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Effects of Land Degradation on Agricultural Land Use: A Case Study of Smallholder Farmers Indigenous Knowledge on Land Use Planning and Management in Kalama Division, Machakos County

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Authors' contributions

This work was carried out in collaboration among all authors. Author MSM designed the study, performed the statistical analysis, wrote the protocol, wrote the first draft of the manuscript and managed literature searches. Authors KMK and KJM managed the analyses of the study and literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The aim of this study was to investigate the effects of land degradation on agricultural land use, planning and management in Kalama Division, Machakos County; and specifically determined farmers' considerations of land suitability for selected types of agricultural land uses in varying cropping zones, investigated farmers' local environmental knowledge of land degradation indicators and finally documented farmers' land management strategies and practices for soil and water conservation. Data was collected using a questionnaire, along a road transect cutting across upper, middle and lower zones (parts) of a slope. A total of 40 households along the transect on the three

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zones were interviewed. Results obtained revealed that crop farming, livestock, poultry, farm forestry and bee keeping were the major agricultural land use activities carried out in the study area. Overall, steep slope was the most important factor considered for farm forestry (17%) (5.29 STDEV). Bee farming was the least land use practice accounting for only 1% of total land use. Most land degradation (15%) was reported in the middle zone while lowest land degradation (7%) was reported in the upper zone. The study found out that most households were aware of land degradation indicators in their local environment and described them using their indigenous environmental knowledge. The smallholder farmers prevented further land degradation by use of their local or traditional ways such as application of organic manure, planting of trees, crop rotation, use of gabions and stone lines. Different zones had different land use and management practices due to differences in terrain and other physical and biophysical characteristics. Overall, the major land management practices included tree planting (23%) (4.04 STDEV) and water conservation and gabion making (10%) (2.52 STDEV). This study clearly established an existence of smallholder farmers' indigenous knowledge, perceptions, and beliefs of the local environmental factors of land condition which are necessary for the farmer's decision-making on land use planning and management. On the basis of these findings, the study argues for place-based analysis and understanding of the landscape structure and local micro-environments in enhancing understanding of local-level decision-making on land use planning and management by smallholder farmers in maintaining livelihood security. Even though the study is limited to the local scope, it can provide a basis for designing policies aimed at rural livelihood security improvement and inform and facilitate targeting of outside interventions such as land use planning and management programs which can be built on existing indigenous knowledge.

Keywords: Land degradation; smallholder; land use; Machakos; agriculture.

1. INTRODUCTION

Desertification is among the most severe global environmental and the socio-economic problems in the world that affects about 1.9 billion hectares of land and 250 million people [1]. Land degradation is widely recognized as a global problem associated with desertification in arid and semi-arid zones, which cover about 47% of the globe's total surface area [2]. This is considered to be highly variable arising from different causes and affecting people differentially according to their economic and social circumstances. According to Thomas et al. [3] land degradation affects a large number of people over a significant proportion of the earth's surface which has led to extreme poverty and hunger. This is associated with declining status of natural resources, and environmental un-sustainability. Around the world, land degradation can be viewed as any change or disturbance to land perceived to be undesirable that affect human activities like agriculture and settlements [4].

According to the Intergovernmental Panel on Climate Change (IPCC) [5] in Africa agriculture has been the main contributor to current economy ranging from 10% to 70% of Gross Domestic Product (GDP) and is highly affected by land degradation leading to exploitation of natural resources like forests, settlement and cultivating of fragile land, like hills and sloppy areas. Due to the information gap among people in Africa on land conservation, this has led to mismanagement of natural resources causing land use change, although this has been highly challenged by global warming throughout the world.

In the early 2000s, approximately 30% of Kenya was affected by very severe land degradation [6] and an estimated 12 million people, or a third of the Kenya's population, depended directly on land that is being degraded [7]. The droughts of 1970-2000 accelerated soil degradation and reduced per-capita food production [8]. According to Muchena [9] land degradation estimate is increasing in severity and extent in many areas and that over 20% of all cultivated areas, 30% of forests and 10% of grasslands are subject to degradation. The expansion of cropping into forested and water catchment zones accounts for much of this degradation. The damage to soil, loss of habitat, change of land use, water shortages and siltation leads to reduced ecosystem services. Since the 1972 United Nations Conference on Human Environment held at Stockholm, Sweden, the Government of Kenya has continued to reinforce formulation of policies and strategies that would address land degradation. Murage et al. [10]

noted that farmers' perceptions and experiences are paramount when planning to implement an enterprise counteracting the on-going land degradation. Moreover, recent diagnostic participatory approaches are increasingly showing that farmers clearly perceive and articulate differences in the levels of soil fertility on their farms.

