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Assessing agroforestry practices and soil and water conservation for climate change adaptation in Kenya: A cost-benefit analysis

Contents

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Acronyms

BMU	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, Government of Germany
CBA	Cost-benefit analysis
CC	Climate change
EfD	Environment for Development Initiative
FAO	Food and Agriculture Organization of the United Nations
GCM	Global Climate Model
Ha	Hectare
IRR	Internal Rate of Return
KNBS	Kenya National Bureau of Statistics
Ksh	Kenyan shilling
NAP	National Adaptation Plan
NCCAP	National Climate Change Action Plan
NCCRS	National Climate Change Response Strategy
NPV	Net Present Value
SWC	Soil and water conservation
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States dollar
WOCAT	World Overview of Conservation Approaches and Technologies

Highlights

- Researchers used cost-benefit analysis to analyse the financial and economic worthiness of agriculture adaptation measures (soil and water conservation and agroforestry) using primary data from a survey of 642 households spread across five counties in Kenya.

- The results show that the assessed climate change adaptation options are economically worthwhile as they generate positive on-farm net benefits resulting from reduced soil erosion, better water retention, higher crop yields and ultimately higher incomes. Positive externalities include public benefits such as mitigation of carbon emissions and reduced siltation of dams.

- The costs of establishing terracing and grass strips are considerably high for most farmers and therefore a major barrier to adoption. Labour cost is a major constraint for promoting on-farm adoption. One possible solution is the deployment of National Youth Service (NYS) staff to undertake terracing as part of their public service.

- The demonstrated profitability of these adaptation options is not enough to guarantee adoption. Governments at the national and county level can increase adoption of economically worthwhile measures by addressing the drivers for adoption.

- Potential areas of government support for adoption of these agricultural technologies include enhancing access to agricultural extension. Government agencies can support extension services to increase awareness amongst farmers on climate change, and educate farmers regarding the technical aspects of the implementation of proposed adaptation practices.

- Improvements to land tenure security, including land titling and prompt resolution of land disputes, ensure that farmers are incentivised to invest in longer term, more expensive SWC and forestry measures. Given that gender is also a driver of the adoption of adaptation actions, gender should be mainstreamed into adaptation programmes. The unique challenges faced by female and male farmers must be addressed in all stages of project design.

- Increasing uptake of analysed adaptation practices also requires continued agricultural productivity. Investing in farmers' access to productive inputs is also crucial. This can be accomplished by creating a conducive macro-economic environment for the private sector. .and improving targeting of farmers in need.

Introduction

Kenya is highly dependent on natural resources that are being threatened by climate change. About two-thirds of the country's population live in rural areas; 40 percent of them live below the poverty line and are heavily dependent on agriculture (KNBS, 2018). Agricultural production is dominated by smallholder farmers who are heavily reliant on rain-fed farming on small land holdings ranging from 0.2 to 3 hectares. Climate events disproportionately affect the livelihoods of poor farmers and pastoralists. For instance, past droughts affected about 3.7 million people, resulting in livestock and crop loss worth about 698 billion Kenyan shillings (Ksh) in 2008 (USD 10 billion) and Ksh 211 billion in 2011 (USD 2 billion) [1] (Republic of Kenya, 2012). Climate change is expected to worsen such impacts in the future. The fifth IPCC assessment projections show an increase in seasonal mean temperature as well as changes in rainfall patterns, especially the short rains (Niang *et al.*, 2014).

The Government of Kenya recognizes the threat of climate change. Kenya's National Adaptation Plan (NAP) addresses the country's vulnerability and resilience to climate change. To be implemented over the period 2015 to 2030, Kenya's NAP proposes a series of adaptation actions in agriculture. However, the on-farm implementation of these actions will require adjustments including new technologies, reallocation of labour, and assistance to resource-poor farmers. Therefore, the widespread implementation of adaptation actions may require policy interventions to address barriers to adoption.

This study analyses the economic worthiness of adaptation measures currently being practised by some farmers on their land. It uses cost-benefit analysis (CBA), which is recommended by the Least Developed Countries Expert Group as one of the methodologies to be used in the preparatory stages of the NAPs to rank and prioritize adaptation options according to their costs and benefits to society (see UNFCCC, 2012, section B.3). CBA quantifies in monetary terms the value of the benefits and costs of a project, both financially (from the perspective on single entities, such as farmers) and economically (considering social costs and benefits accrued to various beneficiaries in society).

