprehensive definition of land degradation (**Figure 1**). TEV is broadly sub-divided into two categories; use and non-use values. 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. TEV approach is not without limitations[1]. 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 (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. These notwithstanding and following the Millennium Ecosystem Approach (MAE, 2005) which captures the comprehensive definition of land and land degradation, the TEV approach is thus appropriately applied to determine the costs of land degradation. Following Remoundou et al (2009), the TEV framework is represented in Figure 1.

<<Figure 1>>

Land and its ecosystem services are often undervalued because many of these services are not traded in the markets. Ideally, the ecosystem services should be considered as capital assets or natural capital (Daily et al. 2011a, Barbier 2011); failure to capture them leads higher rates of land

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

degradation. To adequately account for ecosystem services in decision making, the economic values of those services have to be determined. There exist various methods to evaluate ecosystem services (Barbier 2010, 2011a, 2011b, Nkonya et al. 2011), however, attributing economic values to ecosystem services is challenging, due to many unknowns and actual measurement constraints. The valuation of the natural capital, therefore, should follow three stages (Daily et al. 2000): i) evaluation of alternative options, for example, degrading soil ecosystem services verses their sustainable management, ii) measurement and identification of costs and benefits for each alternative, and iii) comparison of costs and benefits of each of the alternatives including their long-term effects (Daily et al. 2000). However, identifying and aggregating individual preferences and attached values to ecosystem services, for each alternative option, is not a straightforward task (Daily et al. 2000; Barbier 2010.) As economic values are linked to the number of (human) beneficiaries and the socioeconomic context, these services depend on local or regional conditions. This dependence contributes to the variability of the values (TEEB 2010).

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

4. Analytical Approach

We utilize the TEV analytical approach which assigns value to both tradable and non-tradable ecosystem services. We divide the causes of land degradation into two major groups and evaluate the cost for each:

(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 of ecosystem services). For example, change from one hectare of forest to one hectare of cropland could lead to a loss of ecosystem services since the TEV of a forest is usually higher than the TEV of cropland. 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 (2000) to end-line (2009) period). Due to data availability and time constraint, we focus on the cropland biome (maize, rice and wheat) in this study[2].

4.1 Cost of degradation due to LUCC

The cost of land degradation due to LUCC is given by:

$$C_{LUCC} = \sum_i^K (\Delta a_1 * p_1 - \Delta a_1 * p_2) \qquad \textbf{(1)}$$

where; C_{LUCC} = cost of land degradation due to LUCC; a_1 = land area of biome 1 (being replaced by biome 2) while a_2 = land area of biome 2; P_1 and P_2 are TEV per unit of area for biome 1 & 2 respectively.

2 The focus is on anthropogenic land, but due to the lack of relevant TEV data, we 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).

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.

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

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 study, we do so by analyzing the carbon sequestration due to sustainable land management (SLM) and compare this with land degrading 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 (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. DSSAT model was modified by incorporating a soil organic matter and residue module. The DSSAT model used in this study was designed to be more suitable for simulating low-input cropping systems and conducting long-term sustainability analyses.

We use two crop simulation scenarios:

(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;

$$\text{CLD} = (y^c - y^d)P * (A - A^c) + (y_1^c - y_2^c) * A^c)P - \tau\Delta CO_2 \qquad \textbf{(2)}$$

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.

We compute the net carbon sequestration after considering the amount of CO2 emission from nitrogen fertilization and from manure application. We focus on three major crops: maize, rice and wheat, which cover about 42% of cropland in the world (FAOSTAT 2013). DSSAT will simulate maize, rice and wheat yields at a half degree resolution, i.e., about 60km. To capture the long-term impacts of land management practices, the model will be run for 40 years.

4.3 Total cost of land degradation

We combine the total cost of land degradation from LUCC and from static land use as follows:

$$TCLD = \sum(C_{LUCC} + CLD + LLD) \qquad \textbf{(3)}$$

Where *TCLD* = total cost of land degradation; C_{LUCC} is cost of land degradation from LUCC; *LLD* = cost of land degrading due to use of land degrading management practices on a static biome. We express the total land degradation per year basis and assume that the rate of land degradation follows a linear trend. Hence the annual cost of land degradation will be expressed as:

$$TCLD_a = \frac{TCLD}{T} \tag{4}$$

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.

