THE ECONOMICS OF LAND DEGRADATION

# Economics of Land Degradation Initiative: **Kenya Project Report**

## Costs and benefits of sustainable soil fertility management in Western Kenya

www.eld-initiative.org

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# Acronyms and abbreviations

| | |
|---|---|
| **AEZ** | Agro Ecological Zone |
| **AIS** | Agricultural Innovation System |
| **BCR** | Benefits-Cost Ratio |
| **CBA** | Cost-Benefit Analysis |
| **ELD** | Economics of Land Degradation Initiative |
| **FAO** | Food and Agriculture Organisation of the United Nations |
| **FSA** | Farm Systems Analysis |
| **GIS** | Geographical Information System |
| **LM** | Lower Midland |
| **NPV** | Net Present Value |
| **PES** | Payment for Ecosystem Services |
| **ROI** | Return on Investment |
| **SD** | Standard Deviation |
| **SLM** | Sustainable Land Management |
| **WEO** | Ward Extension Officer |
| **WOCAT** | World Overview of Conservation Approaches and Technologies |

# Executive summary

Kenya's soils are being degraded through sub-optimal land management practices, causing declining yields and deterioration of land quality. Sustainable Land Management (SLM) practices can improve soil quality and enhance crop yields. Increasing evidence from the literature highlights the benefits from SLM, but for land users to adopt these practices requires higher net returns on their investments, lower risks, or both. There is also a need to balance costs and benefits over the short and long term. In this study we set out to understand the variation in SLM uptake and to characterize farmers that are more likely to use SLM practices. We also undertake a cost-benefit analysis (CBA) to identify when it makes economic sense for a farmer to implement particular SLM practices and how long it takes before total benefits outweigh total costs. On the basis of this information, we provide policy recommendations as to how interventions might improve uptake if benefits only materialize over the longer term (up to 2030). We follow the Economics of Land Degradation (ELD) Initiative's 6+1 step methodology. We draw on farming system analysis survey data collected through the *GIZ Food Security Programme* from Bungoma, Kakamega and Siaya counties in Western Kenya, interviews with ward extension officers (WEOs) and information from stakeholder workshops. Data are analysed using regression and CBA techniques.

We find that what determines SLM uptake varies between the three counties and according to the SLM practice of interest. Farms where the head of the household is female are more likely to uptake any SLM practice. In Siaya, an SLM practice is more likely to be used where more of the farm is owned and more of the labour used on the farm is from family members. Although we might expect that experience of soil degradation might drive farmers to use SLM practices, there is no simple pattern. Farmers who reported experiencing land degradation are more likely to undertake intercropping but less likely to practice manuring. In terms of access to assets and advice, key variables include membership of agricultural groups or projects, contact with advisers and access to machinery or farm buildings. More recent contact with advisers is related to a greater likelihood of SLM uptake and use of manure. However, the picture with group membership is less clear: in Kakamega and Siaya it leads to increased SLM uptake, but it is not important in Bungoma. Conversely, farmers are less likely to use manure if they are a member of an agricultural group or project.

CBA findings also present a mixed picture. SLM practices with low input costs, such as manuring and intercropping, offer very high benefit to cost ratios for farmers and they provide a positive net present value over the time horizon of the *Kenya Vision 2030*. This suggests that these kinds of simple practices should be prioritised within policy or at least promoted in tandem with those that take longer for benefits to accrue. SLM practices with high upfront costs and high maintenance costs, such as physical terraces and agroforestry, can offer much lower benefit to cost ratios for individual farmers and have a long return on investment period, even though over the time horizon considered, their Net Present Value (NPV) can be positive (depending on the discount rate used). Not all perceived benefits were quantifiable in terms of yields. Some farmers engaged in agroforestry because they perceived benefits for the soil and for water retention, even though they considered it made little short-term difference to crop yields. Had the research looked at wider scale societal values and ecosystem services beyond maize crop yields, different output data are likely.

**Recommendations building from the study findings include: i) extending subsidies to include support for SLM practices that show universal benefits; ii) further investigation into publically-funded payment for ecosystem services schemes and research into other economic measures to support delivery of societal benefits; iii) support for Agricultural Innovation Systems; iv) improved monitoring of land management and yield relationships, building farmer capacity and considering use of mobile phone based monitoring approaches and v) investment in improved climate and soil information services and facilities.**

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# Introduction

Land is a broad term that refers to the Earth's terrestrial areas. It includes soil, vegetation and water, humans and other species, which together form socio-ecological systems (WOCAT, 2016). However, the quality of land is declining across the world. Land degradation is characterised by persistent reduction in productivity and takes a variety of forms across many different systems (Adeel et al., 2005). For example, erosion by wind and water results in increased sediment loading of water bodies and loss of soil fertility in agricultural systems; deforestation of woodland systems results in losses of important habitat and net primary productivity; while reduced ground cover and declining carrying capacity of pastures reduces production within pastoral systems. In this report we focus on soil as a key component of land within agricultural systems.

Land and soil degradation are driven by a range of different processes that operate over multiple temporal and spatial scales (Carpenter and Turner, 2000). Global scale biophysical factors (e.g. climate, soil, topography and hydrological patterns) are overlain with social, political and economic structures and processes (e.g. markets, technological change, population and demographic changes), which together shape decision-making at the smaller scales at which degradation is experienced (Stringer et al., 2007). The overall outcomes of land and soil degradation are both ecologically and socially negative. Degradation disrupts ecosystem health, functions, processes, integrity and services; diminishes food and livelihood security; as well as undermining capacities to adapt to climate variability and change. The rural poor often disproportionately bear the burden of these negative impacts (Nkonya et al., 2008; Warren, 2002), particularly where they have few other options for survival than to depend on the natural resource base for food and water.

Soil degradation is promoted by inappropriate agricultural practices such as continuous cropping and inadequate application of inputs such as manure. Degradation can also be intensified by climate change processes, for example, due to changing frequency and timing of rainfall, which can increase erosion (Reed and Stringer, 2016). In this context, finding solutions to prevent, halt and reverse soil degradation becomes vital. Identifying actions that can support solutions to degradation and promote their uptake is particularly important in agricultural nations such as Kenya, where over 12 million people inhabit areas that are considered degraded (Le et al., 2014). Estimates of the severity of the degradation challenge Kenya faces depends on the methodologies and data sets that are employed in the calculations. However, Kirui and Mirzabaev (2014) raise grave concerns that more than 20% of the country's land area is severely or very severely degraded.

Kenya's soils are currently suffering from degradation in the form of nutrient depletion, acidification and erosion, all of which affect the ability of the land to support agricultural production. Sub-optimal land management practices are thought to play a key role in declining yields (Vlek et al., 2010). The Government of Kenya, in its *Kenya Vision 2030*, recognises the need to increase productivity in the agricultural sector if food security is to be maintained and enhanced, and if food demands from a rapidly increasing population are to be met. However, on-going agricultural yield declines put the achievement of this vision at risk, and for more than a decade the country has experienced a downward production trend (Gicheru, 2012). Land degradation and soil fertility losses are considered to be a key factor in the Kenya Government's failure to achieve its food production goals (Vlek et al., 2010).

Despite the gravity of the current situation in Kenya, there are many actions that can be taken to reverse the degradation trend and yield declines. Such actions are not just important at the national level but can help the country to progress towards the Sustainable Development Goals, in particular target 15.3: "By 2030, combat desertification,

restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world" (UNGA, 2015). One set of possible solutions is found in Sustainable Land Management (SLM). SLM can be defined as "the use of land resources, including soils, water, animals and plants, for the production of goods to meet changing human needs, while simultaneously ensuring the long-term productive potential of these resources and the maintenance of their environmental functions" (WOCAT, 2016).

SLM is grounded in the principles of improving water use efficiency and water productivity; improving soil fertility; managing vegetation; and attending to microclimatic conditions (Liniger et al., 2011). SLM practices therefore seek to reduce water losses (from runoff and evaporation) by enhancing water harvesting, infiltration and water storage, and improving irrigation and managing surplus water. They increase soil fertility by improving surface cover using crop rotation, fallowing, intercropping, applying animal/green manure, composting (ideally as part of an integrated crop-tree-livestock system), and by applying supplementary inorganic fertilizer as needed. SLM practices can also trap sediments and nutrients through the use of vegetative and structural barriers. Microclimatic conditions can be addressed through the use of windbreaks, shelterbelts and trees for shade (via agroforestry and multi-storey cropping) (Liniger et al., 2011). Globally, the wide variety of SLM practices that smallholder farmers implement have been characterised by WOCAT (www.wocat.net). Not all SLM practices target each of the variables listed above, and they can be employed individually or in combination, depending on factors such as tradition, suitability in light of crop choices and the terrain. Each SLM practice also has a unique set of costs and benefits (perceived and actual (Giger et al., 2015)). While the literature provides an increasing body of evidence (from Kenya and elsewhere) that SLM can be effectively employed to improve soil quality and increase crop production (Tesfaye et al., 2016; Mirzabaev et al., 2016; Kassie et al., 2014; KARI, 2006; Lutz et al., 1994), for land users to adopt SLM requires them to gain a higher net return on their investments, lower their risks, or both (Liniger et al., 2011). There is also a need to balance costs and benefits over different time scales (short and long term).

A recent global assessment suggested that it is considerably more cost-effective to take SLM actions to reduce and prevent degradation than it is to attempt to restore areas that have been allowed to degrade. For instance, just in Africa, preventing top soil loss to increase crop productivity can have benefits of ~USD 1 trillion over the next 15 years. The alternative of doing nothing carries costs of double this (ELD, 2015). Such global level studies play a central role in raising awareness of decision makers as to the magnitude of the land degradation issue, the urgency with which it needs to be addressed and the high economic costs of inaction. However, they need to be complemented with more in-depth, nuanced analyses that unpack the types of SLM practices being used, their effectiveness and their scale of use. Such sub-national scale studies are also important in identifying the resource gaps that land users face (e.g. tools and inputs, labour, awareness, knowledge and capacity) as well as highlighting local cultural values and norms that act as barriers to uptake, and return on investment periods where bridging mechanisms might be needed (Shiferaw and Holden, 2001). By identifying where the gaps are it opens up opportunities for policies to tackle them.

