

Biophysical Conditions and Land Use Methods Contributing to Watershed Degradation in Makueni County, Kenya

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Abstract

Land use changes, rapid population growth, poverty, climate change variability and lack of livelihoods diversification aggravate watershed degradation through inappropriate land use methods resulting to water scarcity, land and water pollution, and governance issues. Soil erosion and siltation has led to land denudation, habitat loss and farm lands losing their soil fertility and compromising food security. The purpose of this study was to find out how land use methods influenced the biophysical and socio-economic conditions to accelerate watershed degradation and their effects on livelihoods in Makueni County, Kenya. The study investigated the land use methods practiced and how they affect the biophysical conditions influencing watershed degradation in Makueni County. The study used a descriptive survey research approach to obtain data on socio-economic characteristics of the study sites as well as historical trends of land use. Remote sensing and GIS was used to determine land use categories in the study area. Structured and semi-structured questionnaires were used to collect data from the community and key informants. The data collected was analysed using Statistical Package for Social Sciences (SPSS) and Microsoft Excel 2010. The study established that decline of ground water 90% (S.E=0.602 z=-0.725 sig.=0.468), increase in surface run-off 55% (S.E=0.314 z=0.394 sig.=0.693), increase in soil erosion 86% (S.E=0.660 z=-1.875 sig.=0.061), changes in rainfall and temperatures 75% (S.E=0.374 z=-0.547 sig.=0.585), decline in soil fertility 70% (S.E=0.362 z=-1.370 sig.=0.171) and drying of rivers 37% (S.E=0.398 z=1.739 sig.=0.082), contributed to watershed degradation. This predisposed farmers to adopt inappropriate farming methods and unsustainable livelihood strategies which compromised the watershed's environmental integrity. The study made recommendations for efficient watershed management.

Keywords: Land use changes; Watershed degradation; Watershed management

Introduction

Land/watershed degradation is a global problem, with adverse effects on the functionality of watersheds which provide essential goods and services to local communities and national economies which rely on them for their livelihood outcomes [1]. Human activities and particularly accelerated soil erosion rates are the main cause of land degradation. It contributes to alteration of watersheds, leading to decrease in agricultural productivity as well as all the other natural ecosystems, loss of soil fertility compromising farmer's income and watershed's environmental integrity [2-4]. The African continent is faced with the unparalleled environmental degradation with about 70% of its population being rural, directly depending on land and natural environment for its livelihoods and wellbeing [5]. Rapid population growth, poverty and social inequities contribute to watershed degradation [6,7]. The African savanna landscapes provide economic and ecological services sustaining livelihoods, now threatened by the twin problems of soil erosion and decrease of vegetation cover and depletion of wood land cover [8]. In Kenya and Makueni County, the situation is exacerbated by rapid population growth, high poverty levels, land use changes/ poor land use systems and deforestation (increase of farm lands and exploitation of existing forests for charcoal burning, fuel wood, medicinal herbs construction

materials and fodder), leading to food crises and land/watershed degradation [9-11].

Soil erosion and siltation has led to land denudation, habitat loss and farm lands losing their soil fertility and compromising food security. Farmers tend to intensify agricultural activities in perceived fertile areas, often in fragile ecosystems. In the absence of robust soil and water conservation, the challenges of soil erosion increase, leading to soil detachment and increased run-off on soil surface [4,8,12]. Land form changes owing to infrastructure development in form of roads, often create new landscape factors which change soil properties from the additional drainage culverts in road and other infrastructural projects [13]. This new development increases both on-site and off-site disturbances of the ecosystems. These changes impact negatively on the biophysical and socio-economic arrangements of the environment in the County [14-16]. The declining soil fertility, poverty, deforestation, diminishing land holdings and erratic rainfall patterns contribute to watersheds degradation [17]. The study's main objective was to investigate the land use methods practiced and how they affect the biophysical conditions influencing watershed degradation.

Land/watershed degradation is more than soil erosion [18]; it makes consideration to all interactions on land with users leading to any kind of degradation. The natural processes (biophysical), human activities (socio-economic systems) and the poverty nexus exacerbate watershed degradation in Makueni County. It is caused by both human and natural processes. It is important to make distinction between human

induced degradation and that is caused by climate change which land users have no control over. According to Barbier et al. [7] land degradation is linked to food insecurity and vulnerability to climate change as well as poverty, which impacts negatively on farmers livelihoods and land management practices. It is also important to note that land/watershed degradation is a social problem affecting all the people at all stages of development not only as a causative factor but also as victims of these actions [18]. As poverty increases, people tend to overexploit land resources further increasing degradation [12,19]. Land use ultimately varies on the type of crops planted, size of plot per land use type, land management and cropping systems. Land quality in man modified ecosystems degrades over time, affecting the ability of the same ecosystem to deliver the goods and services intended. It also leads to loss of biodiversity and decline in crop productivity [19].

