



## Evidence on Smallholder Dry Land Farming Systems and Resilience and Adaptation to Climate Change: A Case of Sustainable Land Use Management in Kenya

Simon Gicheha\*

Department of Agricultural Economics and Agribusiness Management, Egerton University, Kenya

\*Corresponding author: Simon Gicheha, Department of Agricultural Economics and Agribusiness Management, Egerton University, Kenya, Tel: +491776338495; E-mail: sgicheha82@gmail.com

Received date: October 29, 2018; Accepted date: November 16, 2018; Published date: December 10, 2018

Copyright: © 2018 Gicheha S. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

### Abstract

Feeding the ever-increasing world population in the face of changing climate may require significant transformation of the existing agricultural production systems. Such transformations have a high potential in terms of delivery of co-benefits in form of increased carbon sequestration and reduced greenhouse gas emissions. It has the potential to generate public goods in terms of climate change mitigation, improved watershed functioning and biodiversity conservation. However, efforts by the farmers to achieve sustainability, ideally demands diversity in technical, socio-economic and natural resource endowment to enable them to efficiently spread risks. It also demands ability and flexibility in management of these resources to enhance adaptation to short term variability. Agricultural farming systems in the Arid and Semi-Arid Lands (ASALS) have been observed to follow non-equilibrium dynamic change rather than predictable linear change. Planning in terms of standardized and simplified approaches is therefore not very practical and farmers in most cases remain vulnerable even in presence of an ideal policy and institutional framework. A wide range of management and technological options at local level are therefore required to assist the farmers to improve their adaptive capacity. Evidence showed that majority of SLM practice results in yield increase except for soil and water conservation in some cases due to slope and soil depth characteristics. Adoption of individual technologies did not necessarily result in increased productivity. Adoption of multiple technologies however requires an understanding of nutrient demand for different soils. Adoption of these practices was observed to be influenced by age of the household head, household size, shocks, off farm income and gender. Institutional frameworks both public and private must adequately address these issues within the technology transfer systems to assure success.

**Keywords:** Dry land; Farming system; Climate change; Sustainable land

### List of Acronyms

AGRA: Alliance for Green Revolution in Africa; ASALS: Arid and Semi-Arid Lands; CIAT: International Centre for Tropical Agriculture; FAO: Food and Agriculture Organization; ICRISAT: International Crops Research Institute for the Semi-Arid-Tropics; SLM: Sustainable Land Management; UNEPL United Nations Environmental Programme; UNESCO: United Nations Education Science and Cultural Organization; UNCCD: United Nations Convention to Combat Desertification; UNFCCC: United Nations Framework Convention on Climate Change; UNFPA: United Nations Population Fund; WOCAT: World Overview of Conservation Approaches and Technologies

### Introduction

#### Climate change and SLM

In majority of developing and emerging countries, agriculture remains a key driver of economic change and progress. The sector is expected to meet 70% extra demand for food to feed the over 9.5 billion population projected by the year 2050 [1]. However, the progress towards achieving this goal is met by a myriad of challenges

including declining land, hunger and malnutrition, pervasive poverty, diminishing water resources, rising energy and environmental costs, increasing prevalence of pests and diseases, increasing biosafety and biosecurity standards and regulations, eroded ecosystems services and climate change characterized by high incidences of floods and droughts [2].

In Kenya, there have been attempts to counter the challenges through intensification but there has been a concern over sustainability issues concerning mining of soil nutrients, soil erosion, biodiversity degradation and environmental impacts of overuse of inorganic fertilizers.

Climate change in particular has piled pressure on intensification in the future due to the magnitude and speed of the expected change. The challenge here is adapting farming system at smallholder level while optimally intensifying and improving climate change mitigation.

There are concerns regarding which technologies are most appropriate to achieve these objectives away from the dominant intensification models (Use of capital inputs such as pesticides and fertilizers). For some time now, the discussion has shifted to SLM technologies which achieve intensification without further depletion of water and soil resources while restoring soil fertility, building resilience and improving the capacity of the farming systems to sequester carbon [3].

Sustainable land management ideally refers to the practice of managing land without reducing biological biodiversity and damaging the ecological processes. Consideration of the natural life support systems and their ability to withstand stress such as climate change underpins the prosperity and survival of human communities. It has benefits including increased land productivity through water use efficiency, increased soil fertility, improved nutrient and organic matter cycles and microclimatic conditions. This leads to improved livelihoods of land users mostly at small scale level and improved ecosystems (Conserve biodiversity, mitigation and adaptation to climate change by increasing the carbon stock).

Irrespective of these potential benefits of the SLM practices to generate both public and private goods, the adoption rate at global level has been relatively low. This generates an interest in understanding the costs, benefits and barriers to its successful adoption in Kenya.

This paper reports a synthesis of result of literature review on the evidence of sustainable land management systems and the contribution to enhance mitigation and building resilience to climate change in Kenya. The study considers SLM adoption studies at household level and yield impacts of the technologies for different crops across Kenya as a yardstick for effectiveness in assisting farmers to adapt and mitigate climate change. Factors influencing technology adoption are also highlighted.

### Statement of the problem

SLM technologies potentially do not only stand to provide benefits in terms of conservation but also in improvement of the natural resources. Increasing the soil organic matter content makes it possible for farming fields to effectively act as carbon sink but also reducing soil erosion and improving the soil water holding capacity. This is crucial for dry land agriculture due to limited precipitation. This ultimately has an implication on biodiversity and food security. This happens without compromising yield levels meaning that increased degree of resilience of the dry land farming systems can act as effective adaptation measure against the risks of drought and huge rainfall variations. Though there have been efforts to promote these technologies, the adoption is still pretty remote and farming families in the dry lands of Kenya continue to face hunger year after year.

### Goal of the study

The overall objective of the study is to contribute towards attaining food security and poverty reduction in Kenya.

### Objectives of the study

To determine Sustainable Land Management implications on land use changes and adaptation to climate change in Kenya.

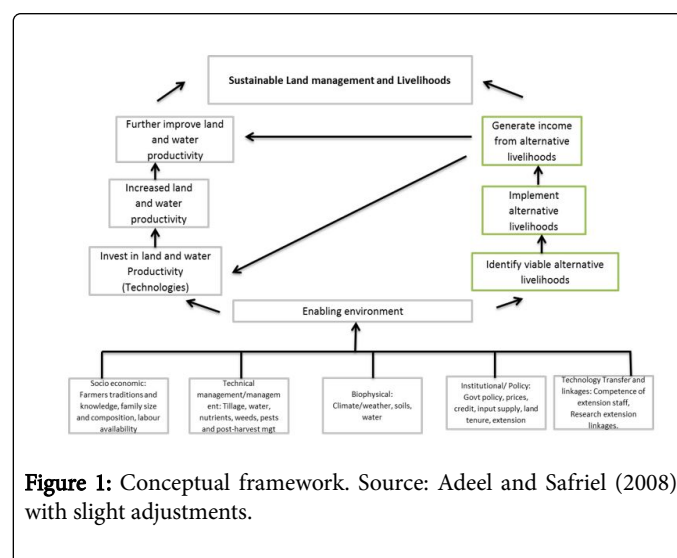
To establish the drivers of Sustainable Land Management technologies adoption in smallholder dry land agriculture in Kenya.

### Rationale and conceptual framework

This paper provides detailed information on the yield performance of Sustainable Land Management technologies and adoption among smallholder dry land farmers.

Achievement of food security in the face of changing climate demands multifaceted approaches among Sustainable Land

Management. If SLM technologies provide an opportunity for smallholder dry land agriculture to adapt to climate change in Kenya, it means adoption and practice can translate to significant progress towards food security especially in the drylands where population has increased six folds between 1989 and 2009. Therefore, any research work that is aimed at quantifying the performance of these technologies either as individual or as a combination and the drivers behind adoption is necessary.