This study recognizes that smallholder farmer's behaviors in maintaining livelihood are controlled not only by socio-ecosystem condition but also by the land condition. Therefore, understanding of the environmental factors of land condition is necessary for the farmer's land use and management. One of the innovative approaches in this endeavor which has received attention in the recent past calls for greater integration of scientific expertise with local knowledge in assessing land degradation indicators [11]. This research used similar approach but went beyond to link farmers land use and management practices with land degradation indicators. It, therefore, sought to reveal the existing differences in knowledge, perceptions, beliefs in decision-making on land use planning and management in Kalama Division, Machakos County, Kenya and hopes to aid understanding of the landscape structure and local micro-environments.

Scientific techniques such as satellite remote sensing, ecological assessment, the measurement of soil properties, economic analyses, expert opinions and interviews [12] have all been used to identify, measure and monitor land degradation. However, science has its limitations and cannot always provide an accurate diagnosis or solutions [13]. There is increasing calls for integrating scientifically proven knowledge with those of the farmers' indigenous knowledge on the current land degradation indicators to develop suitable options for improving land management [14,15,16,17,18]. Studies have reported wide scale knowledge of land users employing these indicators for instance in estimating the extent and effect of soil erosion on soil productivity potential [19]. The erosion indicators not only reflect the changes in the soil properties but also determine the current status of severity of soil erosion and crop production potential [20].

According to Barrera-Bassols et al., [11] information need in land use management practices include: local and/ or linguistic soil classification, soil fertility assessment, soil and water conservation measures, spatial distribution of soil in the farm field, soil erosion recognition and soil quality assessment. The information is useful for large and smallholder agricultural development projects, enabling farmers ability to have high production in a given land use.

It has been suggested that African semi-arid rangelands are trapped in irreversible and uncontrollably worsening degradation [21,22]. This phenomenon is experienced in the study area were land degradation is to the extreme being caused by deforestation, loose soil, steep terrain, poor agricultural practices and increased water scarcity due to destroyed catchment zones; this has affected agricultural land use negatively [23]. Alternatively, others argue that human-induced land degradation can stimulate the innovation necessary to overcome resource scarcity and maintain sustainable livelihoods [24].

It is clear that science has played a key role in providing large-scale responses to land degradation throughout the last 30 years of global discussions on the desertification problem [25]. However, Scientific knowledge has limitations and cannot always provide an accurate diagnosis or solution [3] and [13], as evidenced by the vastly different solutions to perceived degradation that national and inter-governmental agencies have attempted over the last three decades. Top-down applications of scientific knowledge rarely integrate different components of land degradation, focusing instead on single issues, which can lead to bias and prevent an appreciation of the multi-faceted nature of the problem. Local communities who are affected by land degradation rarely participate in science-led approaches, or derive results that can improve the sustainability of their land management. There is, therefore, a need to involve local knowledge on land use change among smallholder farm planning and management so that communities are able to fully realize their capacity to adapt to the challenges of land degradation [26].

The rationale for this study emanates from this recognition, and therefore seeks to incorporate the land use suitability and land management strategies to control land degradation. The aim of the study was to investigate the effects of land degradation on agricultural land use, planning and management. It therefore set out to: (1) determine farmers' considerations of land suitability for selected types of agricultural land uses in varying cropping zones, (2) investigate farmers' local environmental knowledge of land degradation indicators, and (3) document farmers' land management strategies and practices for soil and water conservation.

2. METHODOLOGY

2.1 Study Area

The study was undertaken at Kakayuni, Kyangala and Kinoi sub-locations in Kyangala Location, Kalama Division, Machakos County (Fig. 1). Kalama Division covers an area of 200 square kilometers, located between 1º37' S and 1º45' S latitude and 37º15' E and 37º23' E longitude. The choice of the study site was based on several considerations emanating from the research problem. There is increasing soil erosion due to steep terrain and loose soils. According to [20], there is also encroachment of forest for settlement, land use change and charcoal burning and generally loss of vegetation within the study area that has affected agricultural land use negatively. Bare rocks have been left with little or no soil covering in most parts of the area hence smallholder farmers are left to diversify on other sources of livelihood leading to change of their farm plan and management to cope with land degradation. Kalama Division has four locations and eight sub-locations (Table 1). Kakayuni location is the largest and has steep hills and experiences highest soil erosion compared to other locations. The hill tops are defforestated due to extended settlements and farming activities.