The analysis helps to identify solutions – either policy options or investment projects – for an efficient allocation of scarce financial resources by comparing alternative projects and policies, then indicating whether financial resources should be allocated to support a specific option (Branca, 2018).

The objectives of the study were to:

i. identify priority climate change adaptation measures practised by smallholder farmers in Kenya and describe their application, including costs incurred and benefits realized;
ii. build a solid dataset of costs and benefits of the identified priority CC adaptation options for the Kenyan agriculture sector using a representative survey data set and relevant secondary data sources; and
iii. undertake a CBA of identified adaptation strategies to assess their financial worthiness at the farm level and economic worthiness from a national perspective.

The study's findings can inform policy makers and development practitioners involved in formulating and implementing the NAP process. The study was carried out under the Integrating Agricultural Sectors into National Adaptation Plans programme (NAP-Ag), co-led by UNDP and FAO, with the aim of capacity building, generating evidence-based results for selecting adaptation options, and informing adaptation policy dialogues on adaptation in agriculture.

Agroforestry and soil and water conservation for adaptation

This study analyses the potential of two well-researched practices, soil and water conservation (SWC) measures and agroforestry, to deliver adaptation benefits (FAO, 2013a, 2013b).

The analysis found that the two most common soil and water conservation (SWC) measures in Kenya are terracing and the planting of grass strips (see Figure 1). Researchers concluded that SWC

[1] Average exchange rate 2008: 1 USD = 69 KSH 2011: 1 USD = 89 KSH (source: Central Bank of Kenya)

measures can generally increase crop yields by reducing soil loss, retaining moisture and nutrients, and preventing seed losses (see Pimentel et al., 1995; Bekele and Drake, 2003; Onduru and Muchena, 2011). SWC measures can also reduce the negative effects of climate change on crop yields by conserving soil moisture during a poor rainfall season while simultaneously reducing soil erosion on slopes, thus mitigating the resulting nutrient losses from excess rainfall.

Researchers also found that terraces can increase yields by 40-70 percent (Onduru and Muchena, 2011; Okoba, 2005; Atampugre, 2011). Compared to terraces, grass strips have a moderate effect on yield increases. However, grass strips can reduce soil loss due to runoff, particularly on sloping land. Experimental demonstration shows grass strips can reduce soil loss up to 72 percent (Tefera, 1983). Onduru and Muchena (2011) and Tenge *et al.* (2005) reported that maize yields are 14 percent lower in fields without grass strips compared to those with grass strips. Grass strips are particularly appropriate for gentle to moderate slopes, but have a shorter life span than terraces. Grass strips require renewal after about eight years, but have low establishment costs ranging between 5 to 49 person days per hectare and an annual maintenance cost of approximately 15 percent of establishment cost (Atampurge, 2011; Tenge *et al.*, 2005).

Figure 1. Terraces (left) and grass strips (right)

Source: CIFOR and WOCAT

Agroforestry is a collective name for land use systems and technologies that involve deliberately using woody perennials (trees, shrubs, palms, bamboos, etc.) on the same land management unit as agricultural crops and/or animals in some form of spatial arrangement or temporal sequence (FAO, 2003). Agroforestry is widely practiced in Kenya and reportedly has a positive impact on livelihoods of farmers (Nyaruai, 2016). Trees, especially woody trees, are more resilient to climate change because of their deep roots, which enhance their ability to cope with reduced soil moisture. Agroforestry generates products that households can either use or sell for income, such as fruits, fodder, wood for fuel and construction, medicinal substances, gums, tannins, essential oils, fibres, and waxes, thereby providing alternative livelihood sources. Agroforestry can reverse soil degradation, restore tree cover, improve crop productivity, and diversify households' income sources.

Figure 2 shows an example of a farm with trees planted in crop fields in central Kenya. Among farmers surveyed, about 89 percent were found to be planting trees in their farms. The age and types of trees planted affect the benefits of agroforestry on crop yields. As trees age, they develop canopy and shade that reduce the productivity of crops planted close to the trees, causing some partial opportunity cost. For an agroforestry plot with woody trees, crop yields are reduced after a certain point of tree growth. This may not be the case when the trees are non-woody. For example, farmers will often use leguminous trees as fodder. A recent experimental study performed by Ndlovu *et al.* (2016) in Eastern Kenya found that maize planted on the same plot as woody plants had 30 percent less yield compared to maize planted on plots with no trees. Nevertheless, woody trees also provide substantial returns to the farmers when harvested at about eight years.