**Figure 1:** Conceptual framework. Source: Adeel and Safriel (2008) with slight adjustments.

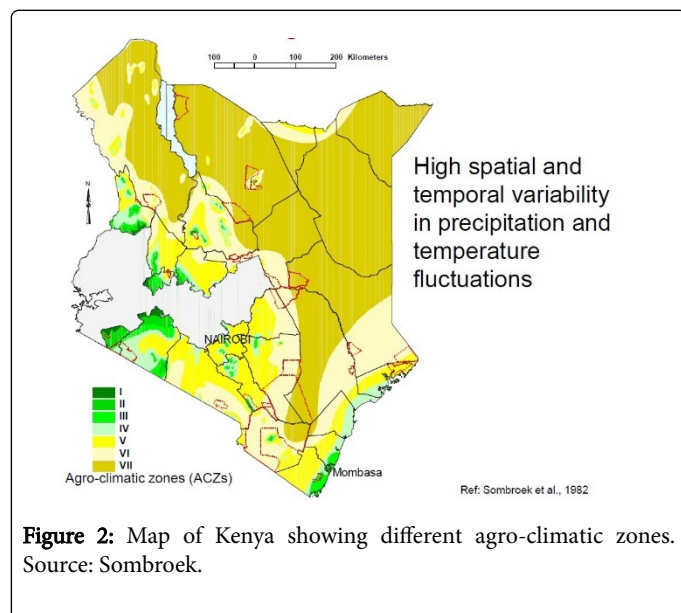
As shown in Figure 1, Social economic factors (family size and composition, labour availability, household incomes both on farm and off farm, occupation), biophysical factors (climate, soils, water pests and weeds), institutional and policy factors (prices, credit, input, supply, land tenure, markets), technical knowledge (tillage systems, seed selection, harvest management) and technology transfer and linkages (availability and competence of extension staff, research extension farmer linkages, farmers attitudes towards new technologies) are likely to influence the capacity of the farmers to produce food sustainably. Integration of these factors forms the framework for conducive and enabling environment for investment in sustainable land management technologies. The success of the technology transfer mechanisms demands an understanding of the local agro-ecosystems in terms of the applicability and also the quality of the extension service. For example, the extension service needs to consider technology alternatives that simultaneously and sequentially act as either substitutes or compliments and whether the adoption decisions are made exogenously. If this effectively happens, farmers can improve productivity and intensify their production systems. The end result is optimization, lower environmental and social costs and sustainability of food production.

Technical options to improve productivity of land and efficiency in water use may not be enough to achieve adoption and the benefits accrued. There is need to introduce alternative livelihoods for the dryland communities. Inadequate or lack of alternative livelihoods may enhance poverty-degradation linkages. These alternatives income sources however should have minimal pressure on land resources and include such examples as value addition to plant and animal products through processing with simple technologies and renewable energy (Solar and wind). Value addition should be tied to market demand and requirements to assure sustainability. When income streams improve, the capacity of the farmers to invest in sustainable land management

also improves and this has an implication on adoption of multiple technologies and also the performance of those already adopted.

## Materials and Methods

This study focuses on the arid and semi-arid regions of Kenya which covers agro-climatic zones IV to VII or approximately 80% of the country. Close to four million people live in the ASALS mostly the pastoral communities plus other rangeland users. These climatic zones are home to over 70% of the country's livestock whose production accounts for 24% of total agricultural output (Figure 2).



ASALS compared to other regions have the highest incidences of poverty and least access to basic services such as healthcare and education. Drought conditions are common, and their frequency has increased rendering the communities vulnerable.

The study involved a review of existing literature on the evidence of impact of selected SLM mitigation technologies on land productivity. Productivity was measured in terms of percentage yield per unit area for different crops in the dry lands. Technologies selected for this study included:

- Irrigation: Terraces, contour farming, Water harvesting,
- Integrated nutrient management: Organic fertilization (use of compost, animal and green manure),
- Agronomic practices: Use of cover crops, Improved crop or fallow rotations, Improved crop varieties, Use of legumes in crop rotations,
- Tillage and residue management: Reduced/minimum/zero tillage,
- Agroforestry: Crops on tree-land, Trees on cropland.

Studies of interest had to record a specific SLM technology considered individually or a combination with other technologies. They also had to report the specific crop and the change in yield. Studies reporting yield impacts from a combination of technologies had to clearly indicate the impact value for each of the technologies otherwise they were not considered.

This study also considered a wider implementation of the SLM technology more specifically farm level as opposed to experiments such as demonstration plots and on station experiments.

Peer reviewed journal papers from open source and publicly available electronic databases such as science direct and AgeCon were the main source of data. Materials from the CIPSEM library and SLUB were also widely consulted.

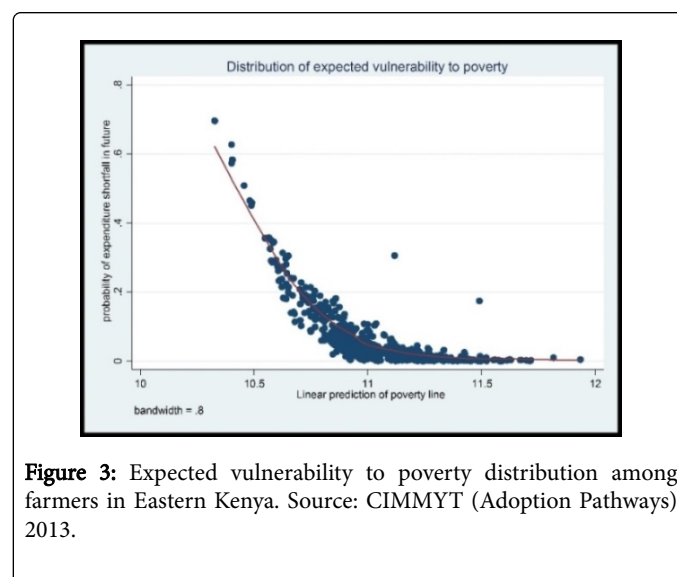
Once a paper was considered fit for consideration, papers cited in that study were used to trace other related literature and ultimately created a richer set.

The information extracted from the journal papers included a description of the technology, the crop on which the technology was used, technology transfer mechanisms and adoption and yield impact in comparison with the situation before the technology or simply conventional scenarios.

## Climate Change Vulnerability and SLM in Sub-Saharan Africa

### Predicted climate change and vulnerability in Sub-Saharan Africa

Smallholder farmers in Sub Saharan Africa face a myriad of challenges more importantly the resource constraints that hinder accessibility to necessary technologies to improve and maintain their food production potential. Climate change is worsening this situation, as erratic weather patterns and increased incidences of drought have significantly decreased the average yields. AGRA [4] records that the uncertainty in precipitation coupled with strong warming trend could lead to substantial increase in drought like the one witnessed in the horn of Africa in 2011, where Kenya and Somalia were severely affected. Climate change is projected to cause a reduction in land area suitable for food production by up to 3% especially in the Sahelian belt [5]. According to World Bank [6], the current variations in water availability observed in this region could get worse under the 2°C warming. It is projected that annual precipitation and ground water recharge may fall by up to 30% and 50% respectively.



The adequacies of temperature, moisture availability and soil conditions for crop growth are the major factors influencing the Length of the Growing period (LGP). According to Sarr, LGP is expected to decrease by up to 20% in the Sub-Saharan region by the year 2050 [7]. However, it's expected to increase in the East African region though it's not projected to lead to improved agricultural productivity. For example, maize yields are expected to reduce by up to 19% under longer growing periods.

Word Bank estimate increases in pest and diseases. In some instances, cases of pest and diseases may intensify in areas where they are currently minor problems [6]. Their prevalence is projected to increase, and new diseases and pests may emerge in areas they have not been seen before.

According to Jones and Thornton, millions of farmers in this region are expected to switch from mixed crop-livestock systems to livestock only [8]. However, this may not be a reprieve to the farmers as this shift is projected to lead to reduced availability of forage due to reduced extent of the savanna grasslands. Productivity of the livestock systems will also be compromised in this case with increasing temperatures impacting on the food intake by the animals. Thornton and Cramer, document that majority of the livestock species perform at temperatures between 10-30°C otherwise above this they reduce their feed intake by 3-5% for each °C rise in temperature [9]. This is an indicator of how climate change will constrain possibilities by farmers to diversify and ultimately spread risks. Community livelihoods that depend on local ecosystems will be severely affected [6].

A study by CIMMYT in the semi-arid eastern Kenya showed that a significant number of smallholder farmers are projected to remain vulnerable to changes in climate. This is interpreted as the probability of a person's expenditure falling below the poverty line as shown in the Figure 3 [10].