The study area is characterized by metamorphic rocks which form the roots of the mountains in the area. The mountains consist of excessively drained, reddish brown, stony and rocky sandy clay loam soils, that vary in depth [27]. The plains and uplands that surround the mountains consist of poorly drained, black cracking and swelling firm clay soils. In the dissected uplands well drained dark reddish brown clay and sandy clay soils are formed. The study area is drained by two seasonal rivers: Thwake and Kaiti. According to EllenKamp [21] the mean annual rainfall of the area is 602 mm, distributed over a long (March-May) and a short (October-December) rain season, separated by a distinct dry season. The rains on the southern and eastern slopes of the mountains tend to be prolonged. The average monthly maximum temperature varies between 22.2°C and 27.3°C and the minimum temperature varies between 11.1°C and 15.2°C. The study area is used as arable land. Farms sizes vary from 500 m2 to 1,000 m2 and most farms are terraced. Mixed cropping is the main farming activity, with maize, pigeon peas, beans and fruit trees as the main crops [28]. Most farms have livestock (cows and goats) which are kept for dairy products and manure.

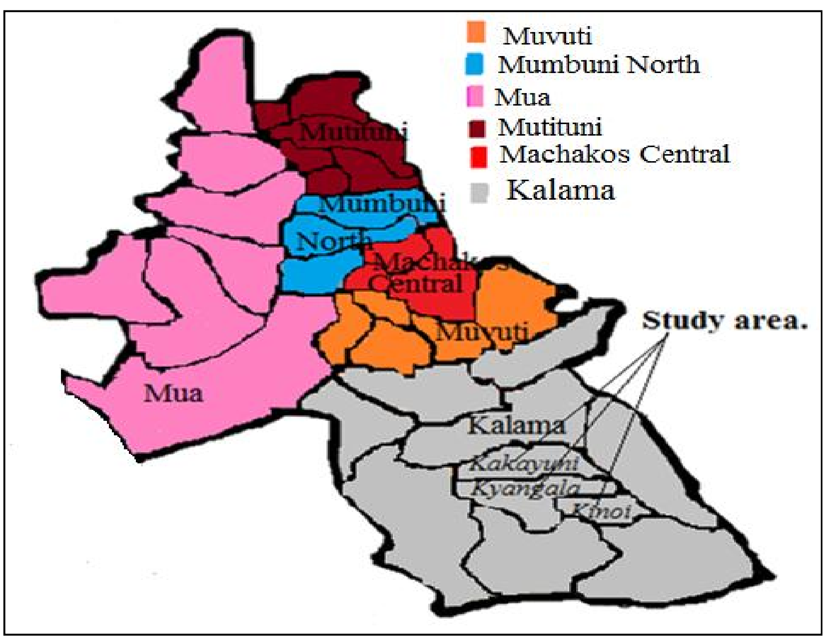

Fig. 1. Location of study area in Machakos County

Table 1. Population and demographic characteristics of Kalama Division

Division	Location	Sub-location	Total Population	Area in Sq. Km.	Population Density	Households
Kalama	Kola	Iiuni	4,415	26.6	165.9	986
		Katanga	7,695	34.2	225.1	1,643
	Lumbwa	Muumandu	12,475	148.6	83.9	2,820
	Kalama	Nziuni	4,870	17.6	277.4	1,015
		K iitini	6,285	35.4	177.7	1,419
	Kyangala	Kinoi	2,342	11.9	197.0	543
		Kakayuni	2,454	7.8	313.0	568
		Kyangala	2,298	10.5	219.7	541
Totals			**7094**	**30.2**	**729.7**	**1652**

Source: [29]

2.2 Data Collection and Empirical Specification

The study employed a survey research design. According to [30], survey concerns describing, recording, analyzing and reporting conditions that exist or have existed. Agronomic survey was used where crop calendar, farming practices and production systems were captured. The second component of the research design was land management strategy having Integrated Soil Fertility Management (ISFM) [31] soil and water conservation measures and farming operations [19], which was captured through ethnographic survey techniques [11]. Lastly land degradation indicators were achieved through ethnopedologic survey technique [11] and the data collected were based on local knowledge/expertise. The survey was designed to collect views from smallholder farmers in three zones on the basis of differential terrain i.e. the upper zone, middle zone and lower zone of Kakayuni, Kyangala and Kinoi sub-locations Kalama Division Machakos County. A questionnaire schedule with both open-ended and closed questions was used for data collection. Data collected was coded and quantified through a process of creating of dummy variable names (short names assigned to each study variable). The responses were assigned numeric value to enable quantitative analysis using SPSS Programme.