Farmers' awareness on the importance of proper land management and SWC practices as well as recognition that human activities and soil erosion are drivers to the current degradation is an important step towards sustainable exploitation and utilisation of land resources [12]. Support of diversification of rural livelihoods and entrenchment of local ecological knowledge and social values [20] in holistic approach to land management offers the best solution to solve these problems. The increase of vegetation covers in farmlands and grazing lands [12,18,21], for both indigenous and exotic trees, will eventually increase livelihoods resilience for farmers and environmental integrity. The intensification of agricultural extension services to farmers ensures that there is sustainable development and regeneration of crop and grazing lands for the benefit of the current and future generations of farmers in the fast changing dynamics owing to climate change and reducing farmlands. The aim of the study was therefore to understand the bio-physical conditions and land use methods contributing to watershed degradation in Makueni county.

Materials and Methods

The study area

The general study area lies within Makueni watershed (Figure 1) of the larger Athi water basin. The semi-arid areas of Makueni County found in the Chyulu-Athi River catchment areas within Athi catchment area in Kenya's water sub-catchment of 3F or drainage area 3 in the Lower Midland (LM) zones extending over elevation of 800-1300 m, with annual average rainfall of 400-1000 mm [16,22]. LM 4 is a marginal cotton zone with fair to poor conditions for cotton and maize, fair for pigeon peas and good for sisal. LM 5 is lower midland livestock and millet zone with natural pastures able to support low density grazing [23]. The main rivers that drain the catchment include Athi, Kiboko, Kibwezi and Masongaleni which are perennial tributaries. The ephemeral tributaries include Thwake, Kaiti, Muooni, Kikuu, Thavu, Kambu and Mtito-Andei rivers. All these rivers traverse the county from West to East and drain into the Athi River which forms the Makueni-Kitui counties boundary in the East [16,22].

The county's rainfall distribution is bimodal received in two rain seasons. The short rain season is between November and December and the long rain season between March and April. The upper hilly parts of Mbooni and Kilungu hills receive an average of 800-1200 mm of rainfall per annum; while the drier southern low lying areas receive an average of 300-400 mm per annum. The mean rainfall in the two seasons range between 200-350 mm (half of the annual precipitation) largely influenced by the altitude among other factors, which is mostly depressed, barely enough to sustain the major staple food crops of

maize and beans grown in the county [10]. The agro-ecological conditions in the area support agricultural activities predominantly comprised of rain fed agriculture, crop and livestock production which dominates land use and household livelihoods in small-scale subsistence farming [10,23]. Rapid population growth, deforestation, diminishing land holdings, erratic rainfall patterns and conflict in water use are among the factors considered to influence watershed degradation in the study area [10,17,22].