The paper analyzed the influence of SLM technology adoption on crop performance as an adaptation strategy to climate change in arid and semi-arid climates of Kenya. Some studies made more than one contribution when the performance of different crop varieties was considered. Consideration of the studies that quantify the yield effect only was pretty limiting and including those (studies) that indicate the direction of effect was deemed necessary. To allow for more confidence in drawing conclusions and make the results more comparable, the amount of change in yields compared to conventional practice reported was harmonized by converting them to percentages. Percentage yield variation under each of the technologies considered (Irrigation, integrated nutrient management, Agronomic practices, Tillage and residue management and Agroforestry) was examined.

According to the Kenya Economic update (2013) the poverty line in rural areas stands at KES 2,900 per month translating to KES 34,800 per annum and KES 95 per day which is above the value of a dollar. This is up from KES 1562 per month in the year 2005. A significant number of households are still expected to remain below the poverty line.

**Sustainable land management practice and performance: global perspective**

Food production in Africa faces major challenges in the face of growing demand for food to feed the ever-increasing population. There has been observed uncertainties from climate variability, erosion of ecosystems services and decline in land availability where land per capital output has been projected to decrease from 4.3 hectares to 1.5 hectares between 1961 and the year 2050 respectively. The growth of crop productivity is also expected to drop. The annual growth rate of cereals will decrease from 3 to 5% to about 1% in 1980 and 2050 respectively [2].

According to ICRISAT, poor soil fertility and health poses a greater challenge to food production than drought in Sub Saharan Africa [11]. A clearer focus on this area therefore may be a more promising direction towards a sustainable solution.

SLM is the opposite of land degradation or a reduction in the biological or economic productivity of rainfed cropland, irrigated cropland or range, pasture, forest, and woodlands including processes arising from human activities and habitation patterns. It is not very clear about the extent of land degradation at global level, but it's estimated to be between 10 and 70% of the total dryland. The millennium Ecosystems Assessment estimate degradation to be between 10 and 20%. Degradation of land directly affects biodiversity and interacts with climate change through the loss of the above and below ground flora and fauna as a result of the habitat change and by altering carbon and other GHG fluxes and cycling. SLM is the specific topic by UNCCD in efforts to combat desertification by adapting farmers and farming systems to changes in climate. A focus on SLM is key since at the biophysical level, maintaining a cover over the ground and developing a better stewardship of the flora and fauna will help prevent and reverse land degradation and increase the resilience of the ecosystems to human induced stresses and climate change.

There are different sustainable Land Management options for drylands that result in ecosystems resilience, adaptation to climate change, mitigation and prevention of land degradation as shown in Table 1.

Sustainable Land Management options	Improvement of ecosystems resilience and prevention of land degradation	Mitigation of climate change	Adaptation to climate change
Technical interventions conservation, characterization and sustainable use of genetic diversity and plant improvement for tolerance to abiotic stresses (Extreme temperatures, droughts, flooding, salinity)	Understanding of functional biodiversity and keystone species will help maintain ecosystem functions and resilience	Increased C sequestration, reduced GHG emmissions from farms and natural habitats In Situ conservation of adapted biodiversity	Better targeting of germplasm to specific environments
Collection and use of commercially promising and underutilized plants with high value and lower water use	More efficient water use		Introduction of new commercial species with low water requirements, to increase livelihood options

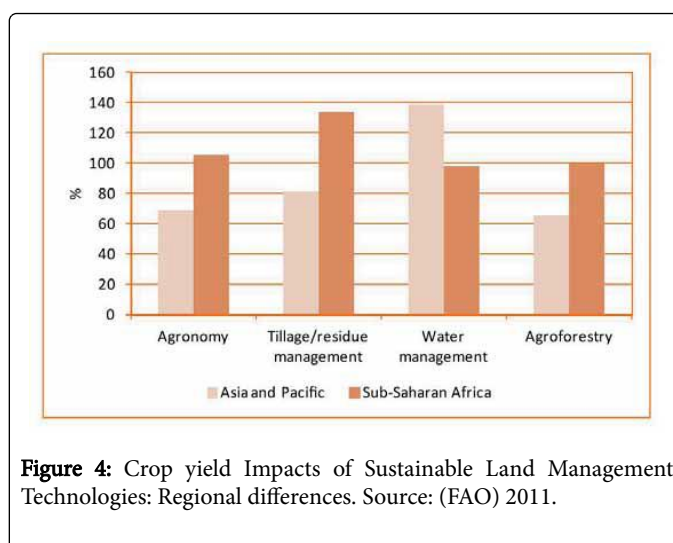
Development of biological controls of pests and diseases under changing climates and plant improvement for biotic stresses	Less reliance on pesticides	IPM options will reduce vulnerability to changes in pathogen distribution	Better control, improved prediction of pests and disease infestations
Better management of livestock, pastures and rangelands	Less overgrazing, more sustainable pastures	Increased C sequestration in rangeland soils and biomass	Increased drought preparedness
Diversification of livelihoods including new crop-tree-livestock options	more sustainable production systems, increased biodiversity	Increased C sequestration, Reduced GHG emissions	Wide range of production systems options for climate variability
Conservation agriculture, including minimum and no tillage and crop rotations with food and cover crop legumes	More robust cropping systems will conserve natural resource base via increased ground cover	Increased C sequestration, lower energy requirements	Wide range of production systems options for climate variability
Improved water use efficiency, water allocation	Conservation of water resources will help maintain environmental services	Reduction of GHG emissions from soils	Production systems adapted to climate variability, especially water scarcity
Improved management of marginal quality water	More sustainable water use, maintenance of environmental services	Increased biomass production and C sequestration	Production systems sustained despite of the use of marginal quality water.
Improved soil management and soil fertility, combining and balancing all nutrient resources	Increased soil organic matter will increase water holding capacity and nutrient cycling	Increased C sequestration	Higher soil organic matter will reduce risk of crop failure from floods and drought
Amelioration and management of of salt affected soils	Salinity mitigation will increase productivity and ecosystem health	Increased C sequestration	With improved crop productivity, amelioration will slow down loss of arable land; in certain cases, amelioration will bring back the degraded soils to a highly productive state.
Policy and institutional interventions Development of better policies and socioeconomic environment for comanagement of water resources	Greater investment in protecting environmental services	Enabling environment for more sustainable production practices	Enabling environment for more sustainable production practices and enhanced uptake and impacts of improved technologies
Documenting and understanding the benefits and trade-offs between development, climate change and land degradation.	Improved ecosystem management		Improved ecosystems management for long term sustainability

**Table 1:** SLM options contribution to ecosystems resilience, prevention of land degradation, mitigation and adaptation to climate change.

Studies have also shown differences in yield impacts of these technologies by region with water management which has more impacts in dry land agriculture recording the highest impacts in the two regions. Agroforestry has the lowest impacts in Asia and Pacific while water management has the lowest impacts in the sub Saharan region as shown in Figure 4.

Use of agronomic practices such as cover crops is expected to result in higher yields since it controls erosion and prevents leaching of nutrients. A study by Altieri showed that the use of cover crops led to an increase in maize yields by between 198 and 246% [12]. Pretty and Ball showed that adoption of mucuna as a cover crop without the application of nitrogen fertilizers led to an increase in maize production to between 3 and 4 tons per hectare [13]. This yield level is at par with the yield levels obtained with recommended fertilizer application.

According to Conant, crop rotation is meant to enhance the fertility of the soils by enriching the supply of nutrients and ensure differential nutrient uptake between the intercrops leading to improved yields [14]. Evidence from Brazil showed that an intercrop between legumes and maize led to a 100% yield increase [15].



**Figure 4:** Crop yield Impacts of Sustainable Land Management Technologies: Regional differences. Source: (FAO) 2011.

Conant [14] and Palm et al. [16] showed evidence of increased yields on average levels after fallow periods. However, the yield increase in successive periods was observed to vary and there was increased risk of soil erosion on bare fallows. Combining fallow and

rotation with leguminous plant elements also showed interesting results. In Zambia for example, inclusion of an indigenous nitrogen fixing tree in fallow rotations led to an increase in maize yield from 6.75 to 7.57 tons per hectare following the three years fallow period [17].