Figure 2. Agroforestry applied in a farmer's field in central Kenya

Source: World Bank

Data and methods

Researchers collected the data used in this study from 642 households across five counties under the Environment for Development (EfD)) initiative.[2] The data covers a wide range of CC adaptation measures with details on establishment and maintenance costs and other relevant information. Researchers filled data gaps using secondary data sources. Five farming systems are identified, corresponding to the agroecological zones of the study sites. Maize was selected as the reference crop because it is the most widely cultivated staple crop in Kenya and the most important for ensuring food security. Maize encompasses 40 percent of all crop area in Kenya and is grown by 98 percent of Kenyan smallholder farmers (Ministry of Agriculture, Livestock and Fisheries, 2013).

Agroforestry is more common in the studied areas than terracing and grass strips. About 630 farmers (98 percent) indicated that they planted trees in the year preceding the survey (they planted 70 trees on average during that year). Trees are often planted in crop fields; densities of up to 200 trees per hectare (of the commonly planted *Grevillea robusta* species) have been reported in maize fields in Central Kenya (Muchiri *et al.*, 2002). Fewer farmers adopted terracing and grass strips on their farms; only 16 percent had terraces and 25 percent planted grass strips.

The analytical method used in the cost-benefit analysis discussed herein is a comparison of net benefits under two scenarios: 'with' and 'without' adaptation measures. Researchers computed the incremental benefits resulting from the implementation of climate adaptation measures as the difference between base income (i.e. the value of income 'without adaptation measures') and the 'with adaptation' income. Farmers who adopt SWC and agroforestry measures incur establishment costs. They also incur annual maintenance costs over the lifetime of the adaptation measure. Since it is assumed that farmers would only adopt adaptation measures if they are profitable, the analysis estimates the on-farm profitability of the selected measures.

Since climate change impacts affect not only individual farmers but also society in general, societal interest in adaptation measures extends beyond the farm gate. The national government intervenes in the agriculture sector (e.g. through input subsidies, price support etc.) with the goal of achieving certain welfare objectives. This CBA is carried out from the perspective of single farmers (via financial analysis) and from the point of view of society in general (using economic analysis).

2 The EfD programme is a global network of fifteen environmental economics research centres supported by the Swedish International Cooperation Agency (SIDA)..

The following steps were carried out during the analysis: (i) computation of costs and benefits of the selected adaptation measures at farm level; (ii) financial analysis; (iii) economic analysis; and (iv) sensitivity analysis.

Results

Computation of costs and benefits of selected adaptation measures

The researchers quantified and assigned value to the costs and benefits associated with the selected adaptation measures.[3] The material unit costs for the establishment of terraces and grass strips did not vary between the different sites. There were, however, notable differences in the prevailing daily wage rate by site. The cost of labour was low in low agricultural potential zones in Kilifi and Homa Bay (rate of USD 2.00) and higher in the higher potential zones (USD 2.50 in Kakamega; USD 3 in Nyeri; and USD 3.50 in Nakuru) (see **Table 4, 5, and 6** for classification of zones). This variation is expected because there is higher demand for labour in higher potential zones compared to the lower potential zones. The establishment and maintenance costs of terraces, grass strips and on-farm tree planting are outlined in **Tables 1, 2 and 3** respectively.

Table 1

Costs associated with adoption of terraces (USD/Ha)

Cost category/Item	Quantity	Unit/Unit price	Amount
Establishment costs			
a) Material costs			
Spirit and line level		12	12
Levelling board and string		18	18
Pegs	Lump sum		60
Total material costs			**90**
b) Labour costs	50	2.6	**130**
Total establishment costs			**310**
Maintenance costs			
Labour costs (average wage rate)	**10**	**2.6**	**26**

Table 2

Costs associated with adoption of grass strips (USD/Ha)

Cost category/Item	Quantity	Unit/Unit price	Amount
Establishment costs			
a) Material costs			
Planting materials	40	(Sack) @ USD 5	200
b) Labour	25	Person-day @ 2.6	65
Total establishment cost			**265**
Maintenance costs			
Labour costs (average wage rate)	10	2.6	26

[3] For comparison purposes, all the costs and benefits are expressed in common units ($/ha[3] of land).