Scale is also important because many of the costs and benefits of SLM accrue to individual farm households (Emerton, 2014). Benefits include increased crop yields and improved resilience to drought (e.g. through improved water holding capacity of the soil). Costs include the time and labour investments needed to e.g. construct *Fanya-juu* (a form of physical terrace). Other costs and benefits are experienced at wider scales, accruing to society more broadly. Benefits of SLM to society include improved water-related ecosystem services (e. g. flood control and water purification), increased carbon sequestration (which regulates the climate), as well as enhanced national food security. Costs of inaction to address degradation include increased reliance on expensive food imports and social protection, as well as increased vulnerability to climate change and other shocks and stresses.

Most land management decisions take place at the level of individual household farm systems. This means it is essential to understand variations in farming systems, SLM practice use and soil fertility at this scale, especially because land users are unlikely to take into account wider societal benefits in their decision making. At the same time, the cumulative impact of local land management decisions ultimately determines whether a ward, county or country is on an upward or downward soil quality trajectory. Interventions at the national level, through development of relevant policies and economic and financial instruments, can play a key role in shaping local decisions to prevent, reduce and reverse degradation. Through appropriate policy and institutional frameworks developed on the basis of empirical evidence, actions and mechanisms can be identified that incentivise SLM, reduce degradation and help to build a more sustainable future, at and across multiple scales.

## 1.1 Purpose of this report

The Government of Kenya (via the State Department for Agriculture as well as other leading decision makers in related ministries) appreciates both the severity of the soil degradation situation the country faces and the potential for SLM to improve agricultural production and meet growing demands for food. The Kenya Government consequently recognised the need for an overall policy to facilitate better management of the nation's soil resource. The research presented in this report is therefore geared towards feeding into the development of a Kenya National Agricultural Soil Management Policy and provides important new empirical data from Western Kenya, building on a widely tested 6+1 step methodology stemming from the Economics of Land Degradation Initiative (see ELD, 2015). The 6 initial methodological steps involve:

1.) **Inception:** identifying the scope, location, spatial scale, and strategic focus of the study;

2.) **Geographical characteristics:** assessing the quantity, spatial distribution, and ecological characteristics of the study area (making use of existing data where possible). Our geographical focus for empirical data collection is placed upon Western Kenya because this area encompasses a wide range of key land management challenges that are present across the country, including soil erosion, soil nutrient depletion and soil mining;

3.) **Types of ecosystem services:** analysing ecosystem services, examining the costs of variation in and changes to soil fertility. We consider provisioning ecosystem services only, with a focus on food production, as this most directly affected by soil fertility within the livelihood contexts of focus. The values we provide therefore do not capture the total economic value of the agricultural system;

4.) **Role of ecosystem services in community livelihoods and economic valuation:** identifying the role of the assessed provisioning ecosystem services in the livelihoods of the land users;

5.) **Land degradation patterns and pressure:** identifying farming practices and yields which are associated with low levels of soil fertility;

6.) **Cost-benefit analysis and decision-making:** assessing SLM options.

The "+1" step requires action. This is achieved through policy implementation so is beyond the scope of the current study.

Our two core objectives are to:

1.) Understand variation in SLM uptake and characterise farmers that are most and least likely to use SLM practices.

This builds on work undertaken elsewhere in the literature (e.g. Tanui et al., 2013) and brings together the first 5 steps;

2.) Understand the costs and benefits of SLM implementation as one major barrier to uptake.

Achievement of the second objective tackles step 6 and involves undertaking a cost-benefit analysis. Put simply, this involves summing up the costs (labour, materials and opportunity costs) and benefits (increased yield, reduced labour requirement) of performing a specific SLM practice over a particular time period, discounting future costs and benefits to give a Net Present Value (NPV) and providing a Benefits-Cost Ratio (BCR). This information allows us to identify when it makes economic sense for a farmer to implement an SLM practice, as well as calculate a return on investment (ROI) period, i.e. how long they might have to wait before the total benefits exceed the total costs.

Through these research objectives, our analysis can provide useful information for decision makers on: (i) which type of farms or farmers can be targeted to increase SLM uptake; (ii) which SLM measures and practices offer the highest NPV for farmers over the time horizon in which a policy is in place; (iii) where policy interventions, such as subsidy schemes, might be best placed to improve uptake if benefits take a long time to accrue. Overall, the study provides deeper understanding of the economic aspects of land degradation, providing justifications for political support for the proposed agricultural soil policy, and can be used to inform governmental budgetary allocations for policy implementation. Agriculture is a devolved function under Kenya's 2010 Constitution, hence the County Governments taking the responsibility for agricultural development are a key target audience of this report.

# 02 Methods

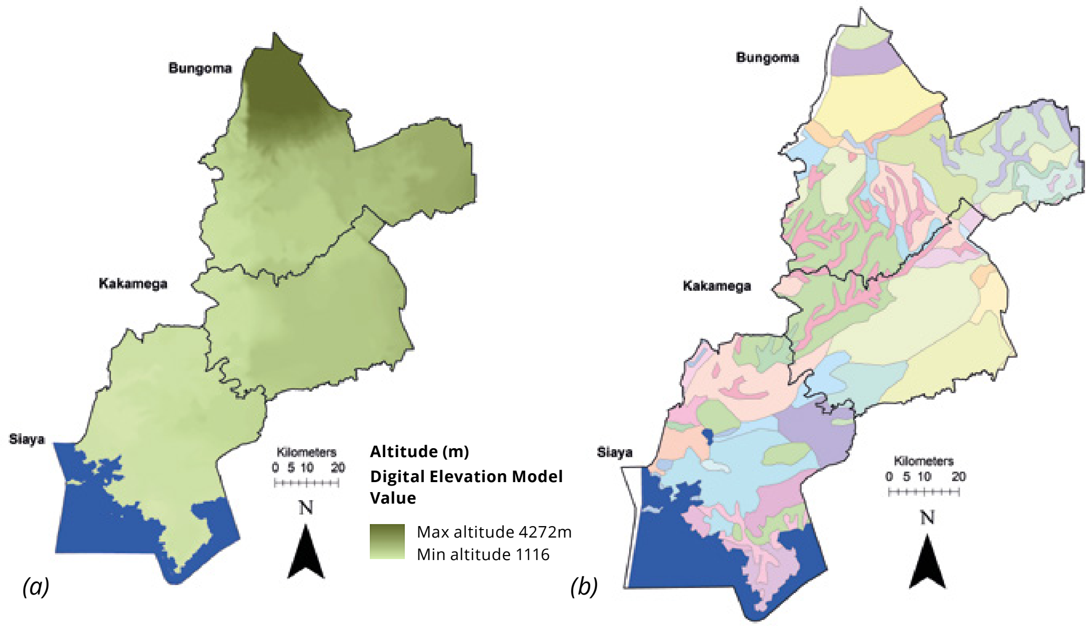
## 2.1 Study System

Within Kenya our empirical data collection focused on the western part of the country, specifically the three counties of Siaya, Kakamega and Bungoma. We concentrated on smallholder farms in this region. This area is considered to have considerable agricultural potential. However, the rapidly growing human population has led to intense land fragmentation. The region has a high population density (up to 522 people per km$^2$ in Bungoma; KNBS 2010) with average farm sizes ranging between 0.5 and 2.0 ha (Tittonell et al., 2007). Despite being classified as having high yield potential, production of the major cereal (maize (*Zea mays*)) is low and declining, averaging 1 t/ha of grain compared to the potential yields of 8 t/ha under optimal land management (Muasya and Diallo, 2001). Such declines are particularly significant given that cereals provide around 50% of the daily calorie intake in Africa (FAO, undated).

The low productivity is attributed to suboptimal land management practices. Land scarcity and an increasing need for food production have put immense pressure on the natural resource base, leading to widespread land degradation. Across the three counties, huge variations are found in altitude, soils and suitability for certain crops and farming systems (Figure 1), as well large differences in farm household characteristics. Within such a diverse system, the current use of SLM practices

FIGURE 1

**Maps showing the variation in (a) altitude and (b) soil types across the three counties** *(colours represent different soil types). Lake Victoria is indicated in dark blue. No legend is presented for soil types as the figure is solely to illustrate the variation present across the counties.*



and their effectiveness (in terms of improving yields and net benefits for farmers), is also likely to vary widely. Focusing on this part of the country therefore provides insights that will be more generally applicable to other parts of Kenya.

## 2.2 Characterising uptake of SLM practices

To characterise the current uptake of SLM practices in our study counties (objective 1), we used an existing dataset collected in 2014, which we refer to as the FSA ("Farming Systems Analysis") dataset. The FSA survey involved 320 farming households and was commissioned by GIZ. It provided a first step in analysing farming practices across the agro-ecological zones (AEZ) in the three counties. The intention was for participants to be identified according to a stratified random sample. However, data limitations meant that this was not possible. Instead the sample was gathered by GIZ county programme coordinators specifically selecting households already known to GIZ (Schuh 2015). In addition to carrying out a farm systems analysis and covering the socio-demographic make-up of the farming household, the FSA dataset included questions directly related to soil degradation and SLM practices, including: (i) whether the farmer had experienced soil degradation in the previous three years, with a follow up question regarding implementation of SLM practices to mitigate degradation; (ii) if intercropping was used; and (iii) if manure had been applied.

We sought to determine which household, farmer socio-demographic and farming system variables that were collected as part of the FSA survey were associated with uptake of SLM. From the FSA dataset we used three response variables which took the value 1 if the respondent implemented the SLM practice and 0 if they did not. Our response variables were "Any SLM Practice Use", "Manuring Use" and "Intercropping Use" (Table 1). For each SLM practice uptake variable we carried out a multiple logistic regression using a variety of variables which might help us understand why farmers implement SLM practices. Variables described the characteristics of the household, the farm or whether the farmer had access to assets and advice. We did not attempt to simplify our models and all explanatory variables were retained in a complete model set.

## 2.3 Cost-benefit analysis approach

Although farmers had been asked about their current use of SLM practices, the FSA dataset did not provide information on the costs and benefits of their implementation, which is necessary to achieve objective 2. New field data therefore had to be collected to fill this gap. Both the costs and benefits of SLM practices vary according to the: (i) biophysical properties of a farm; (ii) underlying socio-demographic factors of the farming household; and (iii) characteristics of the farm business. Our sampling approach intended to capture that variability and examine how costs and benefits varied according to farmers managing their land in different ways for different purposes. We therefore concentrated on the largest subset of the growing conditions (within the "lower midland" or "LM" AEZ) and characterised costs and benefits for farmers in that particular system, thereby including wet to dry conditions and a variety of dominant and secondary crops (Ministry of Agriculture 2009).