4.4 Cost of taking action against land degradation

The approach for determining the cost of action for degradation due to LUCC has to consider 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 (Torres et al., 2010). For example, if a forest was replaced with cropland, the cost of planting trees or allowing natural regeneration (if still feasible) and cost of maintaining the new plantation or protecting the trees until they reach maturity has to be taken into account. Additionally, the opportunity cost of the crops being foregone to replant trees or allow natural regeneration has to be taken into account. This means the cost of taking action against land degradation due to LUCC is given by:

$$CTA_{ia} = A_{ia}\frac{1}{\rho^t}\{z_i + \sum_{t=1}^{T}(x_i + p_j x_j)\} \tag{5}$$

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 $p_j x_j$ represents the opportunity cost of foregoing production of the low value biome *j* being replaced.

The cost of inaction will be the sum of annual losses due to land degradation

$$CI_{ia} = \sum_{t=1}^{T} C_{LUCC} \qquad (\mathbf{6})$$

where CI_i = cost of not taking action against degradation of biome *i* in agro-ecological zone *a*. Given that the benefit of restoring degraded land goes beyond the maturity period of biome *i*, we have to use the planning horizon of the land user. In this study, two time horizons are assumed; 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. Land users will take action against land degradation if $CTA_i < CI_{ia}$.

5. Results and discussions

5.1 Extent of Land Degradation based due to NDVI decline

More recently, Le, Nkonya and Mirzabaev (2014) analyzed global land degradation using decline in NDVI over 1982-2006 period by main land cover/use types counted globally for each country. Unlike Bai et al., (2008) they carry out a number of adjustments to the data such as correction of RF (rainfall factor) and AF (atmospheric fertilization), and account for seasonal variations in vegetation phenology. The land degradation hotspots in Eastern Africa are presented in Figure 2.

<<Figure 2>>

The results (**Table 5**) show that a total of about 453,888km^2 (51%) and 38,912 km^2 (41%) of Tanzania's and Malawi's land area was degraded respectively. In Ethiopia, land degradation was reported in about 228,160 km^2 (23%) and just about 127,424 km^2 (22%) in Kenya. These areas varied across the main land cover-land use type by country. For example, in Ethiopia much of degradation (32%) was experienced in areas with sparse vegetation, in Kenya the highest proportion of degradation was experienced in forested areas (46%) while shrub-land and mosaic vegetation and crop each had 42%. In Malawi highest proportion of degradation was experienced in mosaic forest- shrub/grass (57%) and grasslands (56%) while in Tanzania 76% of degradation reported in degradation was experienced in mosaic forest- shrub/grass and in grasslands.

<<Table 5>>

5.2 Extent of Land Degradation in eastern Africa due to LUCC

Land degradation can occur in two ways – either through productivity decline as a result of such factors as soil erosion, nutrient depletion and mining or changes in land use/land cover (i.e. from more economically and environmentally productive land uses/covers to a less economically and environmentally one). Based on high quality satellite data from Moderate Resolution Imaging Spectroradiometer (MODIS), we discuss changes in land use and cover for Ethiopia, Kenya, Malawi and Tanzania during the 2001 and 2009 period in **Table 6**. Generally, results (Table 5) show significant increase in the cropped area (12%) and grasslands (11%). Significant reductions are reported in forests (23%), bare-land (17%), shrub-lands (4%) and water (3%). Country specific estimates for area changes in hectares and in percentages are presented below. The numbers in parentheses are percentages changes between 2000 and 2009. We present detail changes by region or district at country level in next pages.

<<Table 6>>

5.3 Cost of land degradation due to Land Use Cover Change

We report the total terrestrial ecosystem value and the loss of ecosystems values due to LUCC in **Table 7**. The total TEV for the four countries is estimated at 2007 US$ 582.23 billion/year. This ranged from US$ 24.98 billion/year in Malawi, US$ 127.73 billion/year in Kenya, US$ 206.41 billion/year in Ethiopia, to US$ 223.104 billion/year in Tanzania. Based on the 2007 USD, the GDP values ranged from US$ 3.6 billion in Malawi, US$16.8 billion in Tanzania, US$19.3 billion in Ethiopia, to US$ 27.2 billion/year in Kenya. The annual average cost of land degradation due to LUCC in the four countries was 2007 US$65.92 billion/year. The figures ranged from US$ 1.98 billion in Malawi, US$110.65 billion in Kenya, US$18.47 billion in Tanzania, to US$ 34.82 billion/year in Ethiopia.