The study adopted a transect sampling design whereby a road based transect was designed to cover as much ecological variability of land uses as possible within the study site. A similar approach was used by several authors [32,33]. The approach was based on the distribution of patterns along environmental lines to give a description of the full range of land use in a region by sampling along the full range of environmental variability. The area was divided into three zones i.e. upper zone (hills), mid zone and lower zone. In the upper zone there is encroachment of forest for settlement, land use change and charcoal burning. The middle zone is characterized by increasing soil erosion due to steep terrain and loose soils while the lower zone has fewer observable land degradation indicators. Within each zone, systematic random sampling along a transect road was carried out to select every second household for answering of questionnaires. The transect sampling design was relevant to the study as the research aimed to investigate the effect of land degradation to the farm planning and management within the study area. Each zone has a road cutting across hence the roads that cut across the three zones, upper, middle and lower zones were followed and households that fell within the road to an estimate of 2 km in each of the three zones were sampled. In total, 13 households were selected in both the upper and middle zones and 14 households were selected in the lower zone. The stratification was done according to agro-ecological zones (AEZ) as identified by Jaetzold, R., and Schmidt, H. [34] in Kenya and Tanzania.

3. RESULTS

3.1 Farmer's Considerations of Land Suitability for Selected Types of Agricultural Land Uses

Results obtained on farmers' consideration of land suitability revealed that livestock production, crop farming, farm forestry, poultry farming and bee keeping were the agricultural land use practices in the area (Table 2). All household practiced crop farming (34%) in the three zones (1.15 STDEV). Crop farming was followed by livestock keeping at 30% (upper zone), 33% (middle zone) and 33% (lower zone) (1.73 STDEV). Poultry keeping followed crop farming and livestock keeping with upper zone having 28%, middle zone (33%) and lower zone (33%) (STDEV 2.89). Farm forestry was practiced in upper, middle zone and lower zone at 25%, 23% and 18%, respectively. However, bee keeping was practiced only in the lower zone by 3% of the households interviewed.

Results on reasons for farmers' selection of the field for a particular land use were influenced by its suitability for the particular use. Thus livestock were kept where there was sufficient pasture land; fertile soils influenced crop farming; sloppy areas were chosen for tree planting while chicken were kept where there was security from theft (Table 3).

3.2 Farmer's Local Environmental Knowledge of Land Degradation Indicators

Dry land communities possess vast amounts of indigenous knowledge that science could benefit from by learning about local ways of recognizing, coping and adapting to degradation. This section is devoted to a discussion of this body of indigenous knowledge. According to the study the community was aware of many land degradation indicators which they observed during their daily land use cores. The households identified a consensus list of land degradation indicators which they clearly described in the local language. Seven common land degradation indicators were identified in the research area (Table 4).

Table 2. Agricultural land use practices in study area

Land use practice	Zones in Percentage (%)			Mean (%)	STDEV
	Upper	Middle	Lower		
Livestock production	30	33	33	32	1.73
Crop farming	33	33	35	34	1.15
Farm forestry	25	23	18	22	3.61
Poultry farming	28	33	33	31	2.89
Bee keeping	0	0	3	1	1.73
Mean (%)	24	24	24		

Table 3. Farmer's considerations for choice of land for agricultural use

Agricultural practice	Reason for Choice of Land	Zones in percentage (%)			Mean (%)	STDEV
		Upper	Middle	Lower		
Livestock production	Sufficient pasture and water	28	15	30	24	8.14
	Accessibility	0	0	3	1	1.73
	Conducive climate	0	0	3	1	1.73
	Nearness to homestead	0	3	0	1	1.73
	Security	3	0	3	2	1.73
Crop farming	Fertile soils	25	20	38	28	9.29
	Availability of water	0	3	3	2	1.73
	Conducive climate	0	3	0	1	1.73
	Gentle slope	0	3	3	2	1.73
	Lack of stones	3	3	5	4	1.15
Farm forestry	Steep slope	23	13	15	17	5.29
	To act as wind breaker	3	3	3	3	0
	To conserve soil	5	8	3	5	2.52
	Conducive climate	3	3	3	3	0
	Availability of water	3	0	3	2	1.73
	Fertile soils	0	3	0	1	1.73
Poultry farming	Security (Theft and low draught)	23	33	35	30	6.43
	Availability of feed	0	3	3	2	1.73
	Direction of wind	0	5	5	3	2.89
	Minimal disturbance	0	3	0	1	1.73
Bee keeping	Safety (Minimal disturbance)	0	0	3	1	1.73