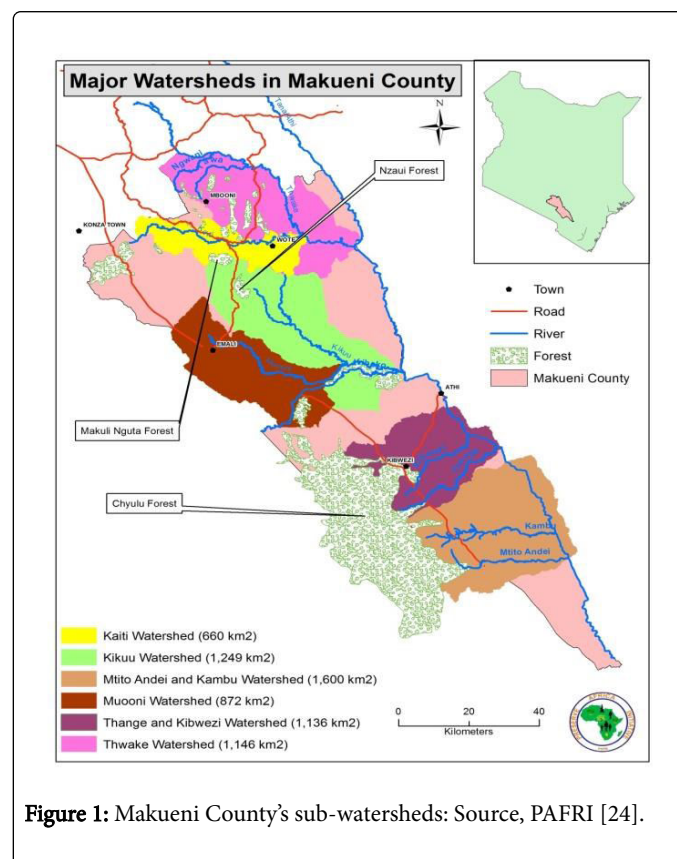


Figure 1: Makueni County's sub-watersheds: Source, PAFRI [24].

The study was done in Kaiti sub-watershed, which lies in the upper area of the county, characterized by high population and density of 120,116 and 248 persons per square kilometer respectively as compared to the average of 110 persons per square kilometer for the county [10]. According to Muriuki [17], high population has a bearing on the state of the watershed due to the increasing human activities and their effects on the wellbeing of the downstream communities in the county. Soil erosion in the sub-watershed is a major problem due to farming on steep slopes with siltation of manmade reservoirs experienced in the downstream of Kaiti River. Data was collected between the months of June-August, 2015 using household survey, Focus group Discussion and key informant questionnaires.

Kaiti sub-watershed, covers an area of 660 km² and is located between 10° 38' South and 10° 51' South and 37° 14' East and 37° 41' East. Kaiti sub-watershed (Figure 2) shows the specific study site in Makueni County. It lies in the fertile upper parts of the county which experience average rainfall of 800 mm-1200 mm. It comprises of Kilungu, Kee, Kalama, Kaiti and Wote divisions. The sub-watershed topography is characterized by mountainous terrain including Kilungu and Mbooni hills. Kaiti River and its numerous tributaries originating from the hills serve the watershed which influence surface water sources and ground water recharge capacity [17].

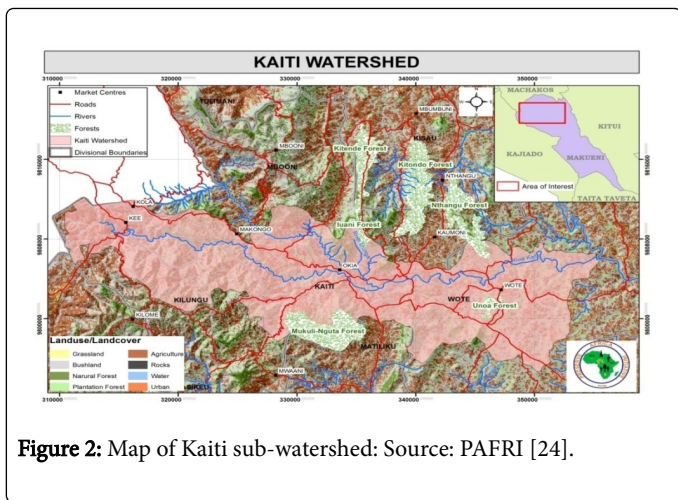


Figure 2: Map of Kaiti sub-watershed: Source: PAFRI [24].

Data collection

The study used a descriptive survey research design [25]. Both qualitative and quantitative methods were used to gather and evaluate primary and secondary data from the field and past studies/reports respectively. The study used multiple methods such as field/household surveys, community maps, observations, Focus Group Discussant interviews (FGDs), and key informant/experts interviews) to gather information and sampling of households along the vertical and horizontal transect lines. It also used triangulation which is a form of cross-checking and the use of multiple methods both qualitative (inquiry) and quantitative (validation) methods in studying the same phenomenon for the purpose of increasing study credibility [26]. The study used multistage probability sampling methods [27] to sample locations and community respondents. Kaiti sub-watershed was purposively selected for investigation based on its population distribution, density and varied physical characteristics [10,17]. Line transect approach [19] was used as part of the sampling framework traversing much of the ecological, socio-economic/land uses and environmental variability in the study site. Random point samples along the transect line were used to sample respondents to obtain information. The sampling was based on spatial organization of interests of the community respondents [28]. In this case agro-pastoralism, as a major economic activity among the community respondents was considered in the sampling of households and focus discussion groups. The study survey targeted 101 respondents, drawn from farmers, community groups' respondents and key informant categories.