To provide a better visibility, we present the average annual costs of land degradation as a percentage of both GDP and TEV. The cost the cost of land degradation for the four countries is about 98% of GDP and about 11% of the TEV. These values are varied across the case study countries; the cost of land degradation is higher than the GDP of 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 (7.9%), followed by Kenya and Tanzania (both reporting 8.3%) but highest in Ethiopia (16.9%).

<<Table 7>>

We compare the cost of land degradation by separating the losses in ecosystem services into two major components: firstly, the provisioning services – which have direct impact on land users; and secondly, the other ecosystem services (regulating, habitat and cultural services) – which include both global benefits and indirect local benefit.

Figure 3 shows that loss of provisioning services account for about 55% of the cost of land degradation while the loss of regulating, habitat and cultural services accounted for 45% of the total losses. These losses were varied by country: higher losses in provisioning services were reported in Malawi and Tanzania (65% and 60% respectively), while the losses in provisioning services were reported at 57% and 52% in Kenya and Ethiopia respectively. This suggests that about half of the costs of and degradation is borne 'outside' community.

<<Figure 3>>

5.4 Cost of land degradation due to use of land degrading practices

Table 8 shows the simulated results of rain-fed maize yield under business-as-usual and ISFM scenarios for a period of forty years. The average maize yield in the four selected countries of Eastern Africa is 2.2tons/ha (baseline) and 1.63tons/ha (end-line) BAU scenario. This implies that the use of land degrading management practices on rain-fed maize leads to a 26% fall in yield compared to yield in the past 30 years. The highest yield decline is reported for Malawi (34%) and Tanzania (27%), followed by Ethiopia (25%) and Kenya (17%). Results further show that average maize yield are higher under ISFM – 2.4tons/ha (baseline) and 2.1tons/ha (end-line) periods. This represents a decline of about 14% compared to yield in the past 30 years. Under the ISFM scenario, the biggest yield decline is reported in Malawi (23%) and Tanzania (16%), followed by Ethiopia (12%) and Kenya (3%). On average the use of land degrading management practices on rain-fed maize leads to a 28% decline in yield as compared to yield the previous 30 years in the four countries. At country level, the yield decline is high in Ethiopia (36%) and Kenya (32%) followed by Malawi (22%) and Tanzania (22%).

Similarly, analysis show that the use of land degrading management practices on irrigated rice leads to a 9% decline in yield as compared to yield the previous 30 years in the three countries (Table 4). At country level, the yield decline is high in Kenya (32%) and Malawi (16%) and least in Tanzania (8%). Further, analysis show that the use of land degrading management practices on rain-fed wheat leads to a 23% decline in yield as compared to yield the previous 30 years in the four countries (Table 5). At country level, the yield decline is high in Kenya (32%), Ethiopia (25%) and Tanzania (6%) and least in Malawi (0.2%).

<<Table 8>>

The cost of land degradation for the three crops is about US$14 million per year (**Table 9**); US$5.7 million in Malawi, US$5.6 million in Kenya US$1.8 million in Tanzania and US$1.1 million in Ethiopia. When these losses are expressed as percent of GDP, the four countries lose about 0.02% of the GDP annually as a result of cropland degradation. At country level Malawi is the most severely affect by cropland degradation – loses about 0.2% of its GDP annually. Similarly, Kenya loses about 0.02%, while Tanzania and Ethiopia each lose about 0.01% of GDP. Statistics show that the three crops (maize, rice and wheat) account for about 42% of the cropland globally. Assuming that the levels of degradation is comparable to that occurring on the three major crops, then the total cost of land degradation on cropland is about 0.1% of GDP in the four countries (**Table 9**).

<<Table 9>>

These costs range from 0.01% in Ethiopia, 0.03%in Tanzania, 0.05 in Kenya to 0.4% in Malawi. The costs of land degradation due soil fertility mining reported in Table 6 are conservative. 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. The DSSAT data used in this study also assumes higher BAU fertilizer application rates – this reduces the actual costs of land degradation.

5.5 Total Cost of land degradation

Table 10 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 biome and these costs as a percent of GDP. The total annual costs of land degradation for the four countries are US$ 80 million representing about 15% of the GDP. The total costs are the highest in Malawi (26%) and Ethiopia (23%) followed by Tanzania (15%) and the least in Kenya (8%).