The choice of farms followed a two stage sampling approach. Initially, in a Geographical Information System (GIS), wards were selected if they were: a) not urban; and b) at least half their area fell within the "LM" AEZ. From this we used a stratified random sampling procedure to select wards within each county on the basis of ward and county area, so that the sample of wards was broadly proportional to the area of each county covered by the "LM" AEZ. This resulted in the selection of ten wards (four each in Siaya and Kakamega, two in Bungoma; Figure 2). Within each ward, six farms were chosen in consultation with the ward-level agricultural extension officers (WEOs). Criteria for selection of farmers included that they cultivated at least one of eight major crops in the region (maize, beans, sugar cane, vegetables, sorghum, millet, groundnuts, bananas), were active farmers and could be considered as smallholder farmers (which we defined for the WEOs as farms typically managing three to five acres and predominantly subsistence in character). We explicitly stated that farms should not be known to the WEO because of their uptake of SLM practices or involvement in programmes intended to improve uptake. Ideally, we wanted to ensure our sample included both farms where SLM practices were in place and farms where they were not. However, prior to data collection whether a given farm used SLM practices was unknown by WEOs.

TABLE 1

**Characteristics of farms included in the FSA survey**
*(presented as a total for all counties and for each county separately)*

| Variable type | Variables | All counties | Bungoma | Kakamega | Siaya |
|---|---|---|---|---|---|
| **SLM practice uptake** | Any SLM practice use | 63 % | 63 % | 62 % | 66 % |
| | Intercropping use | 53 % | 30 % | 57 % | 70 % |
| | Manure use | 78 % | 88 % | 78 % | 71 % |
| **Household characteristics** | Gender of household head ( % male) | 82 % | 77 % | 85 % | 83 % |
| | Resident (years) | 19.8 (12.2)[1] | 19.8 (10.8) | 25.6 (12.1) | 15.5 (11.7) |
| | Education (years) | 9.9 (3.2) | 11.5 (2.4) | 9.1 (3.4) | 9.0 (3.2) |
| | Household size | 7.1 (3.1) | 7.7 (3.4) | 7.2 (3.0) | 6.5 (2.8) |
| **Farm characteristics** | Employ people ( % yes) | 76 % | 85 % | 64 % | 79 % |
| | Total labour on farm | 3.1 (1.5) | 3.7 (1.5) | 2.8 (1.4) | 2.9 (1.4) |
| | Proportion of family labour ( % of total labour) | 82 % (20 %) | 82 % (19 %) | 83 % (22 %) | 83 % (20 %) |
| | Farm size (ha) | 3.9 (4.1) | 4.4 (3.9) | 4.7 (5.6) | 2.9 (2.3) |
| | Owned land ( % of farm size) | 83 % (27 %) | 88 % (19 %) | 87 % (25 %) | 76 % (32 %) |
| | Number of crops grown | 2.9 (1.2) | 3.4 (1.2) | 2.6 (1.2) | 2.8 (1.2) |
| | Area of maize grown (ha) | 1.2 (1.9) | 1.3 (2.3) | 1.1 (2.1) | 1.0 (1.4) |
| | Fertiliser use ( % yes) | 85 % | 96 % | 96 % | 67 % |
| | Chemical use ( % yes) | 58 % | 66 % | 59 % | 50 % |
| | Number of cattle | 3.6 (3.7) | 3.4 (2.8) | 3.5 (3.0) | 3.9 (4.7) |
| | Experienced soil degradation in the previous 3 years ( % yes)[3] | 72 % | 67 % | 65 % | 80 % |
| **Access to assets & advice** | Access to machinery ( % yes) | 70 % | 76 % | 41 % | 86 % |
| | Access to farm buildings and structures ( % yes) | 80 % | 88 % | 62 % | 88 % |
| | Member of agricultural groups / projects ( % yes) | 75 % | 83 % | 63 % | 77 % |
| | Use of external finance (e.g. loans) | 35 % | 40 % | 39 % | 27 % |
| | Contact with advisers on soil conservation[2] | 2.5 (2.3) | 2.9 (2.3) | 2.3 (2.2) | 2.2 (2.2) |
| | Contact with advisers on crops[2] | 3.8 (1.9) | 4.5 (1.5) | 3.5 (2.0) | 3.5 (2.0) |

[1] *Values in the parentheses are the standard deviations.*

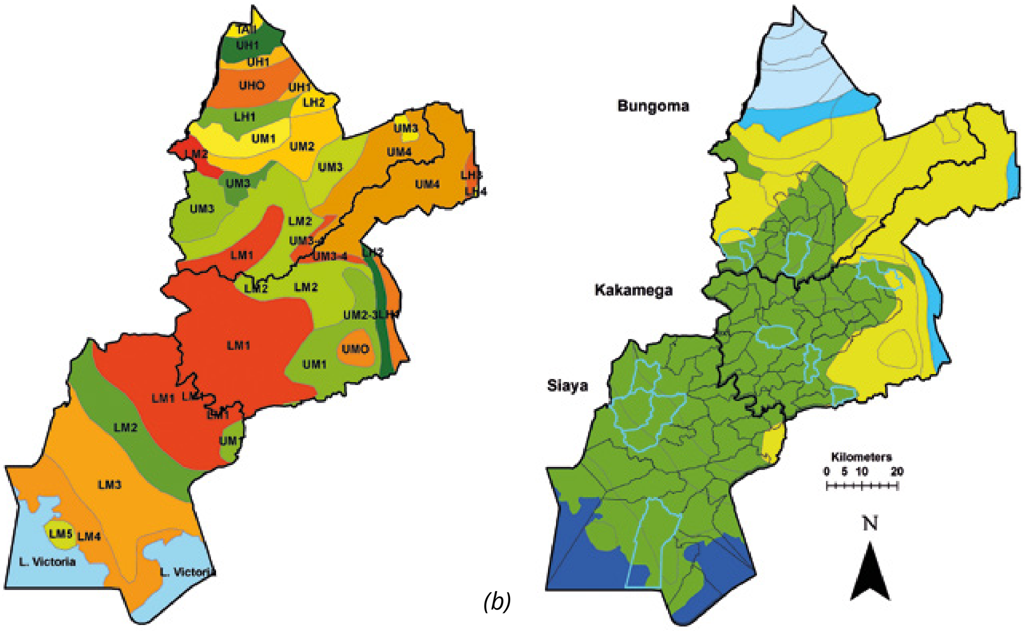
[2] *Access to advice was assessed on a 1 to 7 scale (7 = advice received a week ago; 6 = a month ago, 5 = three months ago, 4 = six months ago; 3 = a year ago, 2 = longer than a year ago; 1 = no contact).*

[3] *Not included in the "Any SLM Practice Use" models as the two variables were not independent (respondents were only asked about SLM practices if they responded "yes" to the soil degradation question)*

FIGURE 2

**Maps showing (a) the agro-ecological zones (Ministry of Agriculture 2009) present in the three counties and (b) the location of wards sampled for the CBA**

*(Central Alego, West Alego, South Sakwa, Ukwala in Siaya; Idakho South, Butsotso South, Shiguro-Mugai, Lusheya / Lubinu in Kakamega; West Sangalo, Bumula in Bungoma), western Kenya. In (a), colours and letters distinguish AEZs, "LM" = Lower Midland Zone (annual mean temperature 21-24°C), "UM" = Upper Midland Zone (18-21°C), "LH" = Lower Highland Zone (15-18°C), "UH" = Upper Highland Zone (10-15°C). For full description see Ministry of Agriculture (2009). In (b) Wards were selected (light blue outline) which had at least half their area within the LM AEZ using a stratified random sampling approach. AEZ types shown are LM (green), UM (yellow), LH (mid blue) UH (light blue). Lake Victoria is shown in dark blue.*




*(a)* *(b)*

Similarly, farm size and crops grown were not known prior to data collection. Our sample was necessarily dictated by availability and willingness of farmers to participate in the project and is neither random nor statistically representative of the wards.

Once farmers had been selected for inclusion in the study, the initial step was to carry out a farm survey to investigate how farmers managed their cropped land in order to provide the necessary data to input into the CBA. The survey was designed following scoping visits to smallholder farmers in December 2015 and a workshop with local experts and key stakeholders in February 2016 (see Koge et al., 2016). The survey was then piloted and any questions which were not understandable or difficult for respondents to answer were refined or removed.

The survey instrument included questions about household and farmer characteristics, farm and land attributes, inputs (e.g. labour, materials and machinery) and outputs (e.g. crop yield) of the main cultivation activity undertaken on the farm (defined as that occupying the largest area of the farm). The survey focussed solely on the most recently completed growing season (the 'long rain season' in 2015) for which farmers had finished harvesting crops and therefore knew their yields. Respondents were also asked which (if any) SLM practices were implemented and the additional inputs (labour, materials, machinery) used in doing so. If an SLM practice required construction / establishment (e.g. physical terraces), farmers were asked to report inputs for construction and for annual maintenance separately. Similarly, if an SLM measure took up land area within the farm, we asked the farmer to state the physical dimensions of the land used.

Many smallholder farms are managed, at least in part, for subsistence purposes, growing several different crops and using personal and family labour. We made several assumptions in order to estimate the total monetary value of inputs (including labour) and outputs associated with crop farming. Hired labour was monetised using the prevailing prices given by the farmers. This included a daily rate and a cost for the provision of meals, if these were in addition. Personal and family labour was monetised using ward-specific agricultural labour rates obtained from consultations with 23 experts during a workshop with key stakeholders (see Koge et al., 2016) and interviews with ten WEOs across the counties. Where machinery was used (e.g. tractors for ploughing), the actual cost paid by the farmer to hire the service was included. In all cases this was a subsidised rate provided by County governments, rather than the market rate. Scoping and piloting indicated that prices for inputs (seeds, materials for cultivation and materials for SLM practices) and average per acre amounts used varied only between wards, not between farms. We therefore collected these data from expert interviews and applied them to all farms within each ward.