Table 4. Land degradation indicators within the three zones

Land degradation indicator	Zones in percentage (%)			Mean (%)	STDEV
	Upper	Middle	Lower		
Field erosion	8	28	28	21	11.55
Stone appearance	8	18	5	10	6.81
Tree reduction	15	28	5	16	11.53
Appearance of tree roots	8	5	5	6	1.73
Water scarcity	0	10	0	3	5.77
Terrace slide	10	15	8	11	3.61
Increased ant-hill	0	0	3	1	1.73
Mean (%)	7	15	8		

The respondents described them as follows:

1. Field erosion - The respondents said that their fields had gullies and rills as compared to the last five years. The observed change caused loss of the fertile top soil hence reduced production within the fields. This also made the plants weak and not well anchored in the soil.
2. Stone appearance - The farmers clearly panted that the stone appearance had increased due to land degradation. The land was highly covered by soil and vegetation but currently a greater surface is covered by stones which have occurred due to erosion.
3. Tree reduction - Generally forest cover in the study area has reduced as compared to the past. Most of the respondents stated that climate change had brought reduced survival rates of trees especially those which required high amount of moisture. The vegetation cover generally was affected negatively hence the land left bear.
4. Terrace slide - Terraces had highly slide and lost their uniformity causing reduced water hold-age within the field and soil. This has also led to deposition of soil to the lower sides of the *Shamba*.
5. Appearance of tree root - The study area had lost most of the top soil, this caused root appearance of the tree roots hence reduced quantity of water uptake and limited tree support. The loose soil and steep slope zone within the study area accelerated the root exposure leading even to vegetation drought.
6. Water scarcity - The farmers indicated that the amount of water in wells and in streams had reduced within the study area. Exhaustion/exploitation of water catchment zones and reduced vegetation/soil led to water scarcity.
7. Increased anthills - Increased number of anthills were reported as the temperatures increased and dried woody materials hence high termite infestation for food. The residents alleged that the ants made the anthills to adapt to climate change.

Field erosion was highest in the middle (28%) and the lower zones (28%) and was in overall the commonest land degradation indicator (21%) reported in the three zones. Further, highest incidences of land degradation indicators were reported in the middle zone where field erosion and tree reduction were the commonest (28%) reported indicators.

Results obtained revealed that heavy rainfall according to the farmers was the main cause of field erosion (20%) (7.51 STDEV) in all the three zones followed by deforestation (14%) and overstocking (8%) (Table 5). The least important cause of field erosion was loose soil (5%). Across the three zones deforestation (13%) and heavy rain (7%) were the highest causes of stone appearance. According to the farmers heavy rainfall (9%) caused tree reduction in the mid-zone. Loose soil was the least cause of tree reduction (3%). Appearance of tree roots was mostly caused by deforestation (9%), followed by heavy rainfall (4%) and overstocking (4%); the least was loose soil (3%). Terrace slide was commonly caused by rainfall (9%) and deforestation (8%); loose soil (8%) and the least was overstocking (4%).

3.3 Farmer's Land Management Strategies and Practices for Soil and Water Conservation

In the study area, farmers practiced land management strategies for soil which included: planting of grass, afforestation, terracing, stone-line, organic fertilizer application and crop rotation (Table 6). The study revealed that the upper zone led in land management strategies for soil and water conservation (18%). In this zone planting of trees was the commonest strategy (25%), followed by terracing (23%) and finally stone line (10%). The mid-zone was the second in soil conservation strategies (16%). In this zone planting of Napier grass was the commonest strategy (28%) and the lowest was crop rotation (8%). The lastly was the lower zone in land management strategies for soil with a mean percentage of 14%. As in upper zone tree planting was also the most practiced strategy in lower zone (23%), while stone-line was the least used strategy (11%). Within the three zones tree planting was the mostly practiced land management strategy for soil (23%) (4.04 STDEV), followed by Napier grass planting (20%), terrace making (16%), organic fertilizers use (13%), crop rotation (13%) and finally stone line making (11%) (6.56 STDEV) (Table 6).