<<Table 10>>

5.6 Cost of action against land degradation

We present 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. As Nkonya et al (2013) note, an action against land degradation will be taken if the cost of inaction is greater than the cost of taking action. To completely rehabilitate land degradation due to LUCC in the four countries, a total of US$112.15 billion will be required in six years (**Table 11**). But if no action is taken to rehabilitated degraded lands it would lead to a loss of US$338.09 billion over the same time period. The cost of action represents just about 33.2% of the cost of inaction in a 6-year time period. At country level, the ratio costs of action to cost of inaction is 32% in Ethiopia, 33% in Kenya, 35% in Malawi and 35% in Tanzania. This means that during the first six years, for every dollar spent on taking action against land degradation users will expect about US$ 3.

During the entire 30-year planning horizon, the cost of action is US$112.4 billion while the cost of inaction is US$457.6 billion. The cost of action represents about 25% of the cost of inaction. At the country level, the cost of action against land degradation ranged from US$4 billion in Malawi to US$54 billion in Ethiopia. Similarly, the cost of inaction against land degradation ranged from US$15.6 billion in Malawi, US$74.9 billion in Kenya, US$138.8 billion in Tanzania, to US$228.3 billion in Ethiopia. These imply that the cost of action represented about 23.7% in Ethiopia, 24.1% in Kenya, 26% in Malawi and 26.1% in Tanzania. This implies that at the end of 30-year period, the returns to taking action against land degradation are about US$4 for each dollar invested.

The opportunity cost accounts of taking action accounts for over 98 % of the total cost of action in the first six years in all countries. This suggests there is a large opportunity cost of taking action against land degradation. Over the 30-year planning horizon, the cost of action falls dramatically once the opportunity cost is dropped at the establishment period. This means it is the establishment period that matters most. The returns to taking action against land degradation are high.

<<Table 11>>

6. Conclusions and policy implications

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. Losses due to land degradation are enormous. The costs of land degradation due to LUCC between 2001-2009 period based on TEV framework amount to about US$2 billion in Malawi and US$18 billion in Tanzania – representing about 6.8% and 13.7% of GDP in Malawi and Tanzania respectively. It is worthwhile to take action against land degradation. 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. This implies that the costs of action as compared to the costs of inaction represented only about 23.7%, 24.1%, 26.0% and 26.2% in Ethiopia, Kenya, Malawi and Tanzania. Therefore for each dollar spent to control/prevent land degradation, it returns about 4.3 dollars, 4.8 dollars, 4.2dollars and 3.8 dollars in Malawi, Kenya, Ethiopia and Tanzania respectively. Use of land degrading practices in croplands (maize, rice and wheat) resulted in losses amounting to US$5.7 million in Malawi and US$1.8 million in Tanzania – 0.2% of GDP in Malawi and 0.01% of GDP in Tanzania. These costs are, however, conservative. We consider only three crops, 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.

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List of Tables

Table 1: Land degradation severity in Eastern Africa

	Land area (%) affected by degradation					Total Degraded Area (%)	
Country	None	Lightly	Moderately	Severely	Very severely	TERRASTAT	GLASOD
Ethiopia	75	0.3	12.7	2.1	10.4	95	25.4
Kenya	85	1.0	3.9	5.7	4.1	93	14.6
Malawi	92	0.1	8.4	0.0	0.0	61	8.5
Tanzania	87	2.5	5.4	5.2	0.4	87	13.4
SSA	83	0.96	3.4	5.1	7.3	67	16.7
Global	83	1.4	4.1	6.8	4.4	64	16.7

Source: Adopted from UNEP/ISRIC, 1991 & FAO, 2000.

Table 2: Land degradation types and extent in Sub Saharan Africa

Type of land degradation	Affected land (% of total)	Affected population (% of total)	Countries affected	Main cause(s)
Water Erosion	46	97	All countries in eastern Africa (Kenya, Tanzania, Ethiopia, Malawi, Zambia)	Deforestation, overgrazing, agric. practices
Wind Erosion	38	18	Botswana, Chad, Djibouti, Eritrea, Mali, Niger, South Africa and Sudan	Overgrazing, deforestation
Salinization			Severe in Kenya (30%), Tanzania (27%)	Water management
Soil fertility and nutrient depletion	Approx. 100	Approx. 100	All countries	Agric. practices, overgrazing, deforestation,
Loss of Habitat (Deforestation)	0.7% of annual change of Forest & Woodland area in East & Southern Africa		Hotspots: Burundi (-5.2%), Comoros (-7%), Nigeria (-3.3%), Togo (-4.5%), Uganda (-2.2%), Zimbabwe (-1.7%)	Deforestation, overgrazing, agricultural practices

Source: Adopted from FAO Global Forest Resource Assessment (2005) and Nachtergaele, (2006).