Table 3

Costs associated with adoption of agroforestry per hectare

Cost category/Item	Quantity	Unit/Unit price	Amount
Establishment costs			
a) Material costs			
Seedlings cost + transport (average)	70	0.3	21
b) Planting labour	4	2.6	10.40
Total establishment cost			**31.40**
Maintenance costs			
Labour costs (average wage rate)	2	2.6	26

The study found an association between the adoption of SWC adaptation measures and an increase in maize yields. **Table 4** gives a summary of the incremental benefits associated with adopting soil and water conservation measures *ceteris paribus*. The adopted SWC measures generated positive net benefits for the farmers, with terraces generating slightly higher net benefits compared to grass strips. It is important to note that the incremental benefits associated with terracing are only realized after the third year of establishment due to the high soil disturbance associated with their installation (Atampugre, 2011).

The dynamics are slightly different for tree planting. In the first three years after establishment, the trees are young and their canopies do not disrupt normal production. Beyond that period, however, maize yield reductions of up to 30 percent can occur. In years eight to ten, the trees are harvested and sold for between USD 50-80 depending on the size and quality of the tree. The study used an average figure of USD 50 per tree, showing an income of USD 3 500 generated. This income can offset the annual income losses due to reduced yield and generate a positive incremental benefit for the farmers (see **Table 5** for a summary of the decrease in maize yields and income associated with agroforestry).

The costs of establishing terraces and grass strips (USD 310 and 265 respectively) are high by the standards of rural areas where average income is less than USD 2 per day and only 7.1 percent of households earn non-farm income (KNBS, 2018). Given competing basic needs within households, many households would have difficulty adopting these measures on their farms. The cost of establishing on-farm forestry through tree planting, on the other hand, is much lower, but the benefits accrue in the long term and the method is associated with reduced yields in the medium term.

Researchers found SWC and agroforestry measures generate a range of environmental benefits for society at large beyond the benefits to farmers. These include carbon sequestration, nutrient recycling, and prevention of siltation of dams and other water bodies through reduction of soil erosion.

Table 4

Incremental benefits associated with SWC adoption measures (Terraces and Grass Strips)

County	Agro-ecological zone/maize potential	Av. maize yield without SWC (Kg/Ha)	Av. Maize yield with SWC measures		Av. price/ Kg of maize (USD)	Incremental income with SWC (USD/Ha)	
			With terraces	With grass strips		With terraces	With grass strips
Kilifi	Low potential/ Coastal areas	1 055	1 266	1 203	0.35	74	52
Homa Bay	Low potential/ Nyanza	1 055	1 266	1 203	0.29	61	43
Kakamega	Western/ medium potential	1 816	2 179	2 070	0.29	105	74
Nyeri	Central/medium potential	1 816	2 179	2 070	0.29	105	74
Nakuru	High potential/ Central Rift	3 265	3 918	3 722	0.22	144	101
AVERAGE		**1 802**	**2 162**	**2 054**	**0.29**	**104**	**73**

Table 5

Maize yield decrease associated with agroforestry (after the third year)

County	Agro-ecological zone/maize potential	Av. maize yield with Agro-Forestry (Kg/Ha)	Av. Maize yield without Agro-Forestry (Kg/Ha)	Av. price/Kg of maize (USD)	Incremental income with Agro-Forestry (USD/Ha)
Kilifi	Low potential/ coastal areas	1 055	1 372	0.35	-111
Homa Bay	Low potential/ Nyanza	1 055	1 372	0.29	-92
Kakamega	Western/medium potential	1 816	2 361	0.29	-158
Nyeri	Central/medium potential	1 816	2 361	0.29	-158
Nakuru	High potential/ Central Rift	3 265	4 244	0.22	-215
AVERAGE		**1 802**	**2 342**	**0.29**	**-157**

Financial analysis

Researchers derived the results of the financial cost-benefit analysis from farm models developed for the five farming systems, which were identified based on the location of the farmers.