Studies show that use of improved crop varieties increase yields on average due to wider diversity of seed from the same crop. CIAT indicated a 44% yield increase with the introduction of new bean varieties in seven African countries [18]. There was also observed increase in yields by 60% with the introduction of new crops and fruit trees in Ethiopia [13].

Organic farming is meant to increase the soil biomass and ultimately the fertility of soils. Evidence from Senegal in West Africa showed an increase in groundnut and millet yields in plots organically fertilized from 0.3 to 0.6 tons per hectare and 0.3 to 0.6-1 ton per hectare [15]. A study conducted in Ethiopia showed that composting led to 107% increase in teff yields but as little as 3% in finger millet [19].

Mulching maintains and increases the amount of nutrients retained in the soils therefore it is expected to positively impact on crop yields. It also increases soil water content [20]. Yield increase was reported on different crops on use of rice husks as residue mulch from 3.0 to 3.7 and 0.6 to 0.8 tons per hectare in maize and soybean respectively [21].

Tillage systems such as zero and minimum tillage improve the soil water retention capacity. This means that such reduced tillage systems are more appropriate for dry land agriculture and farming systems. A study in Morogoro, Tanzania, recorded maize yields of about 65-75% above those from conventional tillage. Other studies in the same area by Khatibu and Haxley showed cowpea yield levels of about 1069 kg per hectare compared to 869 kg under conventional practices [22].

Crop type	Crop Yield (t/ha)		Yield Increase (t/ha)	Percentage Increase
	Conservation Tillage	Conventional tillage		
Maize with bean intercrop	3.3-4.5	1.3-2.2	2.0-2.2	100-150
Wheat	3.3-3.6	1.3-1.8	1.8-2.0	100-150
Potato	12.8	6.4-9.6	3.2-6.4	50-200
Bean with maize intercrop	0.6-0.9	0.2-0.4	0.3-0.5	102-155

**Table 2:** Conservation tillage influence on yields for different crops in Laikipia Kenya. Source: Kaumbutho et al., [28].

However, Paul observed suppressed soybean grain yield under reduced tillage but without residue retention but only when significant amount of precipitation was available. Again, tillage systems when incorporated with residue showed the potential to increase soil carbon content and therefore necessary to understand the technology combinations.

A study conducted by Miriti et al., in the semi-arid district of Makueni in Eastern Kenya compared tied ridging and integrated nutrient management practices impact on maize and cowpea yield [29]. Grain yields obtained in plots with manure and tied ridges increased by between 11 and 14%. Application of nitrogen from farmyard manure increased maize stover and cowpea yields by 29% and 57% respectively compared to treatment without nitrogen. Cowpea yields were however not affected by tied ridges indicating that

Improved management of water can make more water available for use by crops and ultimately improved land productivity [23]. Terracing improves soil condition as shown by evidence from Ulugurus mountains in Tanzania where average moisture levels in terraced areas was higher and soil compaction lower than those without terraces [24]. The same study showed that the yield for maize and beans in terraced areas doubled and farmers were able to introduce new high value crops such as tomatoes and cabbages. Evidence from Burkina Faso and Niger showed an increase in millet yields under terracing and contour farming from 150 to 400 kgs per hectare during the poor rainfall conditions [25]. Water harvesting techniques also supplement the improvement of water management interventions and the potential to increase yields [15]. A study by Parrot and Marsden in Senegal showed an up to 195% yield increase in peanuts and millet while recorded 100% increase in cereal yields in Zimbabwe [26]. These yield impacts were significantly tied to water harvesting technology interventions.

Agroforestry interventions refer to integration of crops and wood trees/grasslands. Agroforestry has the benefits in terms of providing a favorable micro climate, improvement of soil health and structure and organic carbon content [27].

## SLM in Kenya

### Performance of SLM in dry land agriculture in kenya

A study by Kaumbutho et al., [28] in the semi-arid district of Laikipia showed that maize yield with bean intercrop increased by 100-150% under conservation tillage. Wheat yield increased by 100-150%, potatoes by 50-200% and beans with maize intercrop by 102-155% under the same technology as shown in the Table 2 below.

a combination with integrated nutrient management has the potential to improve crop production.

Kaluli et al [30] investigated drip irrigation and rain water harvesting influence on bean production in Arid and Semi-Arid District of Makueni. Zai pits and contour ridges were considered in water harvesting while bucket kit drip was considered for irrigation. Bean yields increased by 20% from 7.5 tons ha<sup>-1</sup> to 9 tons ha<sup>-1</sup> compared to conventional practices.

A study by Parrot and Marsden in the semi-arid eastern region of Kenya indicated that soil and water conservation techniques led to 50% increase in cereal yields [15].

Some contrary results were documented by Nyangena and Kassie who investigated yield differences between farms adopting soil and water conservation and those without in Makueni eastern Kenya [31].

The mean value of yields in plots adopting soil and water conservation technologies was significantly lower at 23.4% compared to those without as shown in Table 3.

Variable	Without SWC	With SWC	Difference	P-Value
Value of crop yield (Ksh)	11320	8670	2650	0.002***
<b>Plot characteristics</b>				
<b>Erosion status</b>				
Slightly eroded	0.057	0.19	-0.133	0.006***
Moderately eroded	0.086	0.16	-0.078	0.005***
Highly eroded	0.014	0.07	-0.056	0.073
<b>Slope</b>				
Low slope	0.543	0.308	0.235	0.000***
Medium slope	0.371	0.407	-0.036	0.573
Steep slope	0.071	0.243	-0.172	0.000***
<b>Soil depth</b>				
Soil depth (<25 cm)	0.314	0.098	0.216	0.000***
Soil depth (25-50 cm)	0.429	0.549	-0.12	0.059
Soil depth (>50 cm)	0.257	0.352	-0.095	0.118
<b>Note:</b> * p<0.01, **, p<0.05, ***, p<0.10				

**Table 3:** Yield output under soil and water conservation. Source: Nyangena and Kassie [31].

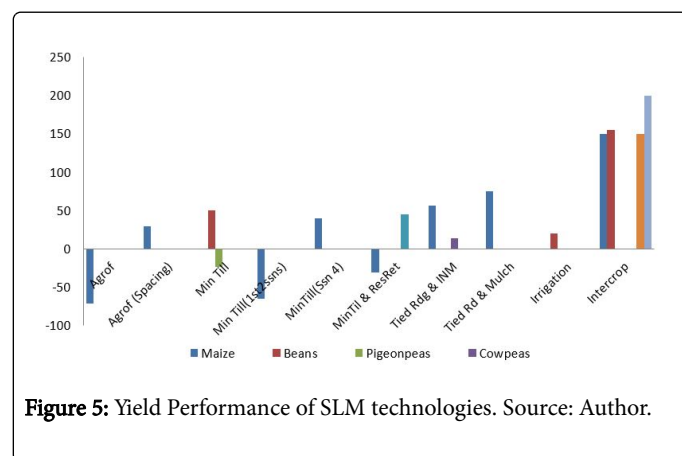
The differences were linked to significant steeper slopes and more erosion in plots with SWC than without. Regressions showed a positive correlation between SWC and steeper slopes, soil depth and more erosion.

Okey evaluated mulching, minimum tillage and tied ridging soil and water conservation technologies in Meru and Mbeere South. In Mbeere south where hot and dry weather conditions were experienced for a greater part of the year, tied ridging and mulching increased maize yields by 75%. Soil and water conservation reduced runoff by 49% during the long rains and 30% during the short rains.

Implications of SLM technologies discussed are summarized in the Figure 5.

Paul investigated the single and interactive effects of tillage and residue management on soil aggregate stability, organic carbon over time and crop yields in Western Kenya. The study was conducted for maize and soybean across from 2005 to 2008. Results indicated that tillage and residue management did not significantly affect maize grain yields. Maize yields were lowest under a combination of minimum tillage and no residue retention at 3.6 t ha<sup>-1</sup> (30%). Soybean average yields were also lowest under the same combination at 0.45 t ha<sup>-1</sup> (45%). Total biomass yields across the four years were lowest under minimum tillage and no residue retention at 1.6t ha<sup>-1</sup> and 8.2 t ha<sup>-1</sup> for soybean and maize respectively. Govaerts observed similar results in a study conducted in the semi-arid highlands of Mexico. In this study, the reduction in soybean yields was highest in the year 2006 which was a relatively wet season (846 mm) compared to other years (625-713 mm). High runoff during this period resulting from soil crusting in

minimum tillage no residue retention combination might have contributed to lower grain yield.