Table 3: Statistics of degrading areas for Eastern Africa (1981–2003)

Country	Degrading area (km2)	% Territory	% Global degrading area	Total NPP loss (ton C⁄23 years)	% Total population	Affected people
Ethiopia	296812	26.33	0.843	14276064.5	29.10	20650316
Kenya	104994	18.02	0.294	6612571.4	35.59	11803311
Malawi	30869	26.05	0.089	1370894.6	19.89	2486085
Tanzania	386256	40.87	1.081	22603896.1	39.48	15300003

Source: Adapted from Bai *et al.,* 2008.

Table 4: 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	- Between 4-7% of land area of SSA is severely degraded (GLASOD & TERRASTAT, 2006). - Estimated average annual losses per hectare in 37 SSA countries are 22 kg of N, 2.5 kg of P and 15 kg of K (Sanchez, 2002). For the last 3 decades, replacing these lost nutrients by purchasing fertilizers would cost about US $4 billion. - Average annual soil nutrient losses of 23 kg/ha from 1980s-1990s increased to 48 kg/ha in 2000 (FAO, 2006). - It is estimated that about 1 billion tons of topsoil is lost annually in Ethiopia (MoFED, 2010). - Loss of soil by water erosion in Kenya estimated at 72 tons per hectare per year; and - Tanzania 105 tons/ha/year in 1960's and 224 tons/ha/year, 1980's- 2000's (de Graff, 1993)
Salinization	- Loss of irrigated lands due to salinization in Kenya (30% of irrigated land), Liniger *et al.*, 2011. - Loss of irrigated lands due to salinization in Tanzania (27% of irrigated land) (ibid)
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 percent 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 to 40% (a mean of 6.2%) for SSA (Lal, 1995). - Annual yield losses for specific crops varied from 4-11% in Malawi (World Bank, 1992 - Field survey in Tanzania: Yields were 30% higher in least eroded areas (Kilasara *et al.*, 1995).
Loss of forest resources	- 3.7 million ha (0.7% of the total SSA land area) lost annually (rising demand for farm land, timber, charcoal). - 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).

Loss of biodiversity resources	- 126 African animal species have become extinct2 and a further 2,018 are threatened. - Some 125 plant species are recorded as extinct and close to 2,000 more are threatened, of which some 250 are critically endangered in SSA. (IUCN, 2006)
Increased food insecurity, hunger and malnutrition	- 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 (World Bank, 2007) - At the end of the 1990's; over 20% of the populations in 30 African countries were undernourished, chronic hunger reported in over 35% of the population in18 countries (ibid). - Malnutrition was expected to increase by an average of 32% (UNDP, 2006).
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% of the total number of rural poor are currently residing on marginal and degrading lands (Scherr, 2007)

Source: Kirui and Mirzabaev, 2014.

Table 5: Area (km^2 and percentage) of long-term (1982-2006) NDVI decline

	Area (km^2) of NDVI decline and in percentages for the corresponding land use							
Country	Cropland	Mosaic vegetation-crop	Forested land	Mosaic forest-shrub/grass	Shrub land	Grassland	Sparse vegetation	*Total*
Ethiopia	35904 (18%)	30976 (19%)	9984 (16%)	59776 (27%)	37824 (20%)	7808 (14%)	45888 (32%)	228160 (23%)
Kenya	15808 (31%)	40512 (42%)	21568 (46%)	9664 (10%)	21952 (42%)	15232 (18%)	2688 (4%)	127424 (22%)
Malawi	576 (50%)	6720 (31%)	11072 (34%)	1088 (57%)	17984 (51%)	1472 (56%)	N/A	38912 (41%)
Tanzania	12608 (32%)	112768 (62%)	139968 (36%)	18688 (76%)	93504 (70%)	75712 (76%)	640 (30%)	453888 (51%)

Source: Adapted from Le, Nkonya & Mirzabaev (2014).