Table 5a. Perceived causes of land degradation in selected zones

Land degradation indicator	Perceived cause	Zones in percentage (%)			Means (%)	STDEV
		Upper	Middle	Lower		
Field erosion	Heavy rainfall	13	28	20	20	7.51
	Overstocking	3	5	15	8	6.43
	Deforestation	20	10	13	14	5.13
	Loose soil	5	8	3	5	2.52
Stone appearance	Heavy rainfall	3	13	5	7	5.29
	Overstocking	5	3	10	6	3.61
	Deforestation	18	8	13	13	5
	Loose soil	3	3	5	4	1.15
Tree reduction	Heavy rainfall	3	18	5	9	8.14
	Overstocking	5	3	8	5	2.52
	Deforestation	8	3	5	5	2.52
	Loose soil	3	5	0	3	2.52

Table 5b. Perceived causes of land degradation in selected zones

Land degradation indicator	Perceived cause	Zones in percentage (%)			Means (%)	STDEV
		Upper	Middle	Lower		
Appearance of tree roots	Heavy rainfall	5	3	3	4	1.15
	Overstocking	3	3	5	4	1.15
	Deforestation	5	13	8	9	4.04
	Loose soil	3	3	3	3	0
Water scarcity	Heavy rainfall	5	10	15	10	5
	Overstocking	15	23	3	14	10.07
	Deforestation	3	5	3	4	1.15
	Loose soil	3	3	5	4	1.15
Terrace slide	Heavy rainfall	8	15	3	9	6.03
	Overstocking	5	3	3	4	1.15
	Deforestation	10	5	10	8	2.89
	Loose soil	8	5	10	8	2.52

Table 6. Land management strategies for soil conservation in selected zones

Land management strategy	Zones in percentage (%)			Mean (%)	STDEV
	Upper	Middle	Lower		
Planting of grass	18	28	13	20	7.64
Afforestation	25	18	25	23	4.04
Terracing	23	13	13	16	5.77
Stone-line	10	18	5	11	6.56
Use of organic fertilizers	18	10	10	13	4.62
Crop rotation	13	8	18	13	5
Mean (%)	18	16	14		

Results obtained on water conservation strategies in the study sites revealed that water harvesting, afforestation, micro-dam making, gabion making, mulching and terracing were the commonest conservation methods used (Table 7). Overall most water management strategies were practiced in the middle zone (8%). In addition, water harvesting (10%) (2.52 STDEV), gabion making (10%), afforestation (7%) and terracing (7%) (2.89 STDEV) were the commonly reported water conservation strategies in all the three zones. However, with respect to zones, water harvesting and afforestation were commonest in the middle zone (13%), water harvesting in the upper zone (23%), gabion making in the lower zone (10%) and terracing in the middle zone (10%).

At first this article has looked at agricultural land use practices commonly practiced in study area. Crop farming and livestock rearing were common while the least was bee keeping. Farmers' selection of farm fields and considerations of land suitability were highly determined basing on the following factors: climate, soil type and fertility, water availability, terrain and security. Farmer's local environmental knowledge of land degradation was clearly brought out by the study in this chapter. The community is aware of land degradation and gave out that: field erosion, stone appearance, tree reduction, terrace slide, appearance of tree roots, water scarcity and increased anthills were the major land degradation indicators experienced. Lastly the study revealed that land management strategies for soil and water were practiced in the study area by the smallholder farmers.

4. DISCUSSION

4.1 Farmer's Considerations of Land Suitability for Selected Types of Agricultural Land Uses

Crop farming, livestock, poultry farming, forestry and bee keeping were identified as the major agricultural land uses in the three selected zones. Crop farming and livestock were among the leading practices in most of the households. It was noted that all households identified crop farming as the main agricultural land use in the study area followed by livestock production. The phenomenon could be influenced by socio-economic factors as in agreement with Waters-Bayer et al., [35]; since occupation play a key role towards planning and management of land use as formally employed farmers had the greatest percentage across the three zones (Appendix 1). This most probably could have made the smallholder farmers to acquire fertilizers, highbred seeds and breeds and able to employ farm labour. Nonetheless the self-employed household heads possibly could have enough time to care, plan and manage their farm land. Most of these practices may highly require experience especially poultry farming which is upcoming in the current economic growth. Moreover farm forestry was mostly practiced in the upper zone and mid-zone this could have been influenced by their steep terrain hence the need to conserve the soil from extreme degradation. In similar study Morgan [36] found that development of different soil erosion indicator at different slope positions does indicate the strong influence of velocity of overland flow and slope steepness- length factors. In support of farmers' observations, Mutchler et al. [37] observed a tendency of rills forming as slopes became steeper mainly as a result of concentrated overland flow that increased depth and number of rills on steeper slopes than less steep slopes. In similar study Moreno et al. [38] found out that rainfall is strongly influenced by elevation, with highest erosivity values at high elevations, coinciding with steep slopes and shallow soils, which make these areas susceptible to erosion. In support of farmers' observations, Yao et al. [39] observed a tendency of rills forming as slopes became steeper mainly as a result of concentrated overland flow that increased depth and number of rills on steeper slopes than less steep slopes.