**Figure 5:** Yield Performance of SLM technologies. Source: Author.

There was no significant management effect on total soil carbon content in the upper soil layer even after the four-year period. This could be affiliated to low residue cover as smallholder farm conditions in sub Saharan Africa has a residue retention of 2 t ha<sup>-1</sup> which might not be sufficient to unfold the potential beneficial effects on soil carbon. The biomass production is low and also faces competition from other uses such as fodder. Residue cover in this study may also have been depleted by the removal of the crop residue by termites.

Kihara found out that 85% of the residue disappeared within 3 months of application and much of it was removed by macrofauna.

Kihara investigated the effect of conservation tillage and local organic resources on maize productivity, soil structure and nutrient balances in semi-arid Kenya. Results indicated that minimum tillage resulted in 30-65% lower average yields compared to conventional during the first two seasons. However, yields were superior under minimum tillage by up to 40% compared to conventional by the end of the fourth season. Even with the modest organic resource application and depending on the number of seasons of use, tied ridges and no till can be effective in improving crop yield, nutrient uptake and soil structure.

Ndlovu investigated the impact of tree species on maize productivity by smallholder farmers in Eastern Kenya. Plots with the G. Robusta tree varieties recorded 71% lower yields at 1.57 t ha<sup>-1</sup> compared to conventional practice at 2.21 t ha<sup>-1</sup>. However, considering spacing between crops and trees, yields were higher by 30% in crop rows at distances of 3.25 m from the tree compared to 1 m spacing from the tree. This indicates a significant competition for nutrients between trees and crops. This could be the reason why farmers are reluctant to adopt agroforestry in drylands as the value of the trees are pretty intrinsic (Table 4).

### Institutional support system and adaptation projects

<b>National Climate Change Response Strategy</b>	The National Climate Change Response Strategy (NCCRS) is based on outcomes of wide stakeholder consultations held all over Kenya coming up with modalities of dealing with climate change. The strategy outlines the evidence of climate change in Kenya, impacts of climate change and the recommended actions the country need to take to reduce the impacts as well as take advantage of the beneficial effects of climate change. The mission of the strategy is to strengthen and focus nationwide actions towards climate change adaptation by ensuring commitment and engagement of all stakeholders while taking into account the vulnerable nature of Kenya's natural resources and society. The strategy recommends robust adaptation measures needed to minimize risk while maximizing opportunities. Specific adaptation strategies recommended include producing and promoting of drought tolerant, diseases and pest resistant as well as early maturing crop varieties, Promoting orphan crops eg sorghum, cassava, pigeon pea and sweet potatoes, Promoting agricultural produce post-harvest processing, storage and value addition, Breeding of animals from various agro-ecological zones that adapt well to climatic variances and providing special livestock insurance schemes to spread and transfer risks from climate change.
<b>National Climate Change Action Plan (NCCAP)</b>	This is a policy initiative by the government of Kenya to enhance the global understanding of climate change regimes and the impacts of climate change in Kenya. It's the first climate change agenda guide and focuses on strengthening and focusing nationwide actions towards climate change adaptation and mitigation (National Climate Change Action Plan, 2010). NCCAP has a vision of low carbon climate resilient development pathways and summarises analysis of mitigation and adaptation options. It gives recommendations on enabling policy and regulatory frameworks setting out the next steps for knowledge management and capacity development, technology requirements, financial mechanisms and a national performance and benefit measurement system (NPBM). Priority actions towards adaptation and mitigation outlined include geothermal power generation, distributed clean energy solutions, improved water resource management, restoration of forests and degraded lands and climate smart agriculture and agroforestry.
<b>Kenya Agriculture Carbon Project</b>	This is a programme through which the World Bank through it BioCarbon fund is showcasing an early action to demonstrate a triple win for mitigation and adaptation and food security for small scale farmers while delivering carbon finance through the sale of credits in the carbon market. It's the first project to sell carbon credits in Africa and it's also paving way for a new approach to carbon accounting methodologies (Institute for Agriculture and Trade Policy, 2011). The project involves sustainable agriculture management practices by smallholder farmer groups for increased crop yields, farm productivity and soil and above ground carbon sequestration. The project aims at enabling smallholder farmers to access the carbon markets and receive an additional income stream of carbon revenues through SLM adoption.
<b>Adaptation to climate change in Arid and Semi-Arid Lands (KACCAL)</b>	The objective of the project is to assist Kenya in adapting to expected changes in the climatic conditions threatening the sustainability of rural livelihoods in its arid and semi-arid lands. The project aimed at increasing the capacity of the in the selected Districts of the ASALS to adapt to climate change. It aimed at creating awareness on climate change and impacts to 20 national and regional policy makers in the ASALS. 180 households were expected to benefit directly at the pilot stage. An additional 360 households were expected to benefit from exchange visits and 10,000 households benefiting from dissemination of adaptation advice at the same pilot stage.
<b>Vi agroforestry</b>	Vi agroforestry is an initiative that contributes to reduced poverty through sustainable agriculture adapted to climate change. This is a concept where trees and crops are planted together and integrated with livestock. The initiative started in the semi-arid districts of west Pokot inhabited by mainly the pastoral communities. The programme works for a transition from the present unsustainable agricultural practices that negatively impact the environment and the climate to production methods that contribute to adaptation to climate change, strengthens ecosystems, reduce poverty and secure access to food. (Vi agroforestry strategy, 2013). Vi agroforestry support market-oriented production through advisory services and capacity building. It strengthens the capacity of the farmers to adapt to climate change through sustainable farming methods. Farmers working with Vi agroforestry are members of organizations such as farmer groups and associations where the programme provide support in building well managed organizations. The programme also works with schools where pupils learn about agroforestry through small gardens planned and managed by the pupils. The programme also aims at getting more women into the decision making by working with men and their attitudes. By the year 2013, the programme had planted 4,118,064 trees, worked with 103,908 families, trained 40,198 farmers, managed to have 6,463 households using alternative energy sources and established 367 small gardens in schools.
<b>Arid Land Resource Management Project (ALRMP)</b>	The objective of this project is to strengthen and support community driven initiatives to reduce the vulnerability and increase the food security of the poverty-stricken communities in the arid districts of Garrissa, Marsabit, Moyale, Tana River, Baringo, Isiolo and Mandera. The aim of the project was to conserve the natural resource base by improving crop and livestock resilience to drought and increasing economic linkages with the rest of the economy.