Table 6: Change in land area of terrestrial biomes between 2001- 2009 (*Hactares*)

Country	Forest	Cropland	Grassland	Woodland	Bare land	Water	Urban
Ethiopia	-1412899 (-25.8%)	2783381 (32.7%)	-3035811 (-10.7%)	-333918 (-1.8%)	-696317 (-12.3%)	-49838 (-7.8%)	82 (0.01%)
Kenya	-456636 (-22.5%)	955321 (27.7%)	10500000 (29.2%)	488149 (9.3%)	-673523 (-32.3%)	-78195 (-6.7%)	-492 (-0.8%)
Malawi	30597 (7.7%)	-52749 (-33.5%)	1042056 (18.3%)	-959338 (-30.9%)	6341 (56.9%)	-1544 (-0.1%)	0 (0%)
Tanzania	-1479437 (-23.1%)	-1724502 (-36.9%)	6125137 (9.7%)	-2066826 (-5.5%)	26265 (29.3%)	-164233 (-2.8%)	-1421 (-1.5%)
Total	**-3318375 (-23.2%)**	**1961450 (11.70%)**	**14700000 (10.9%)**	**-2871934 (-4.2%)**	**-1337233 (-17.1%)**	**-293810 (-2.9%)**	**-1831 (-0.8%)**

Note: Change in area = $Area_{2009} - Area_{2001}$.
Source: Authors compilation (based on Nkonya et al., 2014).

Table 7: Terrestrial ecosystem value and cost of land degradation due to LUCC

Country	GDP 2007 US$ billion	TEV 2007 US$ billion	Costs of land degradation due to LUCC	Cost of LD as % of 2007 GDP	Cost of LD as % of TEV of ES
	2007 US$ billion/year				
Ethiopia	19.346	206.409	34.825	22.5%	16.9%
Kenya	27.236	127.737	10.645	4.9%	8.3%
Malawi	3.647	24.981	1.980	6.8%	7.9%
Tanzania	16.825	223.104	18.474	13.7%	8.3%
Total	**67.05**	**582.23**	**65.92**	**12.3%**	**11.3%**

Source: TEV and Land Degradation –Authors' compilation; GDP –World Bank data

Table 8: Change in maize, rice and wheat yields under BAU and ISFM – DSSAT results

	BAU		ISFM		Yield Change (%)		Change due to land degradation
	Baseline	End-line	Baseline	End-line	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
Total	**2.20**	**1.63**	**2.43**	**2.09**	**-25.9**	**-14.3**	**28.0**
				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
Total	**5.88**	**4.14**	**6.20**	**4.53**	**-29.5**	**-27.0**	**9.3**
				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
Total	**1.44**	**1.20**	**1.55**	**1.47**	**-17.0**	**-5.2**	**22.8**

Note: y_1 = Baseline yield (average first 10 years); y_2 = Yield end-line period (average last 10 years). y_2^c = ISFM yield in the last 10 years; y_2^d = BAU yield, last 10 years.

Source: Authors' compilation

Table 9: Cost of soil fertility mining on static maize, rice & wheat cropland – DSSAT results

Country	Cost of land degradation (soil fertility mining)	Cost as % of GDP	Cost of cropland degradation as % GDP
	2007 US$ million	(%)	(%)
Ethiopia	1.14	0.0059	0.014
Kenya	5.63	0.0207	0.049
Malawi	5.67	0.1554	0.370
Tanzania	1.76	0.0104	0.025
Total	**14.21**	**0.02**	**0.05**

Source: Authors' compilation

Table 10: Total cost of land degradation (cost on static biome and cost due to LUCC)

	Cost of land degradation on static biome (cropland)	Cost of land degradation due to LUCC	Total Cost of land degradation	Total cost of land degradation as % of GDP
Country	2007 US$ million	2007 US$ million	2007 US$ million	%
Ethiopia	1.14	34.825	35.96	23.2
Kenya	5.63	10.645	16.28	7.5
Malawi	5.67	1.98	7.65	26.2
Tanzania	1.76	18.474	20.23	15.0
Total	**14.20**	**65.92**	**80.12**	**14.9**

Source: Authors' compilation

Table 11: Cost of action & inaction against LUCC-related land degradation (2007 US$ billion)

Country	Cost of Action	Cost of Inaction	Cost of Action as % cost of Inaction	Cost of Action	Cost of Inaction	Cost of Action as % cost of Inaction	Opportunity cost of action	Opportunity cost of action (% cost of action)
	First 6 years			30–years horizon			First 6 years	
Ethiopia	53.900	168.674	32.0	54.028	228.317	23.7	53.215	98.5
Kenya	18.027	55.326	32.6	18.067	74.889	24.1	17.767	98.3
Malawi	4.044	11.525	35.1	4.051	15.600	26.0	4.191	103.5
Tanzania	36.182	102.563	35.3	36.250	138.829	26.1	36.091	99.6
Total	**112.15**	**338.09**	**33.2**	**112.39**	**457.64**	**24.6**	**111.26**	**98.9**

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

Source: Authors' compilation based on Nkonya et al. (2014), using MODIS data.