Agricultural returns vary from year to year. In addition, remittances from relatives and families can act as an external 'subsidy' to enable farmers to overcome short-term financial short-falls. Focussing on a single season (in our case, the long rain season 2015) does not provide a long-term picture of farm yield and returns on investments. For instance, poor returns in one year do not necessarily generalise across many years. Nevertheless, negative net returns from cultivation activities were retained in the analyses. Farmers were, at least in part, engaged in subsistence farming with few other options for supporting their livelihoods outside the agricultural sector. It is therefore entirely plausible that long term negative net returns could be characteristic of certain farms, farm types or systems within the study region.

Land taken by a particular SLM practice (e.g. the space required for a physical terrace, the uncultivable basal area of a tree planted as part of an agroforestry scheme) was estimated by the farmers and converted to a proportion of the total farm area cultivated. The opportunity cost of land used by the SLM practice was estimated as the net return from this additional area of land had it been used for cultivation. Finally, we assumed that an additional cost of not implementing an SLM would be a gradual drop in gross profits due to yield declines associated with soil degradation of 2% a year (compared to historical declines of 70% in the past 11 years; (Waswa, 2012). All values are presented in Kenyan Shillings (KSh; 1 US$ = approx 100 KSh) per acre (the local unit of land; 1 acre = 0.4 ha).

To quantify the benefits to farmers of implementing SLM practices we asked participants to state their perception of how the SLM practice altered labour and yield compared to a similar field where the SLM practice was not in place for a single growing season. Assessing the benefits of implementing an SLM practice over the longer term requires longitudinal data (on soil properties, yield and gross profit) covering pre- and post-implementation. However, most farmers in Western Kenya do not keep any written record of past practices. It is likely, therefore, that farmer decisions regarding SLM implementation are based on individual perceptions of the changes to inputs (labour, materials and machinery) and outputs (yield).

In line with the principles of SLM and the types of degradation occurring in the study system, we assumed that the main benefit of SLM implementation to individual farmers would be increased yields through reduced soil erosion and improved fertility. However, the workshop and piloting of the farmer survey highlighted that SLM practices would also alter labour required for cultivation either increasing or decreasing it, depending on the particular intervention and the specific biophysical characteristics of the farm and its soil. For example, fallowing or crop rotation can lead to harder soils and therefore higher ploughing costs; manuring can reduce ploughing costs as the soil is softer, but the time required to weed might increase. We therefore also asked farmers how implementing the SLM practice had changed the labour requirements associated with the cultivation of the main crop. For intercropping, a further benefit is the additional income from the second crop. Many crops generate secondary outputs, such as crop residues and fodder for livestock. Some SLM practices, such as vegetative strips and agroforestry, also produce, for example, fodder, in addition to their role in soil conservation/moisture retention. In this study we

have not monetised these benefits. Similarly we have not considered benefits that might accrue to society more broadly, such as carbon sequestration or flood risk mitigation.

It is unlikely that the benefits from SLM implementation are immediately apparent as changes to soil fertility and reduction in erosion take time to accrue (Liniger et al., 2011). We therefore assumed that there would be a lag between implementation and accrual of benefits, and that the full benefit would only be achieved after a number of years of SLM implementation. Lags varied from one year for manuring and intercropping, to five years for physical terraces and 10 years for agroforestry. Appropriate lag times to use were identified in accordance with farmer and WEO observations and perceptions.

We used these data to calculate costs and benefits of the cultivation activities with and without SLM implementation. Since the costs incurred and benefits obtained happen over a period of time, we must take into account the time-value of money by (i) setting a time frame over which to perform the analysis and (ii) discounting future costs and benefits. This allows us to calculate the Net Present Value (NPV) of investments in SLM practices. Where this value is positive, then it makes (economic) sense for a farmer to implement an SLM practice. Other related measures are the Benefits-Cost Ratio (BCR). This is defined as the benefits divided by costs over the timeframe of analysis. A BCR greater than one indicates that benefits outweigh costs and the SLM practice should be implemented. In many cases an investment in an SLM practice will result in initial losses. Additional yields and labour savings only accrue over time. To understand how long a farmer might have to wait before benefits exceed costs, we also calculated a return on investment period, which is the length of time (in years) after an SLM practice is put in place when total benefits exceed total costs.

Our analyses were based on SLM practices being implemented in 2015 and their continued operation until 2030. (This time period was used to parallel *Kenya's Vision 2030*). In order to investigate the sensitivity of the CBA to the discount rate, we included rates of 5% (e.g. Republic of Kenya 2010) and 10% (e.g. Mogaka et al., 2005) which have been used in previous Kenyan studies, as well as a lower rate of 3.5% (the UK Government discount rate for projects up to 30 years in duration; HM Treasury 2013). We assumed that there will be no changes in labour availability and cost, crop prices, policy regimes and use of machinery during the course of the CBA. While it is unlikely these assumptions will hold true, by taking this approach we are able to make some straightforward comparisons of the financial costs and benefits which will influence decisions made by farmers under present day conditions.

# 03 Results

## 3.1 Farmers' uptake and use of SLM practices

Respondents to the FSA survey (n = 320) were reasonably equally distributed between the three counties (Bungoma 33% of the sample, Kakamega 29% and Siaya 38%) and were mostly male (82%, n = 261), with a mean residence time in the region of 19.8 years (with a standard deviation (SD) = 12.2). The most frequent level of education gained was secondary level (45% or 144 respondents), equating to a mean of 9.2 (SD = 3.2) years in education. Households consisted of an average of 7.1 (SD = 3.1) members. Maize was the most commonly grown crop (62% of farms), followed by maize-beans intercropping (54%) and bananas (31%). An average farm grew 2.9 (SD = 1.2) crops and had 3.6 cattle. The mean farm size was 3.9 ha and the mean area cultivated for maize production per farm was 1.2 ha (Table 1). Across all three counties farmers will own land outright, rent it or manage land on behalf of others, however on average 83% of the total farm area was owned. Farm income and yield data were only available for a subset of the whole sample so were not included in any subsequent analyses. Annual income from farming ranged from 90,000 to 1,212,000 KSh across the three counties. This constituted a mean of 75% of total household income. Maize yields ranged from 846 to 5712 kg/ha.

Of the 320 respondents, 72% (229 farmers) stated that they had experienced land degradation in three years prior to data collection and 63% employed at least one SLM practice. These proportions varied between the counties (Table 2). When farmers were asked specifically about manuring and intercropping, 251 (78%) and 171 (53%) said that they followed these practices respectively, again with proportions varying between counties.

## 3.2 Determinants of SLM practice uptake

Based on the FSA dataset, across all three counties, household, farm, and access to assets and advice variables (Table 2) only weakly predicted whether

a farmer employed an SLM practice (McFadden $r^2 = 0.080$), with the model offering poor accuracy in predicting SLM practice uptake (error rate = 0.345). Looking at this aggregated data from across the three counties, uptake was more likely if a farmer had more recent contact with a crop adviser ($\beta = 0.208$; $p = 0.017$)[1] but less likely if the head of household was male ($\beta = -1.038$; $p = 0.022$). No other variables were significant predictors of the probability of a farmer using an SLM practice (Table 2).

Different predictor variables were significant at the individual county level, with none for Bungoma. For Siaya and Kakamega, farmers were more likely to implement an SLM practice if they were members of an agricultural group or project ($\beta = 4.800$, $p = 0.019$ for Kakamega and $\beta = 1.169$, $p = 0.044$ for Siaya), but there were no other common predictor variables. In Kakamega farming practice was important. Farms which held more cattle were more likely to take up an SLM practice, while those growing a greater range of crops were less likely to do so. In Siaya, farms where a greater proportion of the land was owned or the total labour was from family members, were more likely to implement an SLM practice.

For the aggregated data from all three counties, being a member of an agricultural group or project was negatively associated with the uptake of manure use ($\beta = -1.905$, $p = 0.002$). In contrast manure use was more likely if contact from crop advisers had been more recent ($\beta = 0.345$, $p = 0.008$). Having experienced soil degradation in the three years prior to data collection was associated with reduced likelihood of manure use ($\beta = -1.302$, $p = 0.023$) but increased likelihood of intercropping ($\beta = 0.791$, $p = 0.018$). Farmers who used intercropping were strongly predicted by area of maize (only) that was cultivated (Table 2).

[1] *$\beta$ values are the parameter estimates for the coefficients. This means they indicate the strength of the relationship between variables. Positive numbers mean that as the predictor variable increases the likelihood that a farmer will use that SLM practice goes up and vice versa. P is the p-value, so indicates statistical significance, in other words, how strong the evidence is that the relationships identified are not just down to chance.*

BOX 1

## Key Findings: What determines SLM Uptake?

What determines SLM uptake varies between the three counties, and according to the SLM practice of interest. Key findings from our analysis of the FSA dataset are:

**1. Household characteristics**

- Farms where the head of the household is female are more likely to take up any SLM practice across the three counties, but particularly in Siaya. Gender is not important for manure uptake, but intercropping is more likely to be practiced on a farm with a female household head.

**2. Farm characteristics**

- In Siaya, land tenure is important. An SLM practice is more likely to be used where more of the farm is owned and more of the labour used on the farm is from family members.
- Although we might expect that experience of soil degradation might drive farmers to use SLM practices, there is no simple pattern. Manuring is less likely to be practiced and intercropping is more likely to be undertaken if a farmer reported experiencing soil degradation in the three previous years.

**3. Access to assets & advice**

- Key variables include membership of agricultural groups or projects, recent contact with advisers and access to machinery or farm buildings.
- More recent contact with advisers is related to a greater likelihood of SLM uptake and use of manure. However, the picture with group membership is less clear. Within some counties (Kakamega and Siaya) it leads to increased SLM uptake, but is not important in Bungoma. Conversely, farmers are less likely to use manuring as an SLM practice if they are a member of an agricultural group or project.