Table 7. Water conservation strategies in selected zones

Water management strategy	Zones in percentage (%)			Mean (%)	STDEV
	Upper	Middle	Lower		
Water harvesting	10	13	8	10	2.52
Afforestation	5	13	3	7	5.29
Micro-dam making	8	3	3	5	2.89
Gabion making	5	10	15	10	5
Mulching	3	0	3	2	1.73
Terracing	5	10	5	7	2.89
Mean (%)	6	8	6		

General overview of household land use practices indicated that farmers had reasons for choosing the field, for the land use practices. For example livestock was majorly undertaken in fields with sufficient pasture across the three zones which may have been attributed to quality and quantity production at minimal cost for the smallholder farmers. Accessibility to the field and conducive climate were least considered as the farmer's could have been concerned with pasture to avoid decline in livestock production; these findings are confirmed by studies undertaken by Fynn and O'Connor [40]. Results further indicated that crop farming was practiced in accordance to several reasons which included fertile soil across the three zones but majorly in the lower zone. This might have been influenced by availability of high nutrient supply in soil, aeration and organic matter decomposition which leads to increased crop productivity [41]. Lack of stones in the lower zone most likely influenced crop production. Presence of stones could have highly affected soil structure hence hindering crop growth. Gentle slope slows down surface run off minimizing soil erosion and encouraging water retention. These findings are in agreement with Ceballos-Silva and Lopez-Blanco [42] who noted that planning and farm management is determined by terrain.

Forestry farming was mostly practiced in steep slopes across the three zones but majorly in upper zone. This implied that upper zone farmers could have high experience in reducing soil erosion and maintaining the soil structure hence being clear that their environment was well maintained. The mid-zone recorded the lowest forest cover hence was most likely suitable for crop product and other activities. Which could be attributed to low availability of water and increased land degradation due to steep terrain hence hindering tree growth [37]. Trees are commonly planted on steep slopes because of challenging terrain.

Theft and draught control were the major reasons for keeping poultry across the three zones. Also minimal disturbance and direction of wind triggered the poultry keeping. Lastly bee keeping was overtaken by the other agricultural land use practices in the study area which could be attributed to minimal acreage ownership of land among the farmer's since majority own less than three acres (Appendix 1). Bee keeping was practiced in lower zone most probably due to households' awareness and training in their management in this zone.

4.2 Farmer's Local Environmental Knowledge of Land Degradation Indicators

Great deal of work has been carried out with appreciable attempt to estimate land degradation in the perceived high, moderate and low erosion sites [43]. Results from this study unveiled that the local communities were aware of land degradation indicators which they observed during their daily land use chores. However, this awareness did not differ across the three zones as perceived by the respondents. The households identified a consensus list of land degradation indicators and outlined what they perceived as the development of these indicators (Table 3).

An examination of land degradation indicators within the three zones (Table 3) revealed that all the land degradation indicators were highly experienced at the mid-zone. This was most probably due to reduced vegetation cover, steep land slope and loose soil [36]. The lower- zone experienced the lowest land degradation indicators; this may be due to gentle slope which was mostly present in this zone. The upper zone experienced moderate land degradation indicators. This could be attributed to forest encroachment for settlement, agricultural land use practices and charcoal burning [9]. Field erosion was the main land degradation indicator across the three zones. Erosion plays a more important role to overall soil loss amount [44]. Therefore, it can be noted that most households were aware of land degradation indicators in their local environment. Such levels of land degradation, according to Kilewe and Mbuvi [45], can lead to partial or total loss of soil resource for land uses whereby even addition of higher rates of inorganic and organic fertilizers might still prove uneconomical given the loss of soil rooting depth.