List of Figures

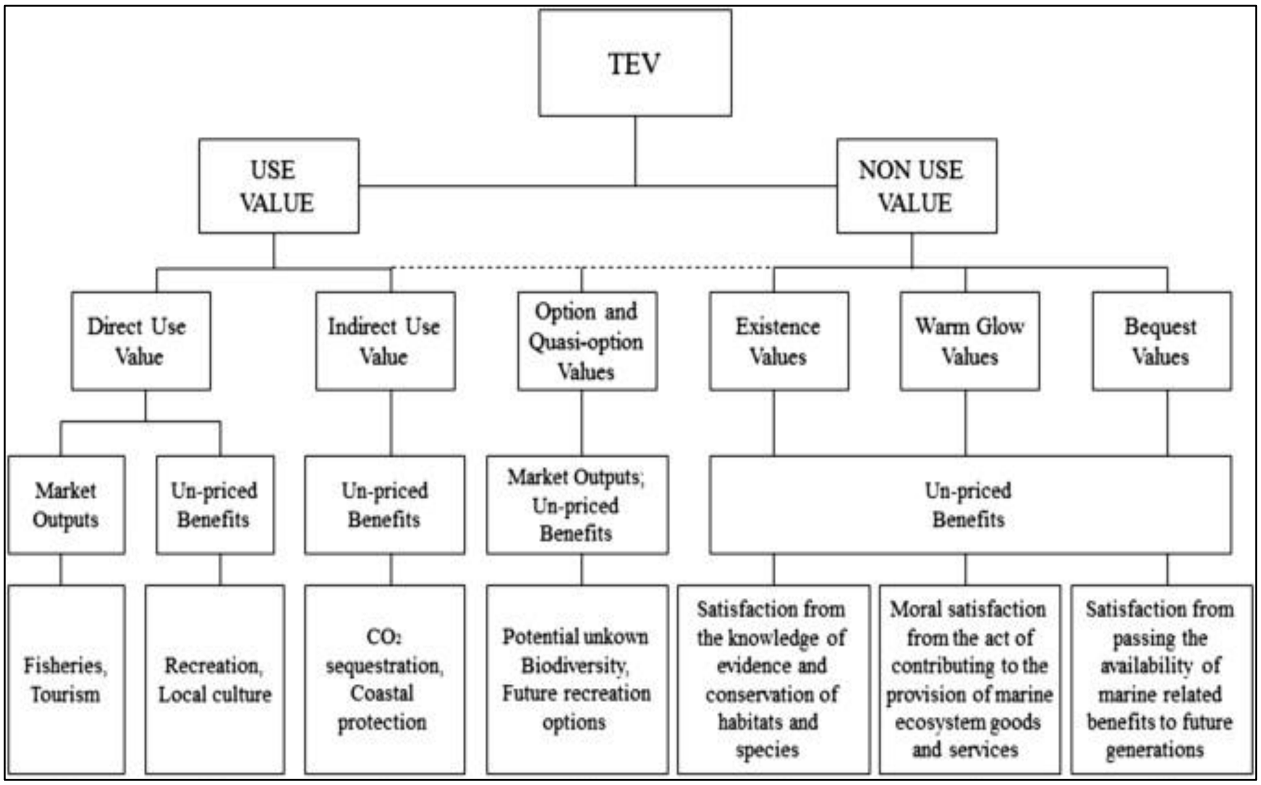

Figure 1: Total Economic Value
Source: Adapted from Remoundou et al (2009).