The questionnaires were administered to respondents sampled systematically along a vertical transect line running from East to West direction, traversing the watershed along the general flow of river Kaiti.

The study used a variety of methods to gather information. Quantitative methods using a standardized open and closed questionnaire was administered to farmers to obtain information at household level on land uses and farmers perception on land use changes. The Qualitative methods involved Focus groups (Focus Group Discussions), involving both men and women because they have different perceptions on environmental changes, land/watershed degradation and livelihoods strategies and dynamics [29,30]. Key informants were also used in the study because of their expert opinion and experience on the ground, to give information on their perception of the watershed degradation in the study area. Geographic Information System (GIS) and Remote Sensing were used to determine major land use categories in the study area [19,31]. Fifteen farmers aged above 60 years were purposively sampled to obtain information about their perception on environmental changes and how the changes affect their livelihoods and the general trends on watershed degradation. These farmers were sampled on top of the 36 households interviewed because the scope of the study was intended to capture changes over a period of 40 years, hence the need to have a sample of elderly respondents.

Three divisions Kilungu, Kaiti and Wote, which fall within the general delineated boundaries of Kaiti sub-watershed, were selected for sampling of the respondents. Kilungu division represented the upstream communities, Kaiti division the midstream and Wote the downstream communities of the sub-watershed. Fifty one respondents were interviewed in each of the 3 divisions. Thirty respondents for focus discussion groups were interviewed in Kaiti division where GPS spatial maps were generated for in-depth study of the sub watershed. The 20 key informant respondents were drawn from among people with technical expertise in the divisions and from the county headquarters.

Data analysis

Data collected was managed and analysed using Statistical Package for Social Sciences (SPSS), version 19 and Microsoft excel 2010. Descriptive tools like percentages and frequencies were presented in bar graphs and pie charts.

Results and Discussions

Bio-physical conditions and watershed degradation

Biophysical conditions and land use methods influence watershed degradation owing to both natural and anthropogenic factors [19], as people continue to interact with the environment for their livelihood strategies. The study established that bio-physical changes have occurred in Kaiti sub-watershed (Table 1).

Bio-physical changes	Ecological zone No. and %							
	Wote		Kaiti		Kilungu		Kaiti sub watershed	
	No.	%	No.	%	No.	%	No.	%
Decline of ground water	13	76	16	95	17	100	46	90
Increase in surface run off	17	100	3	18	8	47	28	55

Sedimentation of rivers and water pans	5	29	2	12	-	-	7	14
Increase in soil erosion	15	88	14	82	15	88	44	86
Pollution of rivers	5	29	2	12	-	-	7	14
Drying of rivers	9	53	4	24	6	35	19	37
Changes in rainfall/temperatures	10	59	12	71	16	94	38	75
Decline in soil fertility	14	82	7	41	15	88	36	70
Reduction of forest /vegetation cover	15	88	14	82	13	76	42	82

Table 1: Bio-physical changes in Makueni watershed (N=51).

The study established that the age, gender and education levels of the household heads were critical in understanding and explaining the biophysical conditions in Kaiti sub-watershed and their influence on watershed degradation (Table 2). Increase in men as household heads (S.E=0.076 z=-1.013 sig.=0.737) indicated, that they had better knowledge and awareness on the biophysical conditions than women (S.E=0.104 z=0.169 sig.=0.866). The more years the household head had in education (S.E=0.174 z=0.347 sig.=0.183), the more they understood the biophysical changes happening in Kaiti sub-watershed.

Farmers were able to identify decline of ground water 90% (S.E=0.602 z=-0.725 sig.=0.468), increase in surface run-off 55% (S.E=0.314 z=0.394 sig.=0.693), increase in soil erosion 86% (S.E=0.660 z=-1.875 sig.=0.061), changes in rainfall and temperatures 75% (S.E=0.374 z=-0.547 sig.=0.585), decline in soil fertility 70% (S.E=0.362 z=-1.370 sig.=0.171) and drying of rivers 37% (S.E=0.398 z=1.739 sig.=0.082), which were significant at 10%. These factors were deemed to cause biophysical changes, which contribute to watershed degradation in the area.