Table 6

Results of the financial analysis for terracing (base scenario)

	Net Present Value (NPV) in USD	Internal Rate of Return (IRR)	Investment decision
Average for the whole sample	+337	30%	Worthwhile (✓)
By Farming system			
High potential (Rift Valley)	+793	37%	Worthwhile (✓)
High potential (Western)	+265	27%	Worthwhile (✓)
Medium potential (Central)	+164	24%	Worthwhile (✓)
Low potential (coastal)	+134	21%	Worthwhile (✓)
Low potential (Nyanza)	+58	17%	Worthwhile (✓)

Based on results shown in **Table 6** (see the profitability indicators net present value, NPV and internal rate of return, or IRR), terracing is financially worthwhile from the perspective of farmers. Terracing is more profitable in the high potential zone where maize productivity is high, and less profitable in the low potential areas. **Table 7** illustrates the results of the financial analysis for the grass strips base scenario.

Table 7

Results of the financial analysis for grass strips (base scenario)

	Net Present Value (NPV) in USD	Internal Rate of Return (IRR)	Investment decision
Average for the whole sample	+208	28%	Worthwhile (✓)
By Farming system			
High potential (Rift Valley)	+186	31%	Worthwhile (✓)
High potential (Western)	+269	38%	Worthwhile (✓)
Medium potential (Central)	+212	30%	Worthwhile (✓)
Low potential (coastal)	+34	16%	Worthwhile (✓)
Low potential (Nyanza)	+34	10%	NPV (✓) IRR (×)

Investing in grass strips generated positive net benefit to farmers over the investment period. However, in the lower potential maize zones of Nyanza, the IRR was lower than the prevailing interest rate. **Table 8** presents the results of the financial analysis for the tree planting adaptation option.

Table 8

Results of the financial analysis for tree planting (base scenario)

	Net Present Value (NPV) in USD	Internal Rate of Return (IRR)	Investment decision
Average for the whole sample	+518	27%	Worthwhile (✓)
By Farming system			
High potential (Rift Valley)	+310	21%	Worthwhile (✓)
High potential (Western)	+514	27%	Worthwhile (✓)
Medium potential (Central)	+540	28%	Worthwhile (✓)
Low potential (coastal)	+670	31%	Worthwhile (✓)
Low potential (Nyanza)	+790	38%	Worthwhile (✓)

Since tree planting is a dynamic process (new ones are planted as old are harvested over time), the study used the average number of trees planted during the year—70. Planting trees on the farm even with the yield reduction trade-off is still profitable for all farming systems.

Economic analysis

Researchers made the following adjustments when performing the economic analysis:

- Researchers adjusted the price of materials subject to taxation by removing the value of value-added tax (rated at 16 percent).
- Researchers corrected the price of maize for distortions. As noted in a report prepared by FAO (2014) on price incentives for Maize in Kenya, price distortion by government action is prevalent through price support, fertilizer subsidies, taxes, etc. The study indicates that the adjusted nominal rate of protection for maize at the farm gate averaged about 12 percent.
- Researchers applied a social interest rate of 5 percent.
- Researchers added the costs of soil erosion in dam siltation and subsequent costs of de-siltation and water purification. The study adapted the costs from a previous study conducted by Nkonya *et al.* (2008) on the off-site economic impact of soil fertility management in Kenya in the catchment area of one of the large dams (Sasumwa dam) that supply Nairobi with water. In their study, they reported that it costs Ksh 9.91 million to cover the annual cost of water treatment due to soil erosion. Given that the Sasumwa dam has a catchment area covering 107 square kilometres (equivalent to 10,700 ha), the average offsite cost per hectare of soil degradation is Ksh 926 (USD 92.6). In the economic analysis, this additional cost is assigned as an 'avoided cost' in the 'with terraces and grass strip' scenario.
- Researchers added carbon sequestration benefits. It is extensively noted in the literature that agroforestry practices and solid conservation measures play an important role in mitigating climate change effects and productively sequestering carbon from the atmosphere. A study by Saiz *et al*. (2016) on the impact of terraces on carbon sequestration in Eastern Kenya showed that sites that had terraces had significantly higher soil carbon (up to 6MgC/ha) compared to sites where farmers practised conventional agriculture. A study conducted by Antle *et al.* (2007) in the Peruvian Andes showed that terracing and agroforestry have the potential to increase per capita incomes of farm households if offered a price of USD 100/Mg C. When analysing terracing, researchers adopted the lower bound of 0.5 Mg C/ha (Saiz *et al*. 2016). Studies show that *Grevilia robusta* sequesters about 3 Mg C/ha of below ground carbon (see Jangra *et al.* 2010). Researchers used this figure as an agroforestry adoption measure. Researchers also adopted the quoted price of a ton of carbon by the European Emission allowances price commodity (USD 23 in August 2018).