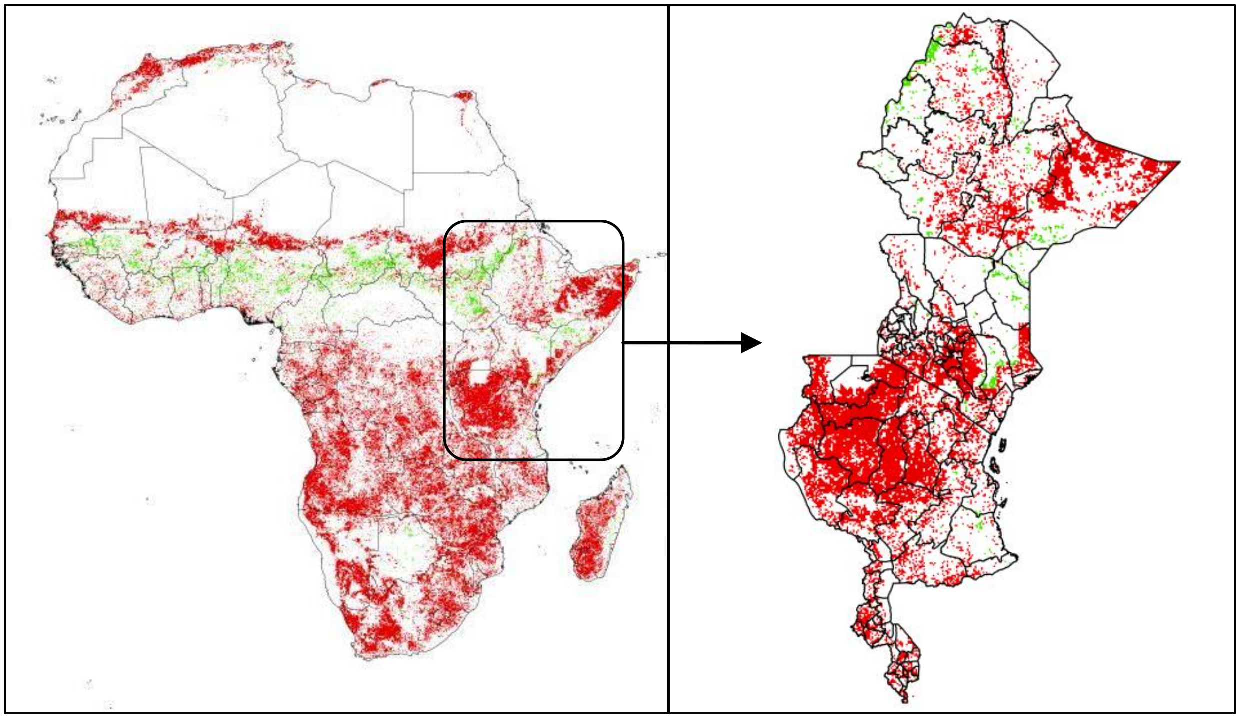

Figure 2: Biomass productivity decline in Eastern Africa over 1982-2006.
Source: Adapted from Le, Nkonya & Mirzabaev (2014).

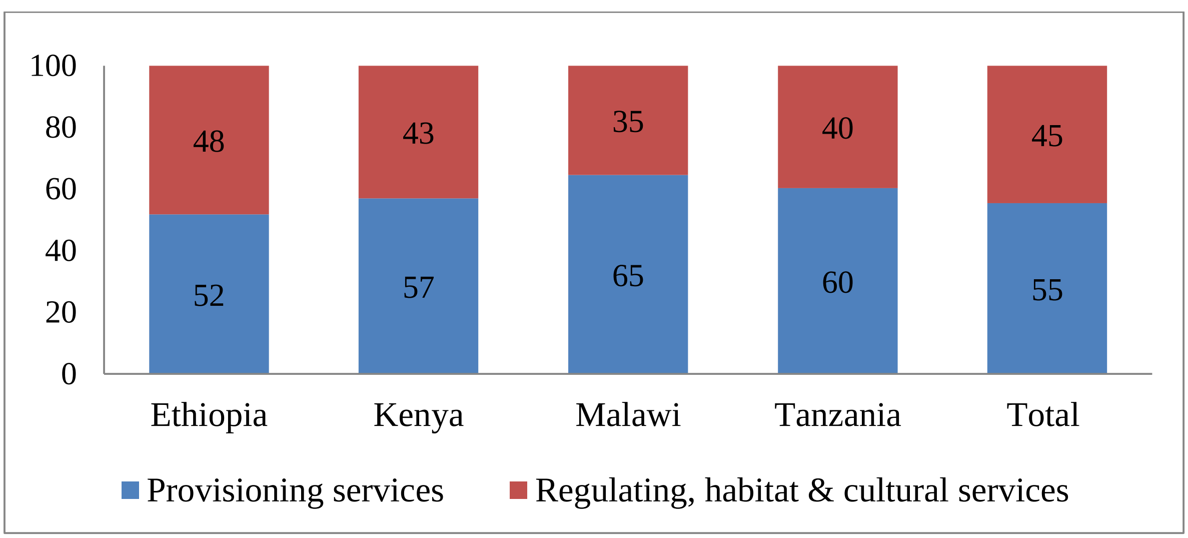

Figure 3: Provisioning verses other components of cost of land degradation
Source: Authors' compilation.