TABLE 2

**What determines the likelihood of SLM practice uptake? Results from regression analyses of the FSA survey data.**[1]

| | | SLM practice uptake | | | | Manuring uptake | Intercropping uptake |
|---|---|---|---|---|---|---|---|
| **Variable type** | **Variables** | **Bungoma** | **Kakamega** | **Siaya** | **Three counties** | **Three counties** | **Three counties** |
| **Household characteristics** | Male head of household | – | – | ↘ | ↘ | – | ↘ |
| | Resident | – | – | – | – | – | – |
| | Education | – | – | – | – | – | – |
| | Household size | – | – | – | – | – | – |
| **Farm characteristics** | Employ people | – | – | – | – | – | – |
| | Total labour on farm | – | – | – | – | – | – |
| | Proportion of family labour | – | – | ↗ | – | – | – |
| | Farm size | – | – | – | – | – | – |
| | Owned land | – | – | ↗ | – | – | – |
| | Number of crops grown | – | ↘ | – | – | – | – |
| | Area of maize grown | – | – | – | – | ↘ | ↘ |
| | Mineral fertiliser use | – | – | – | – | ↗ | – |
| | Chemical herbicide or pesticide use | – | – | – | – | – | – |
| | Number of cattle | – | ↗ | – | – | – | – |
| | Experienced soil degradation in the three previous years | **NA[2]** | **NA[2]** | **NA[2]** | **NA[2]** | ↘ | ↗ |

| | | SLM practice uptake | | | | Manuring uptake | Intercropping uptake |
|---|---|---|---|---|---|---|---|
| **Variable type** | **Variables** | **Bungoma** | **Kakamega** | **Siaya** | **Three counties** | **Three counties** | **Three counties** |
| **Access to assets & advice** | Access to machinery | – | ↘ | – | – | – | – |
| | Access to farm buildings & structures | – | – | – | – | ↗ | – |
| | Member of agricultural groups / projects | – | ↗ | ↗ | – | ↘ | – |
| | Use of external finance | – | – | – | – | – | – |
| | Contact with advisers on soil conservation | – | – | – | – | – | – |
| | Contact with advisers on crops | – | – | – | ↗ | ↗ | – |
| | McFadden $R^2$ | 0.159 | 0.573 | 0.171 | 0.080 | 0.273 | 0.128 |
| | Prediction error rate | 0.277 | 0.117 | 0.271 | 0.345 | 0.156 | 0.311 |

1 *Arrows indicate the direction of any relationship between likelihood of uptake (SLM practice, manuring or intercropping) and the variable. Parameter estimates are not presented in this report but are available from the authors. The arrows can be interpreted as follows: – no significant relationship between uptake and the variable; ↘ there is a negative relationship between likelihood of uptake and the variable; ↗ there is a positive relationship between likelihood of uptake and the variable. For instance, the ↘ for "Male head of household" indicates that uptake was less likely where the household head was male (i.e. uptake more likely with a female headed household). The ↗ arrow for "Owned land" shows that in Siaya SLM practice uptake is more likely on farms where a greater proportion of land is owned. McFadden's $R^2$ and the Prediction Error Rate indicate how much of the variation in uptake the model has predicted and how accurately the model predicts that uptake respectively. Higher numbers show models that are better at explaining the variation and predicting uptake.*

2 *Not included in these analyses. See Table 1 footnotes for explanation.*

### 3.3 Costs and benefits of SLM implementation

Sixty farmers were surveyed to ascertain their individual costs and perceived benefits associated with cultivation and SLM implementation. Maize was the main crop for 51 farms (85%), followed by sugarcane (5 farms; 8%), kale (2 farms; 3%) and bananas and sorghum (1 farm each; 2%). Farmers grew an average of 3.4 (min = 2; max = 6) crops (excluding mixed vegetables/fruit gardens mainly for home use), had 3 (min = 0; max = 15) head of cattle and all kept poultry. Nearly all farmers employed at least one SLM practice (59 from 60). However, this high proportion of farmers implementing SLM practices cannot be extrapolated across the three counties as a whole as our sampling approach was not designed to be representative of the wider farming community. Note also the difference in uptake rates between our sample and the FSA dataset (63%) for which farmers were explicitly selected for already having contact with GIZ projects (Schuh 2015).

Household heads were mostly male (78%, n = 47), with a mean age of 57. Households consisted of an average of 4.1 adults and 2.7 children. Although the largest farm we visited was 17 acres, median farm size was 3 acres and 75% of our respondents managed 5 or fewer acres (cf. farm typologies developed by Koge et al., 2016). 43 farms (72%) owned all the land they managed. Household income ranged from 2,200 KSh/year to 5,600,000 KSh/year. Twenty-one households (35%) generated all their income from farming (mean proportion generated by on-farm activities was 0.68), while 48 participants stated that their farm produced 'enough food' for their household in 2015.

All subsequent analyses were restricted to the 51 farms which cultivated maize as their main activity. Yields, labour use, gross margins and net profit associated with cultivating maize varied substantially across our sample (3). For instance net profit in the long season in 2015 in Siaya was slightly negative (-1,284 (SD = 25,076) KSh/acre), but differed between farms from a minimum of -29,350 to a maximum of 60,635 KSh/acre. Fifty farmers employed at least one SLM practice (mean number used = 5, min = 0; max = 10) related to maize cultivation.

Seven SLM practices were used by over 20 farmers, with the most frequently employed being manuring and intercropping (2). We focused our CBA on four of the most common practices, selecting two that took land out of cultivation and required a construction phase as well as annual maintenance (physical terraces and agroforestry), and two which were carried out annually but did not take space away from cultivation (manuring and intercropping)

TABLE 3

**SLM practice implementation costs, maize cultivation costs, yields and labour use**

| | Bungoma | Kakamega | Siaya | Three counties |
|---|---|---|---|---|
| **Number of farms growing maize** | 8 | 23 | 20 | 51 |
| **Area (acres)** | 0.94 (0.50) | 1.45 (0.97) | 1.46 (1.06) | 1.37 (0.96) |
| **Years farmed** | 29 (15) | 20 (11) | 12 (9) | 18 (12) |
| **Yield (kg / acre)** | 1,451 (439) | 1,155 (584) | 718 (603) | 1,030 (624) |
| **Proportion sold** | 0.35 (0.34) | 0.29 (0.27) | 0.27 (0.30) | 0.29 (0.29) |
| **Gross profit (KSh / acre)[1]** | 45,101 (13,585) | 34,058 (18,392) | 21,182 (20,116) | 30,741 (20,076) |
| **Labour use (hours / acre)** | 599 (275) | 484 (243) | 414 (211) | 474 (240) |
| **Labour cost (KSh / acre)[1]** | 29,655 (12,161) | 22,458 (12,788) | 22,466 (15,414) | 23,590 (13,782) |
| **Net profit (KSh / acre)[1]** | 15,446 (19,662) | 11,600 (19,913) | -1,284 (25,076) | 7,151 (22,718) |
| **SLM practice labour use (hours / acre)** | 175 (136) | 123 (93) | 102 (94) | 123 (102) |
| **SLM practice cost of implementation (KSh / acre)[1]** | 9,349 (6,979) | 6,620 (4,611) | 6,049 (6,426) | 6,824 (5,757) |
| **Intercropped beans yield (kg / acre)** | 140 (112) | 61 (54) | 60 (70) | 73 (76) |
| **Intercropped beans gross profit (KSh / acre)[1]** | 9,796 (9,838) | 3,874 (3,674) | 5,464 (6,545) | 5,426 (6,319) |
| **Fertiliser use (proportion)** | 1.00 | 0.91 | 0.75 | 0.86 |
| **Pesticide use (proportion)** | 0.13 | 0.17 | 0.05 | 0.12 |
| **Herbicide use (proportion)** | 0.13 | 0.04 | 0.05 | 0.06 |

[1] *Monetary values are presented in Kenyan Shillings (KSh; 1 US$ = approx 100 KSh) per acre (the local unit of land; 1 acre = 0.4 ha).*

TABLE 4

**SLM practices included in the CBA survey**

| SLM practice | Brief description | Involves construction | Mean % land removed from cultivation | N. farmers[1] | | | | CBA performed |
|---|---|---|---|---|---|---|---|---|
| | | | | 3C | B | K | S | |
| **Soil testing and liming** | Testing soil pH and gaining subsequent recommendations including application of lime, if required | No | None | 9 | 3 | 5 | 1 | No |
| **Manuring** | Application of livestock or compost manure to enhance soil fertility, water retention and friability | No | None | 46 | 8 | 21 | 17 | Yes |
| **No tillage** | Avoiding tillage to ensure minimal soil disturbance | No | None | 4 | 0 | 0 | 4 | No |
| **Mulching** | Using crop residues as mulch to reduce weed growth and conserve soil moisture through reduced evapotranspiration and limited direct sunlight | No | None | 6 | 2 | 0 | 4 | No |
| **Intercropping** | Planting two or more crops simultaneously (usually a cereal and a legume) in the same field | No | None | 42 | 8 | 18 | 16 | Yes |
| **Rotation** | Seasonal rotation of different crops on the same plot of land | No | None | 31 | 4 | 16 | 11 | No |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Fallowing** | Land left uncultivated, unutilised for a season or more | No | None | 14 | 2 | 6 | 6 | No |
| **Trash heaps / lines** | Piling trash in heaps or lines of vegetation / crop residues to restrict the flow of water / loss of soil | No | None | 28 | 4 | 13 | 11 | No |
| **Vegetative strips** | Cross slope, field boundary barriers solely involving planting of vegetation, such as Napier and Vetiver grass | Yes | 2.9 | 30 | 6 | 15 | 9 | No |
| **Physical terraces** | Any cross-slope barrier which involves the construction of banks | Yes | 3.0 | 31 | 2 | 15 | 14 | Yes |
| **Agroforestry** | Any system where trees are included in the cultivated area or along field boundaries | Yes | 1.0 | 25 | 6 | 12 | 7 | Yes |
| **Ditches** | The presence of ditches intended to alter water flow | Yes | 2.1 | 9 | 1 | 3 | 5 | No |
| **Water harvesting / storage** | Any mechanism to capture water within a field and / or store it for later use | Yes | – | 0[2] | 0 | 0 | 0[2] | No |

[1] *for the Three Counties (3C); Bungoma (B); Kakamega (K) and Siaya (S)*

[2] *Four farmers in Siaya reported use of water storage facilities which were not located within fields*