<p><b>Kaputir Resource Management Association - Agro-pastoralism project Turkana Kenya</b></p>	<p>The semi-arid county of Turkana has undergone cultural and landscape change following launch of the agro-pastoralism project in the year 2013. In this project, irrigation by waters from river Turkwel is done to support the unreliable rain fed agriculture previously practiced. This project aims at diversifying livelihood options for the pastoral Turkana community, improve food security situation and to contain the protracted armed conflicts with the neighboring Pokot community. In the first year of the project operation, herders cum farmers harvested over 1500 bags of maize, up from 750 in the previous season and 2000 bags of sorghum. The government through the ministry of agriculture partners with the Kenya Agricultural research Organization and a private seed company to disseminate technologies to the communities. More funds from United States African Development Fund (USADF) have been made available to implement new irrigation techniques, conduct soil testing and increase acreage. Currently the farmers have adopted the furrow and drip irrigation systems and growing orphan crops such as sorghum and millet.</p>
<p><b>The Sustainable intensification of Maize-Legume Systems for Food Security in Eastern and Southern Africa (SIMLESA)</b></p>	<p>This is a regional programme spearheaded by the International Centre for Maize and Wheat Improvement (CIMMYT). It has a key focus on Eastern and Western regions of Kenya. Through this project, smallholder farmers practice sustainable intensification principles such as zero and minimum tillage, maize legume intercrop and rotations and new legume varieties. The project has tested promising smallholder maize legume cropping systems, attempted to increase the range of maize and legume varieties and facilitated strong capacity building for agriculture research. Impact assessment done in 2013 showed significant yield advantage on plots where legume intercrop, legume crop rotation, minimum tillage, soil and water conservation, improved seed variety and animal manure over conventional practice as shown below. Legume intercrops do not only have the advantage of nitrogen fixation but also improvement in soil physical conditions and higher water infiltration because of their root activity. This is crucial for semi-arid conditions experienced in Eastern and some parts of western Kenya. Maize legume intercrop has the advantage of improving soil fertility and helps prevent the buildup of soil borne pests and diseases. This translates to more yields compared to conventional practice. Plots with legume crop rotation had maize yield advantage compared to those without. Minimum tillage sets the necessary condition for crop establishment and growth and reduces the damage to the soil structures. Soils in semi-arid regions of eastern Kenya are degraded by years of erosion and unsustainable package of practices. It's has therefore been much necessary to avoid further disturbances to set the soils on path for regeneration. Plots under minimum tillage had higher maize yields compared to those without. Under soil and water conservation, plots were protected against soil erosion and deterioration. Farmers harvest water from roads into retention ditches for establishment of fruit trees and food crops such as maize and sorghum. Results showed higher yields in farms where soil and water harvesting were adopted. Due to changes in climate over time, crops varieties that used to perform better in semi-arid regions for example sorghum are no longer able to survive. New varieties that can cope with new conditions have been made available to the farmers under this programme and the results have been positive as shown in the figure. There has been a concern regarding supplementing or moving away from the models advocating for capital inputs such as fertilizer which resource poor smallholder farmers cannot afford. Farmers apply animal manure from the animals they keep and supplement by purchasing from fellow farmers. Costs are significantly low than when inorganic fertilizers are used, and maize yields are high in plots where manure application was adopted compared to the conventional practice.</p>

**Table 4:** Institutional, policy and project support towards climate change adaptation in ASALs in Kenya.

**Kenya Red Cross resilience programme (K4K Turkana North Project)**

This project targets three main areas (East Pokot, Turkana North and Walda in Moyale District) that were hardest hit in 2011 by the worst drought in the horn of Africa in 60 years. The project aimed at adapting the communities to climate change focusing on increasing water supply systems for livestock, domestic and small-scale irrigation. One million heads of livestock were provided with water and pasture regeneration. Water was made available through drilling and

equipping boreholes and then provision and installation of shade nets and drip irrigation systems which minimize water wastage is done.

More than 80 shade net systems have been installed and farmers are growing a variety of crops including tomatoes, spinach, kales and melons. Sweet potatoes and maize are grown under open irrigation systems. According to Redcross Kenya (2013), farmers planted over seven food varieties over the first phase of the project whose harvest is as shown in the Table 5 below.

Type of farm produce	Nakinomet site (Tons/hac)	Loitanit site (Tons/hac)	Kang'ituraa site (Tons/hac)	Long'olemwa site (tons/hac)	Total Tonnage
Tomatoes	11.7	5.2	5.85	3.25	26
Spinach	0.9	0.4	0.45	0.25	2
Kales	0.81	0.36	0.405	0.225	1.8
Maize	0.72	0.32	0.36	0.2	1.6
Watermelon	0.48	0.24	0.144	0.192	1.056
Butternuts	0.2	0.1	0.08	0.05	0.43
Greengrams	-	-	0.36	-	0.36

**Table 5:** Food crop harvested from each site in three months. Source: Kenya Red Cross resilience Programme.

The community was also able to generate income in the three sites as shown in Table 6.

Nakinomet site (€/hac)	Loitanit site (€/hac)	Kang'ituraa site (€/hac)	Long'olemwa site (€/hac)	Total income €
1980	880	990	550	4400

**Table 6:** Income generated from each project site in three months. Source: Kenya Red Cross resilience Programme.

The project has not only supported young people with jobs during project inception but also to venture into agriculture as a business. They have been trained on entrepreneurial skills and value chain. This has therefore curbed the migration of these young people who mainly provide labour support in the farms.

### Drivers of SLM Technology Adoption in Kenya

Food production in the dry lands is challenged by limited precipitation which is variable in timing sometimes within seasons. High temperatures increase the prevalence of diseases and pests and farmers have no option but to do something to reduce absolute crop loss. Based on this background, farmers have been observed to adopt certain technologies to minimize exposure to risks by increasing soil organic matter, conservation of the soil moisture, reducing weeds and pests and soil erosion. These technologies include zero and minimum tillage, soil and water conservation, legume intercrop and crop rotation. Legume intercrop and crop rotation are low risk technologies that involve minimum financial investment [32].

Farmers with limited market access due to distance and information are not likely to adopt SLM technologies. Accessibility influences the availability of technology, use of output and input markets and support networks such as rural credit [33]. Households that lie far away from the markets have a less likelihood of adopting new technologies since distance increases the amount of labour and capital intensity by raising output to input price ratios [34].

A study by CIMMYT [10] showed that more male farmers adopted minimum tillage, improved seed and crop rotation technologies compared to their female counterparts as shown in the table 7. This could be explained by the fact that more males accessed extension services as compared to females as was observed in the same study. These findings are consistent with those of De Groote and Coulibaly [35] who observed women as generally discriminated against in terms of access to information.

Gender	Minimum tillage			Soil and water conservation			Animal manure			Legume inter-crop			Crop rotation			Improved seed		
	No	Yes	$\chi^2$	No	Yes	$\chi^2$	No	Yes		No	Yes	$\chi^2$	No	Yes	$\chi^2$	No	Yes	$\chi^2$
Female	454	36	7.57*	224	266	0.35	298	192	0.68	164	326	7.91*	409	81	0.12	131	359	16.56*
Male	345	51		189	207		230	166		169	227		327	69		61	335	

**Table 7:** Technology adoption by gender among smallholder farmers in Eastern Kenya. Source: CIMMYT (2013).

This discrimination may not necessarily be direct but tied to multiple roles that women have to play compared to men. Women have to grapple with a variety of household chores which includes preparing the children for the day in school, attending to the animals and travelling long distances in search of water for the household. These activities eat into the time for which they would be available to attend extension service meetings. Reaching women farmers is therefore challenging and requires careful consideration. Adoption of these technologies by men however may likely not lead to significant adaptation outcomes as women are more involved in the farms compared to men. It therefore means that there is a disconnect between knowledge and practice.

The study observed more females adopting water and soil conservation, manure and intercropping than males with difference in intercrop technology adoption being significant at 1%. The difference in adoption of maize legume intercrop technology specifically could be explained by the traditional practice by women borrowed across time as an effort to diversify to avert complete crop failure, hunger and malnutrition in the unpredictable semi-arid climates. Amusala et al. [36] used a probit model to investigate adoption of drought tolerant sorghum in Western Kenya. Gender was found to be negatively significant at 5%. A unit increase in the number of male headed

households brought about a decrease in the log of odds in favour of adoption by 3.656. This was interpreted as sorghum farming being a preserve of women as it requires patience in handling, sorting of seeds, winnowing after harvesting which is pretty tedious.

In the same study by CIMMYT in Eastern Kenya, education was positively correlated with improved seed and animal manure but negatively correlated with minimum tillage, soil and water conservation, legume intercrop and legume crop rotation which are generally labor-intensive technologies [10]. Mwangi et al. in a study in western Kenya showed educated farmers having a higher probability of adopting Imazapyr resistant maize variety [37]. These results were consistent with those of Salasy et al. in a related study in the same region [38]. Households with more years of education have a small likelihood of investing in labor intensive technologies as they are able to substitute their labor for higher returns in other activities. They are likely to have more access to off-farm income to purchase inputs such as improved seed [39]. More educated farmers are better able to understand and utilize extension messages due to greater ability to decode. In some cases, they know what kind of information is required to alleviate production constraints and where to find it as well [32].