Having looked at the land degradation indicators, it was important to examine the perceived causes of the identified land degradation (Table 4). Results from this study clearly revealed that natural and anthropogenic factors were the main causes of land degradation across the three zones. Heavy rainfall which caused flash floods highly in middle zone was the major cause of field erosion [46]. Deforestation was the major perceived cause of field erosion in upper zone. This could have probably led to reduction of vegetation cover hence bear land increasing surface run off. Livestock keeping which is an anthropogenic factor could have been one of the major causes of land degradation indicators mostly affecting the middle and lower zones where most livestock was kept (Table 1). Lastly loose soil was perceived as an indicator of land degradation which highly influences terrace slide in lower zone and field erosion in upper and lower zones. Boserupian theorists have argued that human-induced land degradation could stimulate the innovation necessary to overcome resource scarcity and maintain sustainable livelihoods in the dry lands of Africa [24]. Similar views were expressed by Isaurinda et al. [47] who inferred that the relative success of Cape Verde in tackling desertification and rural poverty owes to an integrated governance strategy that comprises raising awareness, institutional framework development, financial resource allocation, capacity building, and active participation of rural communities.

4.3 Farmer's Land Management Strategies and Practices for Soil and Water Conservation

It is evident from this study that tree planting was the major soil conservation measure across the three zones but mostly in the upper zone most likely due to favorable climatic conditions suitable for tree growth. According to Stringer et al. [48] soil is considered one of the world's limited, non-renewable resources. In addition to conserving soil, the other possible reason of afforestation can be a source of; wood-fuel, timber, trees act as wind breakers and is source of food for both human beings and livestock. The middle zone was characterized by steep slope, high water scarcity and loose soils hence more likely supported grass planting as a measure of soil conservation. The grass can do well in shallow soils with little amount of moisture and boosts soil fertility by adding organic matter. Due to minimal land degradation indicators the residents in the lower zone were most probably reluctant to carry out soil conservation measures. Planning and farm management is determined by terrain [42]. Stone line was mostly used in the middle zone; this could be most likely attributed to availability of stones brought about by high land degradation in the mid-zone. This method is likely to be cheap and possibly does not require high skills; also it is more likely to create more space for crop production.

Land management strategies for water in the three zones included; water conservation. Water conservation was done through water harvesting across the three zones. The middle zone led in water conservation strategies most likely due to availability of rocks in the zone which acted as water catchment during rains. The area also had trees and presence of stone lines which reduced surface runoff thereby increasing water infiltration. This zone was characterized by steep terrain and streams hence less use of micro-dams as water conservation strategy; these findings are in consistent with those of Ceballos-Silva and Lopez-Blanco [42]. The lower zone had limited water conservation strategies. This was most probably because the zone was suitable for water catchment because most of the runoff from the upper zones concentrated at this zone probably forming gullies and streams hence need for gabions to conserve water at the lower zone. This observation agreed with the findings by Johansson and Svensson [49].

5. CONCLUSION

From the results obtained in this study it can be concluded that smallholder farmers possess vast amounts of indigenous knowledge of their local environment and are aware of land degradation indicators which they observe during their daily land use cores and have local ways of recognizing and describing them. The study recommends that agricultural land use planning and management should be informed by smallholder farmer's knowledge of landscape structure and local micro-environments hence informed decision making. Further research is required on participatory degradation assessments and quantification and matching with agricultural production.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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APPENDIX

Appendix 1. Selected household socio-economic and asset ownership characteristics

Part A: Socio-economic variable	Zones (%)			Mean (%)	STDEV
	Upper	Middle	Lower		
Gender of household head					
1. Male	30	30	33	31	1.73
2. Female	3	3	3	0	0
Average age of household head					
1. Husband	18	18	18	18	0
2. Wife	15	15	18	16	1.73
Occupation					
1. Formal	23	23	15	20	4.62
2. Self employed	10	13	25	16	7.94
Household size					
1. 1-3	0	0	3	1	1.73
2. 4-6	28	23	13	21	7.64
3. 7-9	5	10	15	10	5
4. 10-12	0	5	3	3	2.52
5. Above 12	0	0	3	1	1.73

Part B: Asset ownership	Zones (%)			Mean (%)	STDEV
	Upper	Middle	Lower		
Land Size (acres)					
1. Below 3	23	10	23	19	7.51
2. 4-6	10	20	10	13	5.77
3. 7-9	0	8	0	3	4.62
4. 10-12	0	0	0	0	0
5. Above 12	0	0	3	1	1.73
House roof type (households)					
1. Thatched	5	3	0	3	2.52
2. Iron sheets	28	33	35	32	3.61
House wall type					
1. Wooden	0	3	0	1	1.73
2. Bricks	25	28	28	27	1.73
3. Stone	8	5	13	9	4.04

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