Parameter	Estimates	Std. Error	z-score	Significance
Age of household head male	-0.025	0.076	-0.336	0.737
Age of household head female	0.018	0.104	0.169	0.866
Education level of household head	0.060	0.174	0.347	0.728
Decline of ground water	0.0-0.437	0.602	-0.725	0.468
Increase in surface run-off	0.124	0.314	0.394	0.693
Sedimentation of rivers	0.006	0.575	-0.010	0.992
Increase in soil erosion	-1.238	0.660	-1.875	0.061
Pollution of rivers	-0.761	0.491	-1.548	0.122
Drying of rivers	0.693	0.398	1.739	0.082
Changes in rainfall and Temps.	-0.204	0.374	-547	0.585
Decline in soil fertility	-0.495	0.362	-1.370	0.171

Note: Significance level of 10%

Table 2: Logistic regression results for Land use effects and Biophysical changes (parameter estimates).

It was clear that reduction of forest and vegetation cover due to farming and grazing activities has led to increase in soil erosion and reduction of soil fertility [21], which has impacted negatively on crop and livestock production, and the livelihood strategies [32]. This was more pronounced in Wote and Kaiti Divisions which have less afforestation efforts as compared to Kilungu in the upper watershed. Degradation and depletion of riparian vegetation and ecosystem has contributed to adverse changes with riverbeds becoming drier leading to loss of important biodiversity like Phragmites plant species and animal/bird habitats [11], a trend fairly observed in all the rivers/streams in the study area.

The decline of ground water 95% and 100% respectively and drying up of rivers and streams were mentioned in the mid and the upper watershed area. Water scarcity is more pronounced now in Kilungu where respondents reported streams and springs to have dried up forcing them to trek long distances in search of water. This contrasted with the past where they confirmed water was found to be plenty and common in the streams and ridges. Everything has changed to the worse, because, where as they were using the water to plant vegetables and arrow roots in the past, they have completely abandoned growing of some of these food crops. This can be attributed to climate change effects and rainfall variability, noted in the last couple of decades

[30,32]. The entire watershed faced similar problems as most of the respondents could identify water scarcity as a problem on the increase. This state of events then explains why despite farmer's willingness to use irrigation farming, only 4% of the respondents in the watershed reported to have been currently involved in micro-irrigation farming. The decline of ground water and fast drying of riverbeds (37%) were mentioned as the greatest impediment to sustainable agriculture and addressing of the perennial food insecurity in the area.

These findings support previous work done by Muia et al. [21]; land uses and human (anthropogenic) factors highly influence watershed degradation in the study area, because the majority of the people directly depend on the environment for their livelihood outcomes and survival [32]. Unsustainable utilisation and extraction of natural resources were identified in the form of unsuitable livelihood strategies like charcoal burning, timber harvesting and sand harvesting in the absence of robust livelihood opportunities and diversification options for the communities [10,32]. Farmers account and key informants indicated that the local community contributes to watershed degradation i.e., (poor quality terraces and non-maintenance), as attested by the increase in soil erosion 86% mentioned by farmers. The other factors include non-adherence to land use/management policies in relation to implementation of various development programmes was also contributing to the problems of degradation in the watershed.

The widespread watershed degradation owing to biophysical changes is attested in the rills, gullies, sedimentation in rivers, particularly in the mid and downstream area. There are barren/bare grounds, soil deposits in gentle slopes, vegetation change, accumulation of soil deposit around vegetation clusters and increased run-off [14,21]. The scenario signifies increased land/watershed degradation, depletion of soil nutrients [17] whose ramifications can only lead to decline of food production/yields, loss of flexibility in land management as large swathes of land become unproductive and possible diversion of resources to expensive rehabilitation efforts, in an already cost laden agricultural sector [10]. Reduction of forest/vegetation cover exposes the soil to water erosion [21], leading to the decline of soil fertility and loss of arable land, a trend with connections of the bio-physical conditions obtaining in the watershed. This can largely be attributed to both natural causes and human activities. However anthropogenic factors outweigh the former, due to increased agricultural activities in the watershed.

Land use and watershed degradation

The study revealed that land use changes have occurred in the study area, with rapid changes as a result of farming and development activities [14]. The main land use changes identified (Table 3), included subsistence crops (croplands and grazing lands), human settlements/institutions, forest/vegetation cover and infrastructure development such as roads and water masses (earth dams).

The main land use categories identified were comprised of built up areas, homesteads, schools, road infrastructure and shopping/market centres and urban areas. Others included herbaceous crops, tree or shrub, crops, forests and wetlands (Figure 3). Some physical structures like homesteads, schools road infrastructure, shopping centres and other institutions were easily identified from satellite images and were easy to locate and determine. Changes in land terrain and depletion of riverine vegetation were observed in the study area. However rills, erosion trends in the farms as well as differentiation between indigenous and exotic forests were difficult to make in the farm lots

along the farm edges and boundaries. This is despite the fact that there are increased agro- forestry efforts in individual farms, across the watershed.