TABLE 5

**Benefits of implementing SLM practices**

*for an acre of maize for (a) manuring, (b) intercropping, (c) physical terraces and (d) agroforestry within each individual county, and for the data from the three counties combined.*

| (a) Manuring | Bungoma | Kakamega | Siaya | Three counties |
|---|---|---|---|---|
| Assumed time lag between implementation and benefit accrual | Full benefits accrued in Year 3, 75 % in Year 2 | | | |
| **Cost of construction (labour KSh / acre)** | – | – | – | – |
| **Annual cost (labour KSh / acre)** | 3,975 | 1,652 | 2,761 | 2,445 |
| **Perceived benefit (increase in yield kg / acre)** | 878 | 624 | 485 | 626 |
| **Perceived benefit (decrease in labour hrs / acre)**[1] | 35.0 | 51.5 | 7.7 | 29.2 |
| **Gross profit from second crop (KSh / acre)** | – | – | – | – |
| **Perceived benefit (KSh / acre)** | 29,880 | 21,314 | 14,347 | 20,639 |

| (b) Intercropping | Bungoma | Kakamega | Siaya | Three counties |
|---|---|---|---|---|
| Assumed time lag between implementation and benefit accrual | Full benefits accrued in Year 3, 75 % in Year 2. Additional gross profit from the intercrop of beans is accrued immediately. | | | |
| **Cost of construction (labour KSh / acre)** | – | – | – | – |
| **Gross profit from second crop (KSh / acre)** | – | – | – | – |
| **Annual cost (labour KSh / acre)** | 1,612 | 2,315 | 2,259 | 2,160 |
| **Perceived benefit (increase in yield kg / acre)** | -85 | 67 | 87 | 46 |
| **Perceived benefit (decrease in labour hrs / acre)**[1] | 51.2 | -2.9 | 0.6 | 8.7 |
| **Gross profit from second crop (KSh / acre)** | 9,796 | 4,950 | 6,830 | 6,589 |
| **Perceived benefit (KSh / acre)** | 9,032 | 7,110 | 11,739 | 9,240 |

| (c) Physical terraces | Bungoma | Kakamega | Siaya | Three counties |
|---|---|---|---|---|
| Assumed time lag between implementation and benefit accrual | Full benefits accrued after 5 years; 75 % in Year 4; 50 % Year 3; 25 % Year 2 | | | |
| **Cost of construction (labour KSh / acre)** | 4,500 | 1,982 | 2,385 | 2,249 |
| **Annual cost (labour KSh / acre)** | 750 | 1,077 | 1,303 | 1,160 |
| **Perceived benefit (increase in yield kg / acre)** | 1,080 | 313 | 92 | 249 |
| **Perceived benefit (decrease in labour hrs / acre)**[1] | 30.6 | 21.9 | 22.0 | 22.3 |
| **Gross profit from second crop (KSh / acre)** | – | – | – | – |
| **Perceived benefit (KSh / acre)** | 41,384 | 12,214 | 3,917 | 9,826 |

| (d) Agroforestry | Bungoma | Kakamega | Siaya | Three counties |
|---|---|---|---|---|
| Assumed time lag between implementation and benefit accrual | Full benefits accrued after 5 years; 75 % in Year 4; 50 % Year 3; 25 % Year 2 | | | |
| **Cost of construction (labour KSh / acre)** | 523 | 786 | 809 | 745 |
| **Annual cost (labour KSh / acre)** | 167 | 280 | 0 | 170 |
| **Perceived benefit (increase in yield kg / acre)** | 162 | 50 | 20 | 61 |
| **Perceived benefit (decrease in labour hrs / acre)[1]** | 0.0 | 85.2 | -49.8 | 26.7 |
| **Gross profit from second crop (KSh / acre)** | – | – | – | – |
| **Perceived benefit (KSh / acre)** | 4,841 | 1,512 | 569 | 1,817 |

[1] *Positive values indicate a decrease in labour, negative values an increase (i.e. the benefit is negative and is therefore an additional cost)*

For all SLM practices, farmers stated perceived benefits as proportional changes from an equivalent field where no SLM practices were followed. We converted these proportions to farm-specific yield, labour hours and gross profits which were in addition to those reported for the cultivation activity alone (given in Table 3, assuming that any single SLM practice was limited to doubling yield or halving labour requirements). SLM practices varied enormously in their perceived impacts on labour requirements, yield and profit (Table 5). For instance, the perceived benefit of agroforestry in Siaya was 569 KSh / acre / year compared to 4,841 KSh / acre / year in Bungoma. Conversely, farmers in Siaya perceived an average benefit of 11,729 KSh / acre / year for intercropping compared to 7,110 KSh / acre / year in Kakamega. Differences in perceived monetary benefits were due to variations in perceived savings in labour time, perceived yield increases and variation in wage rates and crop sale prices.

### 3.3.2 Cost-Benefit Analysis (CBA)

For the CBA, we assumed that SLM practices began in 2015 and would continue to be implemented until 2030. The 'business as usual' scenario (the cost of inaction) was assumed to be that the SLM practice in question is not implemented on a typical acre of maize, but all other management activities continue. SLM practices are often implemented in parallel. However, there is a wide variety of practices that are used in combination. We therefore assumed that other SLM practices also continued and our findings refer to a farmer taking up the SLM practice in question in addition to all other activities.

We based our CBA on the mean inputs and outputs, both across all three counties, and within each county separately. Inputs and outputs for the 'business as usual' case were taken from those farms not employing the SLM practice in question. On the basis of this CBA, the NPV of each practice to the individual farmers concerned was estimated as the sum total of the value of enhanced yield and reduced labour requirements, minus the implementation and management costs.

#### Manuring

When working with input and output costs, farms across all three counties which grow maize (n = 51; see section 2.3), the benefits of action in implementing manuring over the time horizon of the policy far outweighed the costs (NPV of up to 140,000 KSh / acre; Table 6a; Figure 3), regardless of the discount rate used. Although the magnitude of the BCR varied between counties (1.14 to 2.42 for r = 3.5 %), the benefits that accrued to individual farmers from manuring were universally positive. ROI periods were all less than three years.

#### Intercropping

The NPVs of implementing intercropping (the benefits of action) were always positive, regardless of discount rate or county (Table 6b; Figure 3). NPVs ranged from 15,400 KSh / acre (in Kakamega for r = 10 %) to 74,000 KSh / acre (in Bungoma for r = 3.5 %) for the duration of the time horizon examined. There was substantial variation between counties, with farmers in Bungoma perceiving that intercropping resulted in a drop in the yields for the main crop (maize), while those in Kakamega and Siaya perceived an increase in labour required for cultivating the main crop of maize. Despite this, BCRs were uniformly high.

TABLE 6

**Net Present Value (NPV), Benefits-Cost Ratio (BCR) and Return on Investment (RoI) periods for SLM practices**

*stated over the lifetime of the project (2015 to 2030) for three discount rates (r) for implementing four SLM practices ((a) manuring, (b) intercropping, (c) physical terraces and (d) agroforestry)*

| SLM | Scale | Measure | r = 3.5 % | r = 5 % | r = 10 % |
|---|---|---|---|---|---|
| **(a) Manuring** | Three counties | NPV (KSh / acre) | 140,000 | 125,000 | 88,200 |
| | | BCR | 2.50 | 2.47 | 2.38 |
| | | RoI period (years) | 1.02 | 1.02 | 1.01 |
| | Siaya | NPV (KSh / acre) | 50,000 | 43,900 | 29,000 |
| | | BCR | 1.45 | 1.43 | 1.38 |
| | | RoI period (years) | 2.42 | 2.47 | 2.66 |
| | Kakamega | NPV (KSh / acre) | 131,000 | 117,000 | 82,400 |
| | | BCR | 2.21 | 2.18 | 2.10 |
| | | RoI period (years) | 1.14 | 1.15 | 1.18 |
| | Bungoma | NPV (KSh / acre) | 162,000 | 144,000 | 100,000 |
| | | BCR | 1.93 | 1.91 | 1.83 |
| | | RoI period (years) | 1.38 | 1.40 | 1.46 |
| **(b) Intercropping** | Three counties | NPV (KSh / acre) | 46,900 | 42,500 | 31,900 |
| | | BCR | 1.95 | 1.94 | 1.93 |
| | | RoI period (years) | 0 | 0 | 0 |
| | Siaya | NPV (KSh / acre) | 60,400 | 54,700 | 40,800 |
| | | BCR | 2.19 | 2.18 | 2.17 |
| | | RoI period (years) | 0 | 0 | 0 |
| | Kakamega | NPV (KSh / acre) | 22,900 | 20,700 | 15,400 |
| | | BCR | 1.44 | 1.44 | 1.43 |
| | | RoI period (years) | 0 | 0 | 0 |
| | Bungoma | NPV (KSh / acre) | 74,000 | 67,300 | 51,000 |
| | | BCR | 2.73 | 2.73 | 2.74 |
| | | RoI period (years) | 0 | 0 | 0 |
| **(c) Physical terraces** | Three counties | NPV (KSh / acre) | 46,400 | 39,500 | 23,000 |
| | | BCR | 2.13 | 2.04 | 1.77 |
| | | RoI period (years) | 4.95 | 5.07 | 5.54 |
| | Siaya | NPV (KSh / acre) | -2,680 | -3,900 | -6,710 |
| | | BCR | 0.94 | 0.90 | 0.78 |
| | | RoI period (years) | – | – | – |
| | Kakamega | NPV (KSh / acre) | 68,900 | 59,400 | 36,900 |
| | | BCR | 2.77 | 2.66 | 2.30 |
| | | RoI period (years) | 4.15 | 4.22 | 4.67 |

| SLM | Scale | Measure | r = 3.5 % | r = 5 % | r = 10 % |
|---|---|---|---|---|---|
| | Bungoma | NPV (KSh / acre) | 290,000 | 254,000 | 167,000 |
| | | BCR | 6.53 | 6.25 | 5.37 |
| | | RoI period (years) | 2.46 | 2.48 | 2.59 |
| **(d) Agroforestry** | Three counties | NPV (KSh / acre) | -7,470 | -7,710 | -8,200 |
| | | BCR | 0.624 | 0.582 | 0.459 |
| | | RoI period (years) | – | – | – |
| | Siaya | NPV (KSh / acre) | -13,000 | -12,400 | -11,000 |
| | | BCR | 0.249 | 0.231 | 0.180 |
| | | RoI period (years) | – | – | – |
| | Kakamega | NPV (KSh / acre) | -12,900 | -12,600 | -11,600 |
| | | BCR | 0.436 | 0.408 | 0.325 |
| | | RoI period (years) | – | – | – |
| | Bungoma | NPV (KSh / acre) | 12,500 | 9,580 | 2,950 |
| | | BCR | 1.61 | 1.50 | 1.19 |
| | | RoI period (years) | 8.34 | 8.73 | 10.75 |