Farmer's membership to groups was observed to positively influence adoption of drought resistant sorghum variety in western Kenya [36]. Mwangi et al. found out that membership to groups by farmers increased their probability of adopting Imazapyr resistant maize variety and Pull-Pull technology by 54% and 30% respectively [37]. The strength of social capital which also includes family members and the number of traders that farmers can contact in case they wish to sell their produce can influence technology adoption probabilities [31]. It's within these networks that crucial exchange of information happens and farmers are able to overcome credit constraints to access crucial inputs such as improved seeds. Social network arrangements such as collective action help the farmers to reduce transaction costs through cost sharing when transporting their produce to the markets and increase their bargaining power translating to higher returns in markets. Increased returns and information flow and access may improve the farmer's ability to adopt new technologies [40]. In Kenya, farming systems challenged by limited and unreliable precipitation and high temperatures are characterized by risk sharing among farmers through informal insurance. For example, relatives or group members may experiment on different technologies at the same time with annual crops such as maize to identify the most suited. Farmers experimenting on technologies which fail and lead to crop failure are indemnified by the farmers whose experiments are successful. In some cases, however, adoption is challenged as this kind of arrangement sometimes results in some farmers exerting less effort banking on the concept that they will still be food secure even if their technologies do not work.

Access to land is a big challenge in Kenya with more than 50 years of independence. A few individuals own huge chunks of land which mostly lie idle and majority of people are squatters. Access and ownership of land has a huge bearing on the performance of the agricultural systems [41]. Majority of the farmers are wary of investing on technologies whose benefits are captured in the long run such as manure application and soil and water conservation on land with an uncertain future. Farmers in this case have confidence to invest in such technologies as improved seed and intercropping [42]. Smallholder farmers in western Kenya who had allocated a large portion of their land to sorghum production were observed to have a higher likelihood of adopting the drought resistant variety compared to those who had allocated smaller portions. However, increase in the size of land owned reduced the adoption probability as farmers can confidently diversify their on-farm investment banking on certainty guaranteed by ownership and reduce reliance on sorghum [36].

Off-farm incomes play both negative and positive incentive for SLM adoption [43]. Alternative sources of income translate in additional capacity to finance investment in new technologies. According to Amusala et al., farmers in the dry regions of western Kenya adopted the drought resistant sorghum variety with increased off-farm incomes

[36]. Technologies such as soil and water conservation (construction of benches) are labour intensive and may demand huge financial investment. On the other hand, off-farm engagement may divert efforts away from the farms reducing the labour available to implement the technologies. Majority of young people in the semi arid rural areas in Kenya have moved to the cities running away from the risky production systems leaving behind a gap in labour supply required for technology adoption.

The probability of older farmers in western Kenya adopting drought resistant sorghum varieties and Imazapyr resistant maize varieties was higher compared to their younger counterparts [36,37,44]. These results contradicted findings by Rahelizatovo and Gillespie who observed older farmers as risk averse compared to younger farmers and therefore less likely to adopt. Older farmers in this region of Kenya have accumulated farming experience over time and have a broader understanding of their environment. They have over the years used their traditional knowledge to adapt to changes and variability in climate and their challenge now is the speed of change in weather patterns. They are therefore more likely to open to new ideas (adoption). Sorghum is this region is mainly consumed by the older generation who attach special nutritional value which is scientifically true as opposed to young generation who regards it as an inferior crop.

Mwangi et al. observed a significant relationship between household size and the adoption of the pull-pull technology among smallholder farmers in western Kenya [37]. A unit increase in household size increased the adoption probability by 10%. He attributed this to increased availability of labour (family) with increased household size. This would be more pronounced if the technology in question is labour intensive, for example soil and water conservation. Amudavi et al. also observed similar relationships [45]. A large household also creates a platform for which a large pool of information and ideas on technologies can be gathered.

Physical capital is defined as size of the farm, value of major farm equipment and livestock ownership which is a common practice in majority of the semi-arid Kenya. More household assets translate to the capacity to take risks. Households with more assets are likely to adopt new technologies even in absence of either formal or informal insurance [32]. In Embu County Western Kenya, farmers use bulls as draught animals especially in soil and water conservation saving on labour costs. The same animals provide manure for their farms reducing the cost of fertilization. Majority of households in semi-arid Kenya are limited in household assets and therefore highly constrained in adoption of these technologies. Table 8 shows the ranking of various selected constraints by farmers in Eastern Kenya in order of how they felt it mattered to them over a previous planting season. Rank 1 show the highest constraint and 10 is otherwise.

Constraint	Rank										
	1	2	3	4	5	6	7	8	9	10	11
Timely availability of improved seeds	15	21	18	28	32	22	17	13	3	4	1
Prices of improved seeds	3	113	130	60	60	24	15	8	6	0	1
Quality of improved seeds	7	20	41	47	31	36	18	12	7	2	0
Availability of credit	8	36	34	59	64	42	25	11	3	2	0

Access to output markets	9	5	12	8	8	17	20	20	18	12	6
Access to input markets	7	8	9	14	17	15	33	26	29	18	10
Access to labour	10	20	32	42	17	27	11	9	8	8	5
Grain prices	8	23	11	51	27	46	23	27	14	7	4

**Table 8:** Constraints to technology adoption. Source: CIMMYT [10].

From a general outlook, many of the constraints are highly ranked between 1 and 5 showing similar characteristics among the farmers. This is a serious challenge to adoption and the state of food security now and in the future.

## Conclusions and Policy Recommendations

Kenya has insignificant contribution to the observed changes in the global climate as emission levels are pretty low. The main focus therefore is on adapting populations to these changes and reducing vulnerability to the impacts. Climate related effects continue to pose serious threat to the society, the environment, economy and ultimately the attainment of the vision 2030. Drought experienced in Kenya between the year 2008 and 2011 had an estimated impact of around \$12.1 Billion and a significant slow growth of the country's economy. The situation is not predicted to get better in the future either. Increase in temperatures might potentially lead to significant reduction in the number of reliable crop growing days by the year 2050 and this may highly impact on some parts of south western Kenya. SLM is one of the measures that can potentially assist farming populations to adapt to climate change. If effectively and widely utilized, agriculture mitigation potential could go up to between 4500 MtCO<sub>2</sub>-6000 MtCO<sub>2</sub> per year. Soil carbon sequestration contributes up to 90% of this potential from agriculture. This could be more important for semi-arid regions where soils have been degraded by years of erosion and soil organic matter is acutely deficient. Current efforts in sustainable land management in the semi-arid regions of Kenya have shown significant levels of success in performance pretty much similar with the rest of the sub Saharan region although it fails in some instances. The difference in yield levels is highly significant compared to conventional practice and this would be a window of opportunity to avert food insecurity. It cannot be ignored however that technology combinations when necessary could be tricky and would require knowledge of complementarity and complementarity. It also demands an understanding of the slight differences in climatic conditions, soils and crops for which the technology is applied and which could significantly influence outcomes.

Despite these outcomes, adoption levels are still very low, and this undermines progress towards adaptation. The community support group is pretty strong from the well formulated strategies and action plans by the government to the local and international organizations.

However, Shocks, Gender, education, household assets, household incomes, social capital and land tenure systems are the key drivers of adoption and need to be addressed at policy level and at the design of technology transfer if any progress is to be realized. An in-depth stakeholder analysis is required in order to arrive at workable technology transfer models. Technology transfer mechanisms need to recognize the need for farmers to understand how technologies work otherwise they may fail to adopt technologies that have impacts in a

longer term in terms of adaptation such as agroforestry. Agroforestry need to assure short term economic benefits, and this could be achieved by planting fruit trees.

The scale-up of these technologies requires an integration of the traditional knowledge, necessary enhancement of knowledge on SLM approaches and practices, encouragement of land user innovation and raising awareness about the predicted impacts of climate change. A keen interest must be taken into account to make sure that the approaches advocated are locally appropriate and do not only deliver environmental benefits but also short-term economic benefits in terms of increased yields. Raising awareness should be more about enhancing research extension farmer linkages by making information available in appropriate formats such as posters and pamphlets in local languages. To further synthesis the extension messages, information on adaptation should be integrated in farmer field schools, farmer field visit and school curricula to inculcate these values among the young generation. Scale-up should also look into accessibility of productive resources such as improved seeds, tree seedlings, agricultural services such as advice on pests and diseases, value addition and soil testing and better storage facilities to reduce on post-harvest losses.