Land uses	Ecological zone No. and %							
	Wote		Kaiti		Kilungu		Kaiti sub watershed	
	No.	%	No.	%	No.	%	No.	%
Farming	17	100	15	88	17	100	49	96
Grazing	15	88	14	82	11	65	40	78
Forest and vegetation cover	10	41	10	59	13	76	30	59
Human settlement	5	29	3	18	10	59	18	35
Infrastructure development	6	35	3	18	9	53	18	35
Horticulture	2	12	3	18	2	12	7	14

Table 3: Main land use in Makueni.

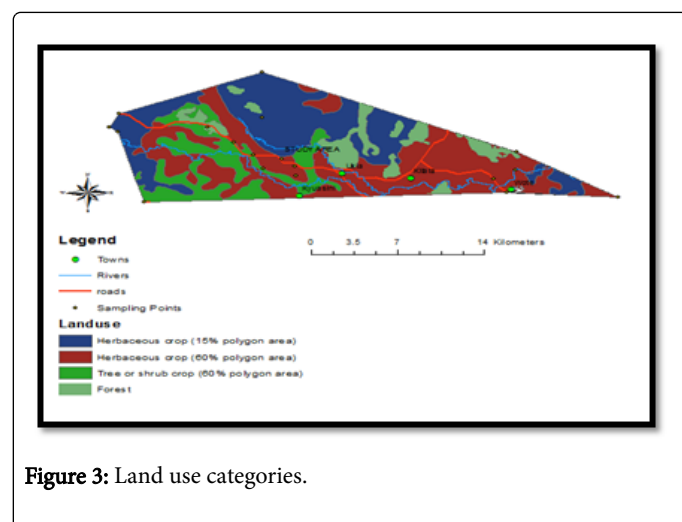


Figure 3: Land use categories.

Infrastructure development (i.e., roads, schools and earth dams) has also contributed to land/water degradation in the watershed. Infrastructure development has considerably increased in the recent years in form of roads, schools and earth dams [10,29]. There is neglect of maintenance of the rural roads which influence formation of gullies, crossing over to grazing land and ridges in the upper hilly areas causing large tracts of land to be denuded. In some cases soil/water erosion action happens in far places from the roads infrastructure sites. This has impacted negatively on farms and grazing lands as well as increasing sedimentation in rivers downstream. The other major land use changes noticed to have occurred in the study area were the expansion of cultivation from the higher elevation to the mid and in the lower elevation zones. This trend intensified from the opening of Makueni settlement scheme in 1948 onwards [14,23], which was basically a low lying and densely vegetated grassland. The newly introduced farming activities, included crop/livestock production, where food crops like maize, beans, cow peas, pigeon peas and green grams occupy the greatest percentage of crop production. These crops are grown by nearly all farmers with the intensity of legumes

preference depending on the ecological zone, and mostly concentrated in the mid and upper watershed areas.

Soil and water conservation in form of terraces were also examined in the watershed area. By use of satellite imaging, terracing structures in the area was found to be widespread in the area. Historical perspectives on soil and water conservation approaches, farmers and agricultural extension workers account was also used to understand the extent of adoption of terracing technologies in the study area. In the 1950s and 1960s decades, farmers testified that land was plenty as there were still new areas where people could migrate and ease pressure on land. Shifting cultivation, crop rotation, fallow cropping and intensive soil and water conservation were commonly practiced due to availability of land and the farmers' perceived profitability in crop production and livestock production. Population pressure and unavailability of more new settlement areas, farm sizes decreased considerably with fragmentation of the farms increasing at higher rates to absolve the growing population [32,33].

This led to more land being used for settlement and establishment of homesteads, agricultural land expansion accelerated, encroaching to fragile ecosystems, clearing of forests/vegetation cover to increase food production [17]. The decline of Soil and Water Management conservation measures led to increased soil erosion and soil fertility decline. The sustained practices of overgrazing in the low lands over the decades also increased land/watershed degradation as demonstrated in the cattle paths along road reserves and farm demarcation paths. Rills and gullies are commonly evident in many areas [21]. Farmers have also contributed to this problem by fencing off and encroaching on road and pathway reserves. In some instances such roads/pathways have been completely eroded to be unmotorable.

