LAND USE AND LAND COVER CHANGE AND ITS IMPLICATIONS ON GULLY EROSION IN SUSWA CATCHMENT, NAROK COUNTY

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Abstract

This study investigated land use and land cover change for the last 26 years in Suswa Catchment, Narok County using satellite imageries. Changes in land use and land cover (built up areas, agricultural land, grassland, bareland and shrubland) for 1985-2000, 2000-2011 and 1985-2011 were determined using Chi-square test. Results showed no significant changes in built up areas, agricultural land, bareland, grassland and shrubland during the period. Overall change of built up area, shrubland, bareland, agriculture increased in 26 years, while grassland decreased. Grasslands were therefore converted to build up areas, shrubland, bareland and agricultural areas during this period. An increase in built up area, bareland and agricultural land and a decrease in grassland are therefore drivers of gully erosion. A decrease in grassland results in an increase in soil erosion. Projections (2020) indicate a significant increase in built up area, agricultural land and bareland and a decrease of grassland.

Key words: Land use and cover change, Soil Erosion, Remote Sensing, GIS, Narok County

1. Introduction

Land use and land cover change has become a central component in managing natural resources and monitoring environmental changes. Land use and land cover is dynamic in nature and provides an understanding of the relationship of human activities with the environment, which is important in the Suswa Catchment. Socio-economic processes for example agricultural, urban land, forestry, a shape land cover and land use, and therefore need to be understood in order to mitigate human impacts on the environment (Nagendra*et al*., 2004).

According to Teferi*et al.,* (2013) transitions in land use and land cover can be caused by negative socio-ecological feedbacks that arise from a severe degradation in ecosystem services or from socio-economic changes and innovations. Transitions can be random or systematic, with random transitions being characterized by abrupt changes, whereas systematic transitions evolve steadily or gradually. Information on land use/cover change and possibilities of their optimal use is essential for the selection, planning and implementation of land use strategies to meet increasing human needs and welfare.

Land use and land cover change involves the modification, either direct or indirect, of natural habitats and their impact on the ecology of the area (Garede*et al.,* 2014). Land use and land cover change is often used to assess the impact on climate variability, land degradation, ecosystem stability and diversity. Land use and land cover addresses where changes are likely to take place and at what rate are changes likely to progress (Veldkamp*et al*., 2001). Change detection using remote sensing and geographic information systems helps to assess landscape changes caused due to human activities. According to Lambin*et al.,* (2003) cropland as derived from remote sensing, has increased globally from 300–400 million ha in 1700 to 1500–1800 million ha in 1990, a 4.5 to fivefold increase and a 50% net increase just in the twentieth century. The area under pasture increased from around 500 million ha in 1700 to around 3100 million ha in 1990. These increases led to the clearing of forests and the transformation of natural grasslands. Forest area decreased from 5000–6200 million ha in 1700 to 4300–5300 million ha in 1990. Grasslands also declined from 3200 million ha in 1700 to 1800–2700 million ha in 1990. Pasture land has decreased in Eastern Africa and is attributed to an increase of cattle over this period, with an additional 872,000 head of cattle per year between 1992 and 1999,

Results by Brink*etal.,* (2009) in sub-Saharan Africa reveal that over the 25 year period (1975 and 2000) agricultural land has increased by 57% from just over 200 million hectares to nearly 340 million hectares. This increase has taken place at the expense of forests and natural non-forest vegetation, which have diminished respectively by 16 and 5%. The area of these classes lost equates to 71 million hectares (Mha) and nearly 60 Mha respectively. Barren areas have increased by 15% which amounts to 6.5 Mha. The annual change results show that on average sub-Saharan Africa has been gaining almost 5 Mha agricultural land every year, which means an average annual change rate of 2.3%. The yearly deforestation rate has been 0.7%, which means that the whole region has been losing nearly 3 million hectares of forests every year. The yearly deficit in non-forest natural vegetation has been 0.2%, which equates to more than 2 Mha lost every year. Barren areas are estimated to have increased by a yearly rate of 0.6%, which means over 0.26 Mha every year.