*All estimates given to 3 significant figures. Monetary values are presented in Kenyan Shillings (KSh; 1 US$ = approx 100 KSh) per acre (the local unit of land; 1 acre = 0.4 ha).*

### Physical terraces

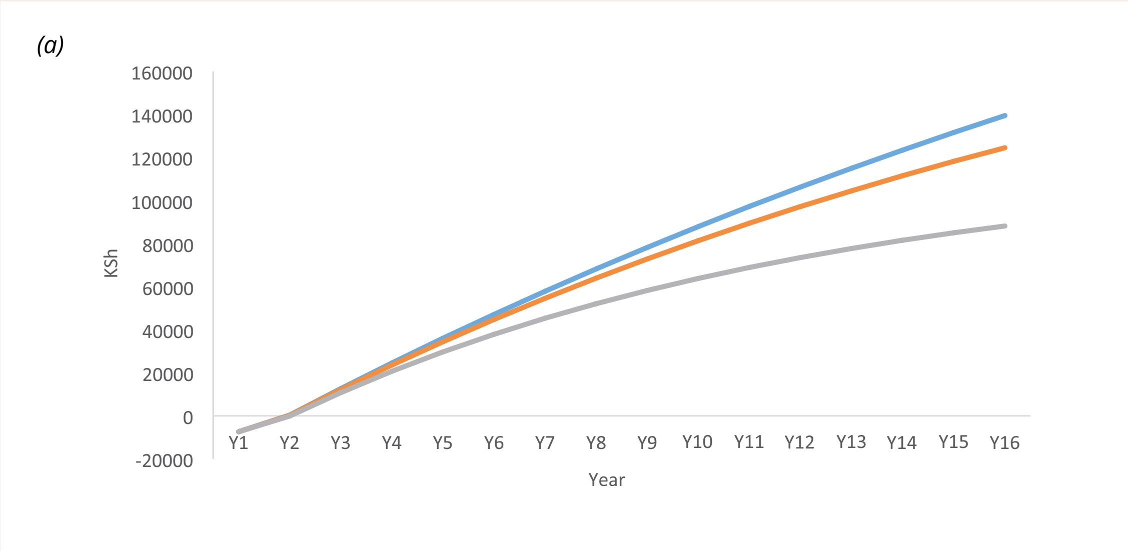
Averaged across all three counties, the benefits of physical terraces outweighed the costs (BCR 2.13, 2.04 and 1.77 for r = 3.5, 5 and 10% respectively; Table 6c; Figure 3). The ROI period, however, was up to 5.54 years. For Siaya, the BCR was less than one, indicating that costs outweighed benefits and, under current circumstances, investments in physical terraces in the county are unlikely to result in a positive return and NPVs were uniformly negative for all three discount rates. For Kakamega and Bungoma, however, NPVs from an investment in physical terraces were up to 290,000 KSh / acre across the time horizon we examined. BCRs were similarly high, and were above 5 for all discount rates in Bungoma. This suggests that whether an investment in physical terraces is going to be beneficial (in terms of having a positive NPV or benefits larger than costs) depends on local conditions and contexts. Even within our study counties there is variation, so an investment that makes economic sense in one place will not necessarily make sense in another. It is nevertheless possible that inclusion of other variables could allow identification of further benefits (and costs) not considered with our study.

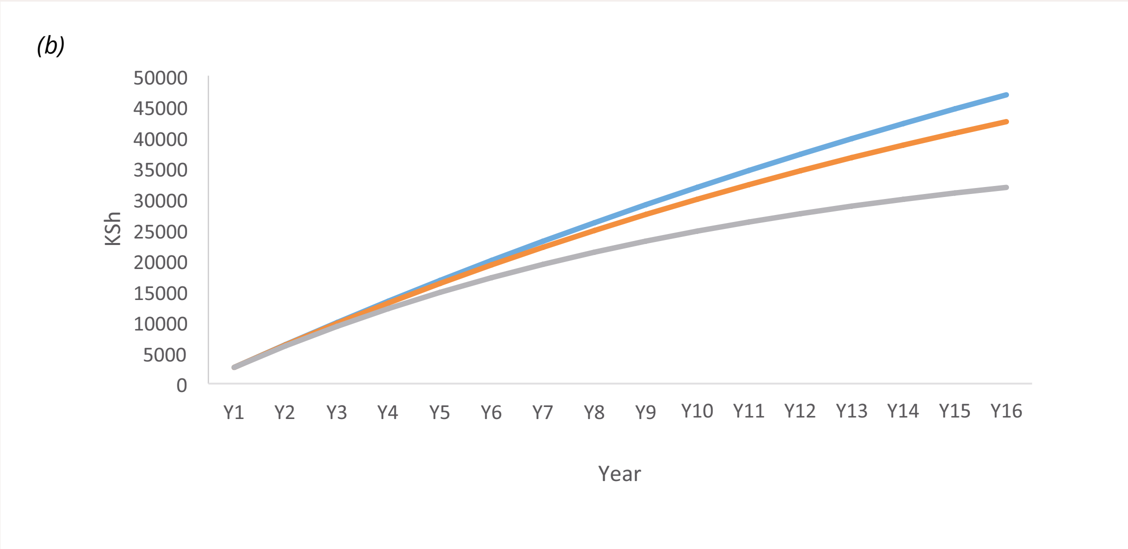
### Agroforestry

Averaged across all three counties, the cost of action in implementing agroforestry was greater than the cost of inaction. BCRs were below one (i.e. costs outweighed benefits) for all three discount rates applied (Table 6d; Figure 3). However, this general pattern was not universal when the counties were considered individually. In Siaya and Kakamega, investments in agroforestry did not result in positive NPVs during the time horizon we investigated. However, in Bungoma, the NPV at r = 3.5% was 12,500 KSh / acre, and although the ROI period was over 8 years, the BCRs were above one, indicating that the costs of action outweighed the costs of inaction for these farms.

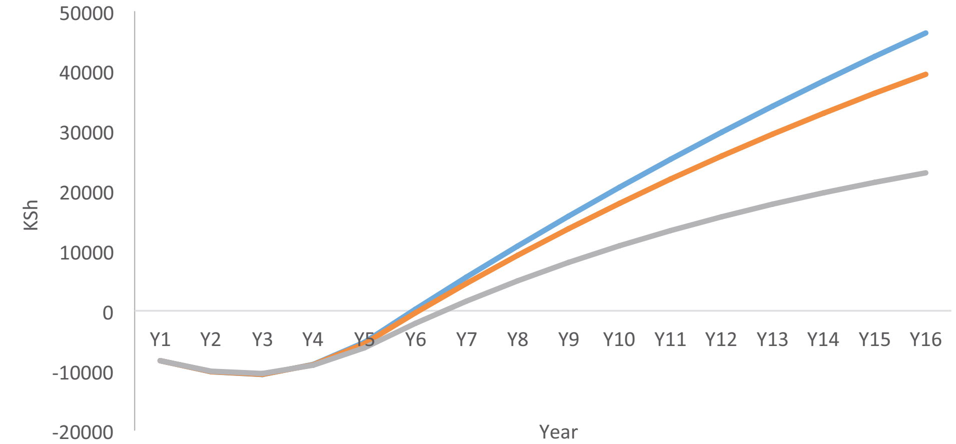
FIGURE 3

**Cumulative NPV (KSh) for implementing four SLM practices**
*in Year 1 (2015) until Year 16 (2030), for a typical area of maize within the three counties.*

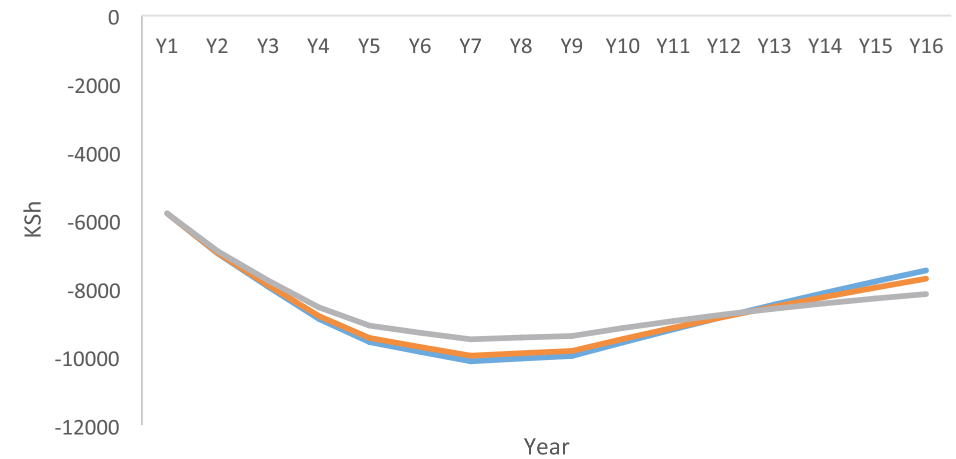


(c)




(d)




*The four SLM practices are: (a) manuring; (b) intercropping; (c) physical terraces; (d) agroforestry. Three discount rates were applied: r = 3.5 % (blue); 5 % (red); 10 % (grey). For (a) manuring, farmers rapidly see their initial expenditure outlay covered by increased incomes (all three lines become positive after Y1), but for (d) agroforestry, the cumulative NPV never becomes positive, indicating that farmers would not see a return on their investment within the time horizon that we examined (2015-2030).*

# 04 Discussion

Our research has produced a number of key findings which provide deeper insight into the types of farmers that are most and least likely to use SLM; and the costs and benefits of SLM. This section addresses each of the research objectives in turn in relation to these findings, discussing their wider implications for tackling land and soil degradation in Kenya.