Farmers and key informants indicated that quality terracing has declined in the recent past with by-laws/agricultural rules on river bank encroachment not strictly followed and enforced as was the case in the past [14]. Steep slopes were increasingly being cultivated without adequate soil conservation measures. Population pressure was fairly mentioned to have led to clearing of forests, bushes and depletion of natural vegetation cover to increase crop production for food needs in the families. Land fragmentation to accommodate young generation and subdivision of land has contributed to watershed degradation in the area, with majority of new farms increasingly being used without proper and adequate conservation measures (terraces) increasingly encroaching into fragile ecosystems. Generally from field verification, observation, satellite images and account of agricultural extension personnel in the area, terracing structures in the area remain intact as depicted by this account (Figure 4). However, most of them are in a state of disrepair, generally neglected and not regularly maintained as required. In the absence of adequate agricultural extension services in the last 3 decades, some of the recent constructed terraces are not laid to contour; aggravating soil and water erosion. Most of the old farmers interviewed were in agreement, that they benefited immensely from the conservation technologies when the government was actively involved in SWC methods in the past.

The findings of this study are in agreement with previous studies by 14. Tiffen et al. [14]; Onyango et al. [30]; Ifejika et al. [32] on the importance of Self Help Groups (SHG) in conservation (terracing) work in the past. However, currently the "mwethya" group concept (Figure 5) of SWC has declined in the area with intermittent revival by NGOs supporting food for work programmes like German Agro-

Action (GAA) and World vision. Their efforts in terracing have considerably declined because the NGOs operate in limited areas to have watershed wide impact.



Figure 4: Terracing structures in the study area as depicted by Google earth satellite image January, 2015.

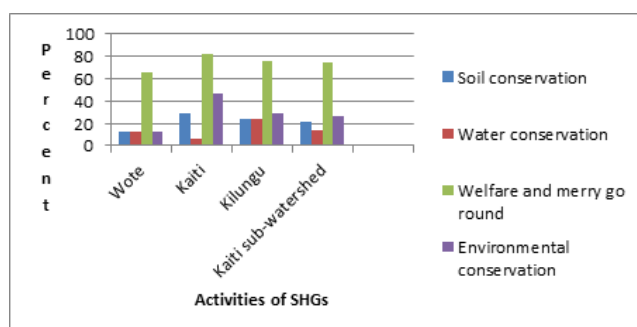


Figure 5: Activities of "mwethya" groups (self Help Groups) in the study area.

The respondents indicated that currently welfare and merry go round activities at 75% were the primary purposes and activities of the current "Mwethya" groups. Environmental conservation (27%), soil conservation (22%) and water conservation (14%) were the other activities of these groups. However they depended much on NGOs activities and presence, with most of the activities concentrated in welfare, tree nursery establishment for environmental conservation [30]. Most of these NGOs implemented short term programmes to enable sustained action in watershed management, and widespread soil and water conservation in individual farms.

The absence of proper maintenance of terrace structures, sheet and rill erosion in terraced farms has developed and was visible in the farms with neglected conservation structures. Gully formation is common along the edges of farm boundaries, cattle tracks and Pathways/roads in the area. This has considerably increased land/water degradation in the watershed with bare land and gullies seen in open grazing lands in the lower watershed area and the parched and bare/scanty vegetated landscapes common in the eastern parts of Kilungu hills in the upper catchment area. Lack of proper terraces is thus a further threat to the bio-physical conditions of the watershed as depicted by the decline of the quality of terraces.

Farmers' perceptions on land use and environmental changes

The study attempted to understand farmers' perception on land use and environmental changes which have occurred in the watershed as a result of bio-physical changes and land use methods (Figure 6).

Farmers' perception in land uses and environmental change indicated that they considered cultivation in fragile ecosystems (30%), reduction of forests/vegetation cover (32%), introduction of cash crops and exotic trees as some of the important land use changes in the watershed [17]. The other factors mentioned by the farmers were decline of SWC measures 26%, climate change and rainfall variability deemed to have contributed to watershed degradation. Land use changes and biophysical changes in the watershed were found to have occurred with negative impact, variously affecting agricultural activities. Crop/livestock production was found to be on the decline in the area. Land sizes have decreased, soil erosion has increased and natural soil fertility is declining owing to land use and biophysical changes [14,21]. These changes have led to the decline of land productivity, with majority of farmers acknowledging the increasing food insecurity threats in the watershed.