Tables 9, **10** and **11** present the results of the analyses for terracing, grass strips and agroforestry respectively. From the perspective of the economic analysis, the study found that all of these practices are profitable in all the farming systems considered.

Table 9

Results of the economic analysis for terracing (base scenario)

	Net Present Value (NPV) in USD	Internal Rate of Return (IRR)	Investment decision
Average for the whole sample	+878	32%	Worthwhile (✓)
By Farming system			
High potential (Rift Valley)	+1 153	25%	Worthwhile (✓)
High potential (Western)	+746	28%	Worthwhile (✓)
Medium potential (Central)	+552	25%	Worthwhile (✓)
Low potential (coastal)	+495	24%	Worthwhile (✓)
Low potential (Nyanza)	+357	20%	Worthwhile (✓)

Table 10

Results of the economic analysis for grass strips (base scenario)

	Net Present Value (NPV) in USD	Internal Rate of Return (IRR)	Investment decision
Average for the whole sample	+208	28%	Worthwhile (✓)
By Farming system			
High potential (Rift Valley)	+984	33%	Worthwhile (✓)
High potential (Western)	+1 104	37%	Worthwhile (✓)
Medium potential (Central)	+984	29%	Worthwhile (✓)
Low potential (coastal)	+269	17%	Worthwhile (✓)
Low potential (Nyanza)	+376	12%	Worthwhile (✓)

Table 11

Results of the economic analysis for tree planting (Base scenario)

	Net Present Value (NPV) in USD	Internal Rate of Return (IRR)	Investment decision
Average for the whole sample	+1 596	30%	Worthwhile (✓)
By Farming system			
High potential (Rift Valley)	+1 305	24%	Worthwhile (✓)
High potential (Western)	+1 440	30%	Worthwhile (✓)
Medium potential (Central)	+1 612	31%	Worthwhile (✓)
Low potential (coastal)	+1 813	33%	Worthwhile (✓)
Low potential (Nyanza)	+1 860	35%	Worthwhile (✓)

Table 12 compares the results of both financial and economic analyses in the base scenario.

Table 12

Summary of financial and economic analyses (base scenario)

Adaptation option	Financial CBA		Economic CBA	
	NPV	IRR	NPV	IRR
Terracing	+337	30%	+877	32%
Grass strips	+208	28%	+557	28%
Tree planting	+518	27%	+2 699	29%

Sensitivity analysis

A sensitivity analysis was conducted for two scenarios: (i) varying discount rates by +25 percent and +50 percent; and (ii) varying yield changes by -25 percent.

(i) By varying the discount rates, researchers could make a number of observations. The tree planting option remained stable, and financially and economically worthwhile. The terracing option was stable under the varying interest rates for both financial and economic analyses. A similar pattern was observed with grass strips; they were found to be stable under varying interest rate considered. However, in the low potential zones in Nyanza, grass strips failed the IRR test even as NPV remained positive.

(ii) The results of CBA remained stable when yield gain was reduced by 25 percent for terracing and grass strips.

Discussion and policy implications

Analytical results show that the climate change adaptation measures analysed are financially and economically profitable. However, profitability varies by the agro-potential of the area: adaptation options are most profitable in high potential areas, even if the opportunity cost may be highest in those areas. Results are stable and do not vary when discount rates and yield changes change.

The study's findings concur with similar analyses conducted in Kenya that found positive net present value for SWC practices: Onduru and Muchena (2011) (on terracing and grass strips in upper Tana region in central Kenya); Atampurge (2014) (on terraces and grass terraces in Central Kenya); and Ng'ang'a *et al*., (2017) (on climate smart soil conservation practices in western Kenya). A cross-country study by Lutz *et al*., (1994) in central America and the Caribbean showed IRR values ranging from 11-84 percent for various types of soil and water conservation measures. Increased yields associated with the adoption of SWC represent an important option that can be used to improve household food security.