## 4.1 Understanding variations in SLM uptake

In undertaking our analysis, we defined our beneficiary scale as that of the individual farm household, and we limited the ecosystem services we were valuing to crop yields (focusing on a provisioning ecosystem service only – maize). In reality, farmer decision making takes into account a multitude of interacting input and output variables, including some of those incorporated into our analysis. Different farmers in different parts of the country and even within different parts of Western Kenya are contending with economic, social and environmental contexts that differ to varying degrees, as well as receiving different amounts of institutional support for SLM. All of these factors combine to influence decision making and SLM uptake.

According to Ndah (2014), uptake of an SLM practice is a product of complex interactions between individual farmers, particular practice characteristics and the frame conditions or surrounding contexts such as the social- political systems and policies in place. Our results showed that the majority of farmers are using at least one SLM practice but the diversity of the study area made it difficult to elucidate universally applicable relationships across the three counties. In Bungoma, we found no statistically significant characteristics that can be used to predict farmer uptake of SLM. In Kakamega, participation in agricultural projects is found to be associated with wider SLM uptake, as is a lack of access to machinery, farming fewer crops and owning a greater number of cattle. In Siaya too, project membership was found to be important, and uptake was more likely the higher the proportion of land owned and the higher the proportion of labour used from within the household. Overall, farmers who are members of projects generally also pursue SLM practices. This suggests that in general, the projects represent a useful channel through which SLM uptake can be promoted. However, when we consider manure application, project membership is negatively associated with manure use. At the same time, those farmers who had contact with crop advisers more recently were more likely to use manure. This implies that project membership is important for encouraging uptake of some, but not necessarily all, SLM practices. Similarly, contact with agricultural extension advisers is important in fostering uptake. The two variables, projects and extension advice, encapsulate some of the key aspects of theories in the literature that aim to understand the uptake of agricultural innovations. They emphasise the importance of social interaction and knowledge/experience exchange (e.g. through farmer field schools) in the uptake of particular practices.

Rogers (2003) notes that farmer decision-making about whether to adopt a particular SLM practice plays out iteratively over a period of time, starting with exposure to knowledge about that practice. Exposure itself is shaped by an individual's characteristics, their socio-economic status as well as their communication behaviour. Once exposed to particular SLM practices, farmers form their attitude towards that practice, evaluating its attributes and weighing up its advantages and disadvantages. At this stage, if farmers are interacting with others through projects or are in contact with advisers, it can have an important influence on whether uptake happens or not. Such

contact with others can help to dispel or reinforce farmer concerns about the practice in question or support or change their positive evaluation. Adoption of an SLM practice is considered to happen when the decision is made to use it. Even then however, it needs to be implemented. In this research, we considered farmers who are already implementing SLM practices. Once a practice is being used, farmers still need to see results that reinforce their decision to use it otherwise they may cease its implementation. Discontinuing its use or dis-adopting a particular practice can happen for a number of reasons, including disenchantment and replacement with a new or superior approach. Our research participants almost universally implemented at least one SLM practice. However, our non-representative sample is likely to omit those farmers who have dis-adopted SLM practices after finding them not to be cost-effective in terms of their own personal costs of action, inaction and personal discount rates.

Social interactions between different farmers were found to be important in shaping uptake in our study area (either through contact with extension advisers or through project membership) and may also be vital in reducing dis-adoption of SLM. Approaches that explicitly consider social and institutional measures could be useful to include within the Kenya National Agricultural Soil Management Policy, especially because national-level polices are not implemented in a uniform way due to the devolution of agriculture to County Governments; nor will the same practices result in the same benefits everywhere, and across all farm and household types. One way to incorporate social and institutional factors would be to strengthen and reinforce agricultural innovation systems (AIS) in order to tackle soil degradation through SLM. Aerni et al. (2015) define an AIS as "a network of actors or organisations and individuals together with supporting institutions and policies in the agricultural and related sectors that bring existing or new [SLM] products, processes and forms of organisation into economic and social use; policies and institutions (formal and informal) shape the way that these actors interact, generate, share and use knowledge as well as jointly learn". Inclusion of AIS within the Kenya National Agricultural Soil Management Policy could help identify where support is needed for farmers to use particular SLM practices (building on analyses like those linked to our second objective, where costs and benefits have been evaluated), and could integrate existing approaches including participation in projects and interaction with extension advisors. It could also help to support farmer-to-farmer learning.

## 4.2 Understanding the costs and benefits of SLM implentation

Similar to the diversity in characteristics of farmers that shape uptake as addressed above, the CBA findings present a very mixed picture. SLM practices with low requirements for materials and implementation costs, such as manuring and intercropping, offer very high BCR for farmers and they provide a positive NPV over the time horizon of the *Kenya Vision 2030*. This suggests that these kinds of simple practices should be prioritised within policy or at least promoted in tandem with those that take longer for benefits to accrue.

In contrast, SLM practices with high upfront costs and high maintenance costs, such as physical terraces and agroforestry can offer much lower BCR for individual farmers and have a long ROI period, even though over the time horizon considered their NPV can be positive (depending on the discount rate used). In all cases though, where cultivation activities are already profitable, SLM practices will increase yield (and profits) and NPVs are positive. Cultivation on some farms took place at or below financial profitability. In these cases remittances from relatives and families can help farmers to overcome short-term financial short-falls. However, where cultivation is not financially profitable, our analyses suggest that the additional costs of implementing SLM practices can exacerbate the losses that farmers make if the additional labour and inputs are not outstripped by substantially higher yields. This indicates that policy should carefully target the areas in which SLM practices are promoted so that appropriate support is provided both where it is most needed (benefitting individual farmers whose land is severely degraded) and where there is greatest potential for positive NPVs (benefiting food security and agricultural production at the national level).

It will be important to balance needs and priorities across different scales. Decisions as to whether to implement SLM practices are not based on a societal-level CBA, but on the perceptions of farmers themselves. Furthermore, the CBAs undertaken in this research were based on farmers' actual costs and perceived benefits. Not all perceived benefits were quantifiable in terms of yields. For example, some farmers engaged in agroforestry because they perceived it provided benefits for the soil and for water retention, even though they considered it had made little short-term difference to crop yields. Had our research looked at wider scale societal values and ecosystem services beyond maize crop yields, different output data are likely. Benefits such as improved water retention, reduced siltation of rivers and dams, lower downstream flood risk, enhanced carbon sequestration should all be included in a follow-up CBA of societal values, as benefits are accrued by society as a whole. This would be especially critical for public and communal lands (managed by public institutions or communal institutions). Costs of SLM implementation are nevertheless currently borne by individual farmers.

# Conclusion and policy recommendations

Kenya's diversity creates a complex backdrop against which steps can be taken to prevent, reduce and reverse land and soil degradation. Indeed this emphasises the importance of employing a varied portfolio of mechanisms to adequately match the multiple contexts in which the policy will be implemented. A wide range of different measures exist which could be explored within the Kenya National Agricultural Soil Management Policy. These include economic and financial instruments, institutional and capacity building actions, and changing the legal, political, social and technical context in which land users operate. Below, we outline options for consideration within the Kenya National Agricultural Soil Management Policy, taking into account the findings in this study. Key points are in bold text.

- **Subsidies:** The Government of Kenya already has a subsidy system in place for tractors (county level) and fertilisers (national level). These **could be usefully extended to include support for SLM.** For example, where farmers have to pay for manure, the costs of transport could be reduced to enhance its use. Similarly, lowering the cost of seeds for plants such as beans which can be intercropped with maize is likely to improve uptake. As an example, reducing the cost of manure to zero in Bungoma would raise the BCR to over 6, irrespective of discount rate, indicating a substantial increase in the financial attractiveness of implementing this SLM practice. Similarly, halving the cost of bean seeds across the three counties would raise BCRs for intercropping above 2.5, again improving the financial attractiveness of this SLM practice. **This would target the 'easy wins', i.e. the SLM strategies which have shown to be universally worthwhile adopting in this study.** Subsidies may still be a useful tool even for SLM practices such as agroforestry and terraces, where BCRs and NPVs for individual farmers were more diverse. Support for implementing and maintaining physical structures and agroforestry systems would provide wider societal gains, beyond helping the individual farmers. To improve uptake of these SLM practices that deliver more diverse results requires that individual farmers do not solely bear the costs. **The appropriateness of publically-funded Payment for Ecosystem Services schemes (PES) and other economic measures could be investigated in further research, alongside new assessments of societal as well as individual benefits from SLM.** Finally, tools such as the Agricultural Public Expenditure Review (APER) could be used to provide improved understanding of current and future subsidy expenditure in support of SLM practice implementation.

- **Institutional measures: Providing support to AIS** and innovation platforms represents a useful way to enhance interaction and learning between farmers, through projects, farmer field schools and in consultations with extension advisers. AIS can often be developed based on existing networks, platforms, projects and institutions and offer a flexible approach that can embrace the complexity of the socio-economic and biophysical landscape to promote knowledge exchange and SLM uptake. AIS could also help to reduce dis-adoption rates of SLM practices.

- **Improved monitoring of relationships between land management practices and yields:** During our data collection we found very few farmers who kept records of their land management practices. Fewer still related practices to the yields they obtained. This identifies a key area in which **building farmers' capacity to monitor** would be useful and could be **supported by public investments in e.g. improved provision of weather or soil information.** Improved

farmer records of SLM practices, yields and weather (e.g. rainfall) would provide decision makers with a better overview of (both positive and negative) soil quality changes and would strengthen monitoring over the longer-term. Farmer reporting could itself be linked to subsidies, where, for example, farmers submit their practices and yields in return for reduced input prices. It is possible that farmers may be suspicious about the use of information, so any fears in this regard would need to be allayed through adequate awareness-raising of the importance and benefits associated with farmer monitoring. In some African countries, experimental work is taking place to **monitor farmer decision-making** in a cost-effective way **using mobile phone technology**. This approach could be considered in the Kenyan context too.

Once the Kenya National Agricultural Soil Management Policy is finalised and adopted, it will be crucial to ensure its regular evaluation and review. Based on the findings and policy recommendations presented here, a number of possible indicators can be identified to assist in evaluation. Policy success in improving the country's soil condition could be measured through proxies such as SLM uptake (with increased numbers of households representing a positive change); farmer participation in AIS and knowledge networks; and numbers of farmers keeping records and reporting. Gaining sufficient robust data about the direction of soil changes upon which decisions can be made is vital if the other policy measures are to be appropriately targeted. It is also paramount if a mixture of individual and societal benefits is to be gained through soil conservation and improvement.

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