Farmer's attitudes and perceptions must be guarded by harmonizing programmes. Small scale short term fragmented interventions by local non-profit organizations may fail to yield any meaningful results and farmers may be wary of future large scale programmes with potential for positive results in the future. This is more likely to happen with the agro pastoral communities who mostly inhabit the semi-arid regions in Kenya.

## References

1. UNFPA (2011) State of the World Population 2011, United Nations Population Fund Vi Agroforestry Strategy, Africa.
2. FAO (2011) An ecosystems approach to sustainable crop production intensification: A conceptual framework. Food and Agriculture Organization.
3. World Bank (2006) Sustainable Land Management: Challenges, Opportunities and Tradeoffs. Washington D.C 20433. The International Bank for Reconstruction and Development.
4. Agra (2014) African agriculture status report 2014. Climate change and smallholder agriculture in sub Saharan Africa. Nairobi, Kenya.
5. Lane A, Jarvis A (2007) Changes in climate will modify the geography of crop suitability: Agricultural biodiversity can help with adaptation. ICRISAT/CGIAR 35th Anniversary Symposium, India.
6. World Bank (2013) Environmental, Social and Economic Sustainability. Annual report.
7. Sarr B (2012) Present and future climate change in West Africa: A crucial input for agricultural research prioritization for the region. *Atmos Sci Let* 13: 108-112.
8. Jones P, Thornton P, Owiyo, Kruska L, Herrero M, et al. (2008) Climate change and poverty in Africa: Mapping hotspots of vulnerability. *African J Agri Resour* 2: 24-44.

9. Thornton P, Cramer L (2012) Impacts of climate change on the agricultural and aquatic systems and natural resources within the CGIAR's mandate. *Agriculture and Food Security*.
10. CIMMYT (2013) Development of opportunities and intensification pathways for African farmers. Preliminary Report.
11. International Crops Research Institute for the Semi-Arid Tropics (2009) Archival report. *Crop Research*.
12. Altieri M (2001) Applying agro-ecology to enhance the productivity of peasant farming systems in Latin America. University of Essex.
13. Pretty J, Ball A (2001) Agricultural influences on carbon emissions and sequestration: a review of evidence and the emerging trading options. University of Essex.
14. Conant T (2009) Rebuilding resilience: Sustainable land management for climate mitigation and adaptation. Resources Management and Environment Department.
15. Parrott N, Marsden T (2002) The Real Green Revolution: Organic and agroecological farming in the South. Department of City and Regional Planning.
16. Palm O, Weerakoon W, Ananda M, Silva DP, Rosswall T (1988). Nitrogen mineralization of Sesba sesban used as green manure for lowland rice in Sri Lanka. *Plant Soil* 108: 201-209.
17. Kwesiga F, Coe R (1994) The Effect of Short Rotation Sesbania Sesban Planted Fallows on Maize Yield. *For Ecol Manage* 64: 199-208.
18. CIAT (2008) The impact of new bean technologies on rural livelihoods in seven African countries. Highlights CIAT in Africa. Kampala, Uganda.
19. Edwards S (2000) A Project on Sustainable Development Through Ecological Land Management by some Rural Communities in Tigray. Institute for Sustainable Development.
20. Scopel E, Macena F, Corbeels M, Affholder F and Maraux F (2004) Modelling crop residue mulching effects on water use and production of maize under semi-arid and humid tropical conditions. *Agronomie* 24: 1-13.
21. Lal R (1987) Managing the Soils of Sub Saharan Africa. *Science* 236: 1069-1076.
22. Khatibu A, Huxley A (1979) Effect of zero tillage on growth nodulation and yield of cowpea at Morogoro Tanzania. In: *Soil tillage and Crop Production*. Lal R (ed.) IITA proc Series 2, IITA, Ibadan, Nigeria, pp: 271-280.
23. Rockstrom J, Barron J (2007) Water productivity in rainfed systems: overview of challenges and analysis of opportunities in water scarcity prone savannahs. *Irrig Sci* 25: 299-311.
24. Dosteus L (2012) Towards Operational Payments for Water Ecosystem Services in Tanzania: A Case Study from the Uluguru Mountains. *Oryx* 46: 34-44.
25. Dutilly-Diane C, Sadoulet E and Janvry AD (2003) How Improved Natural Resource Management in Agriculture Promotes the Livestock Economy in the Sahel. *J Afri Econ* 12: 343-370.
26. Pretty J, Noble D, Bossio D, Dixon J, Hine R, et al. (2006) Resource-Conserving Agricultural Increases Yields in Developing Countries. *Environ Sci Tech* 40: 1114-1119.
27. WOCAT (2011) "Database on SLM Technologies. WOCATpedia Community Platform.
28. Kaumbutho P, Kienzle J (2008) Conservation Agriculture as Practiced in Kenya: Two case studies. Food and Agriculture Organization of the United Nations.
29. Miriti M, Kironchi J, Gachene C, Esilaba O, Wakaba P, et al. (2009) Effects of water conservation tillage on water use efficiency in maize-cowpea systems in semi-arid eastern Kenya. *E Afr Agric J* 74: 95-101.
30. Kaluli J, Nganga K, Home P, Gathanya J, Muriuki, A et al. (2012) Effect of Rain Water Harvesting and Drip Irrigation on Crop Performance in an Arid and Semi-Arid Environment. *J Agri Sci Tech* 14: 99-108.
31. Nyangena W, Kassie M (2011) The Role of Social Capital in Sustainable Development: An Analysis of Soil Conservation in Rural Kenya. *Agricultural Investments, Livelihoods, and Sustainability in East African Agriculture*.
32. Kassie M, Jaleta M, Shiferaw B, Mmbando F and Geoffrey M (2011) Plot and Household-Level Determinants of Sustainable Agricultural Practices in Rural Tanzania. *Environment for Development*.
33. Jansen H, Pender J, Damon A and Schipper R (2006) Land Management Decisions and Agricultural Productivity in the Hillsides of Honduras. International Association of Agricultural Economists Conference, Australia.
34. Binswanger H, McIntire J (1987) Behavioral and material determinants of production relations in land abundant tropical agriculture. *Econ dev cult change* 36: 73-99.
35. De Groote H, Coulibaly N (1998) Gender and generation: An intra-household analysis on access to resources in Southern Mali. *Afri Crop Sci J* 6: 79-95.
36. Amusala G, Nyangweso P, Gudu S, Mose I, Inyanje L, et al. (2012) Adoption of Drought Tolerant Sorghum in Western Kenya. 2012 Eighth AFMA Congress.
37. Mwangi B, Murage A, Obare G (2014) Estimating the Adoption Rates of Two Contrasting Striga Weeds Control Technologies in Kenya. *Quart J Int Agriculture* 3: 225-242.
38. Salasya B, Mwangi W, Mwambu D, Diallo A (2007) Factors Influencing Adoption of Stress-Tolerant Maize Hybrid (WH 502) in Western Kenya. *Afri J Agri Res* 10: 544-551.
39. Pender J, Gebremedhin B (2007) Determinants of Agricultural and Land Management Practices and Impacts on Crop Production and Household Income in the Highlands of Tigray, Ethiopia. *J Afri Econ* 17: 395-450.
40. Wollni M, Lee D, Thies E (2010) Conservation Agriculture, organic marketing and collective action in the Honduran hillsides. *Agri Econ* 41: 373-384.
41. Jacoby H, Li G, Rozelle S (2002) Hazards of Expropriation: Tenure Insecurity and Investment in Rural China. *Amer Econ Rev* 92: 1420-1447.
42. Kassie M, Holden T (2008). Sharecropping Efficiency in Ethiopia: Threats of Eviction and Kinship. *Agri Econ* 37: 179-188.
43. Mahmoud C, Shively G (2002) Agricultural Diversification and Integrated Pest Management in Bangladesh. *Agri Econ* 30: 187-194.
44. Rahelizatovo NC, Gillespie JM (2004) The adoption of best-management practices by Louisiana dairy producers. *J Agri Ap Econ* 36: 229-240.
45. Amudavi D, Khan R, Midega O, Pickett J, Lynam L, et al. (2008) Push-pull Technology and Determinants Influencing Expansion among Smallholder Producers in Western Kenya. 24th Annual Conference of Association for International Agricultural and Extension Education (AIAEE) on Global Entrepreneurship in International Agricultural and Extension Education, Costa Rica.