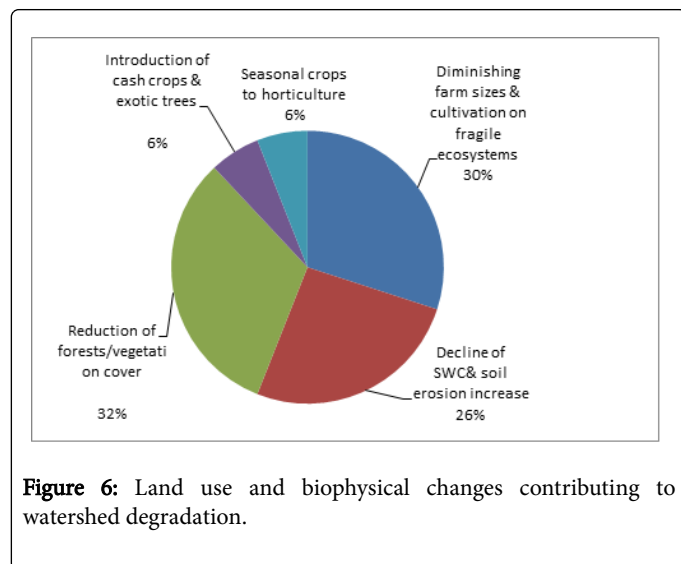


Figure 6: Land use and biophysical changes contributing to watershed degradation.

High value fruit crops like mangoes, citrus, avocado and vegetable growing (14%) are also considered as a major land use change [10,30] in the area, with many farmers now embracing their growing, with different levels of success. The farmers indicated that fruit tree farming gives them incentive for soil erosion conservation in form of terracing to increase water retention for their fruit tree management [14,34].

The introduction of exotic tree species (59%) like *Grevillea robusta* and *Eucalyptus Spp.* were mentioned by farmers as another major land use change with evidence of these trees grown along farm edges and in the homesteads and public places like schools and other government/community institutions [17]. Their preference however has continuously replaced the natural vegetation and tree species. In some cases, these trees are planted along riverbanks which may consequently lead to environmental changes with increased cases of drying up of rivers in the area. The farmers were aware of the negative effects but they preferred them due to their fast rate of maturity, timber products and as a major source of fuel woods in the face of depleted natural shrubs/vegetation which used to be an important fuel woods energy sources in the past.

Conclusion

The study revealed that bio-physical changes have occurred in the watershed, owing to both natural and anthropogenic causes. Population changes/ growth and increase in poverty influences land use and bio-physical changes, which have significantly contributed to watershed degradation. Land uses/methods such as subsistence crop farming, human settlement and infrastructure development (roads, schools and earth dams); have over the years increased in the area with varied degree of watershed degradation influences especially in the road sub sector in the rural landscape causing serious secondary erosion in the hilly areas. Forests, bushes, riverine ecosystems and wetlands were other notable land use categories observed in the watershed. Cash crop farming and exotic trees planting were a major land use observed in the area.

The decline of SWC measures and terracing in the face of declining agricultural extension services and inadequate government support and funding of SWC programmes has impacted negatively in the watersheds environmental integrity. Poor land use methods, inappropriate agricultural technologies and high cost of agricultural inputs have considerably slowed and compromised terraces development in the area. The trend threatens the biophysical conditions in the watershed with further degradation due to poor quality terracing. To understand the scope of the problem, it is important to take into account the drivers of these bio-physical changes and farmers' perception on them and their impacts. Farmers clearly understood the changes occurring in the area over the years like terracing (its peak and decline), cash crops farming and exotic tree species introduction which positively impacted on their lives. Fruit tree farming and agricultural intensification has been on the rise in the recent past. These changes continue to influence land use and biophysical changes in the watershed. Farmers also acknowledged their individual actions and land management decisions contributed to watershed degradation.

This study confirms that population change has a bearing on land use and biophysical changes in the area. However, the limited nature and scope of the study cannot rule out inherent gaps and recommends that further investigations on the matter should be undertaken to conclusively determine the extent of the dynamics of population change and the present situation in the area, where land sizes have considerably declined in the absence of more new lands to absolve the growing population and robust agricultural extension services.

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Authors' Contribution

Author 1' designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript and managed the literature searches. 'Author 2' and 'Author 3' managed the analyses of the study. All authors read and approved the final manuscript.

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