Most people in Kenya depend on wood fuel and charcoal for energy. The most recent Kenya Integrated Household Budget Survey reported that 84.3 percent of households in rural areas used firewood as the main energy source for cooking. Even in urban areas, the survey reported that only 30 percent of the households use clean energy (LPG or electricity) (KNBS, 2018a). The current efforts by the government to conserve forests will also limit the amount of wood sourced from natural forests. Therefore, it is reasonable to expect that a substantial part of the demand for fuel wood will be supplied by agroforestry. This will make on-farm tree planting a profitable option, especially with climate change expected to negatively impact the yields of annual staple crops. In the future, agroforestry may become an important resource used to improve households' energy security.

Even though the adaptation practices considered in the analysis are profitable, their level of adoption is limited. The factors that inhibit their adoption and application at farm level are well documented. A study conducted in Meru County, found that providing training on impacts of soil erosion, access to credit and land ownership significantly influenced the adoption of SWC measures (Alufah *et al*., 2012). A study conducted in Ethiopia (Asfaw and Neka, 2017) reported similar factors influencing the adoption of SWC. They reported that farmer education, access to extension services and training were positively correlated with adoption of SWC practices.

Studies from different parts of the world report that agroforestry can be profitable for farmers. Current et al. (1995), reporting on case studies of twenty-one agroforestry projects in six Central American and two Caribbean countries, found that many agroforestry practices are profitable under a broad range of conditions, and are therefore likely to be widely applicable. Profitability of agroforestry for farmers provides a crucial incentive for farmers to adopt a given practice. In Kenya, several studies have analysed the drivers of adoption of agroforestry practices. Some critical drivers include land tenure (Wafuke, 2012; Kaua, 2012; Nyaga *et al.*, 2015), gender (Mawuli, 2014; Wafuke, 2012), education level (Kaua, 2012; Mawuli, 2014; Oino and Mugure, 2013), and access to extension services (Mawuli, 2014; Kaua, 2012; Oino and Mugure, 2013).

From a methodological perspective, data should be as reflective of the local conditions as possible. Using national level data to generalize for local conditions may lead to inaccurate results. Farmers make decisions based on the local prices that they confront. As noted in the study, wage rates and prices of agriculture outputs varied considerably across different agro-ecological zones. The current yield levels are critical determinants of the profitability of climate change adaptation options. Complementary efforts aimed at increasing farm productivity are critical in determining the long-term profitability of climate change adaptation measures.

The profitability of agricultural technologies is not high enough to guarantee adoption. Other intervening factors must support uptake of these technologies. Often, these factors are beyond the control of individual farmers. The government should intervene to relax the constraints that limit adoption. This need is even more urgent in the face of climate change, as already vulnerable farmers are exposed to even greater stress. Farmers face several challenges in adapting to climate change, and appropriate supporting interventions should be made available to them.

Greater investments in rural and agricultural development are needed enable households to make strategic, long-term decisions that positively affect their future well-being. Some recommendations for increasing adoption include:

- *Creating awareness and enhancing access to agricultural extension*. Awareness campaigns aimed at increasing knowledge of climate change among farmers is an important precursor to investment in adaptation measures. Farmers must be made aware of the long-term impacts of climate change and the need to make necessary adaptations to deal with these impacts.
- *Establishing land tenure security and addressing drivers of adoption*. SWC and agroforestry measures are costly and their benefits can only be appropriated in the medium- and long-term. Therefore, farmers need secure tenure on their land to be able to invest in these measures. The government must ensure that land tenure security is conferred to owners and subsequently protected. In Kenya, land title registration and quick resolution of existing land disputes would enhance adoption of adaptation measures. To address the unique challenges faced by female farmers when adopting these measures, national and county governments should make explicit efforts to mainstream gender into their extension service work and climate change adaptation programmes at all levels, including project design, budgeting, implementation, and monitoring and evaluation.
- *Increasing productive inputs and finance.* Investment into agricultural production is premised on achieving a profitable return. Additional investments in climate adaptation measures can only be justified by increased productivity and higher profits. To achieve increased productivity, farmers must have access to modern productive inputs such as improved seeds, fertilizers, agro-chemicals, machinery and such other productive inputs.

The government can use other policy levers to encourage adoption. The government can enhance access to credit and inputs by creating a conducive macro-economic and business environment for the private sector to operate. For expensive inputs, the government has been providing subsidies (e.g. fertilizer subsidy) but the targeting has proven inefficient. These subsidies need to better target poor farmers who are unable to purchase fertilizers at market prices. As noted in the analytical results, the economic attractiveness of adaptation strategies depends on the agricultural productivity of the farming enterprise.

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