Land use and land cover change (LULCC) are important factors that can affect gully formation and development. Causes of gully formation are overgrazing due to high cattle population, expansion of cultivation in steeper or marginal land, cultivation without taking care of surplus runoff water and deforestation due to clearing of vegetation (Pathak *et al*., 2006). Gullies are very destructive and cannot be eliminated by tilling or ploughing because of their depth. Damages due to gully erosion include disconnection of roads and bridge breakage, recession of water table, immigration of people and movement of the location of villages (Shahrivar et al., 2012). Livestock and community members are falling inside the gully (Plate 1), flooding is affecting homes and the gully is cutting through homesteads making movement difficult in the Suswa catchment.

Studies have looked at the impact of gradual or sudden changes in land use and exploitation systems on the initiation and development of gullies. According to Murillo *et al.,* (2011)changes in land use can modify gully development leading to an increase in soil erosion or the reduction of the presence of gullies due to either their suppression by machinery or their colonization by vegetation. In a study by Wan *et al.,* (2007) in China, results showed that the ascending order of the runoff of five land use and land cover types was woodland, shrub, grassland, arable land and built-up land. The influence of land use and land cover change on runoff was therefore transforming other land use types into built-up areas. Hence, there is a correlation between different land covers and runoff. A study by Farhan*et al.,* (2014)in Jordan also showed that the average soil loss from mixed rainfed cultivation across the watershed is much higher when compared with forest area, and open rangeland, and bare soils. This study investigated land use and land cover change for the last 26 years in Suswa Catchment, Narok County using satellite images and implications for gully erosion.

2. Materials and Methods

The study was conducted in Suswa in Narok County (Fig 1) which lies between latitudes 0^0 50' and 2^0 05' South; and longitudes 35^0 58' and 36^0 0' East and covers an area of 15,087.8 km^2 (NEMA, 2009).Narokcounty has five agro-climatic zones namely humid, sub-humid, semi-humid to arid and semi-arid (NEMA, 2009). Two-thirds of the county is classified as semi-arid. The agro-ecological zones found in the sub-county include: Tropical Alpine (TA), Upper Highland zones (UH) Lower Highland zones (LH) and upper-midland zones (UM). According to NEMA (2009) the county has a population of about 460,793, with only about 11% residing in the urban areas. The population in the county ranges from 12 to 119 persons per km^2 (NEMA 2009). The county has diversified topography which ranges from a plateau with altitudes ranging from 1000 m-2350 m.a.s.l at the southern parts to mountainous landscape which is about 3098 m.a.s.l at the highest peak of Mau escarpment in the North (NEMA, 2009). According to NEMA (2009), the sub-county experiences bi-modal pattern of rainfall with long rains (mid March-June) and short rains (September-November). Rainfall distribution is uneven with high potential areas receiving the highest amount of rainfall ranging from 1200 mm-1800 mm p.a while the lower drier areas classified as semi-arid receiving 500 mm or less p.a. (NEMA, 2009).

The county serves an important ecological and economic role and supports wildlife, tourism, livestock, farming activities and human settlements (NEMA, 2009). The main soil types in the county include Andosols, Luvisols, Phaeozems, Vertisols and Acrisols. Areas with deep and well-drained soils include hilly and mountainous areas of Mau escarpment, Ngorengore, Shatuka, Suswa and Loita hills (NEMA, 2009).

The Suswa Catchment was chosen as the study site due to the impact of gully erosion on livelihoods. In addition, there is an on going collaborative project being carried out by KARI, Sustainable Land Management, GEF/UNDP, KEFRI, UON and JKUAT to rehabilitate the gully. The community requested that gully rehabilitation be a priority because it is threatening their livelihood. Furthermore, the road leading to Narok town is being affected by soil deposition from the gully.

2.1 Land use and land cover change analysis

Landsat images were used to classify land use and land cover changes for 1985, 2000 and 2011 and were classified using ENVI 4.7 software. The gully in the study area was not observed in the landsat imageries because of the scale. Images were classified into land use and land cover change using supervised classification and ground- truthing of the major land uses done within the study area. Land use and land cover change were analyzed on grasslands, forests, settlements, agricultural land and water bodies. Image selection was based on their availability and clarity with no cloud cover. Images were within the same season of the year, that is, January for 1985, 2000 and 2011. The interval for the selected images was 15 years where possible. Thematic change detection was established using ENVI Ex software. This was done by comparing 3 images of different times (1985-2000, 2000-2011 and 1985-2011) to show possible causes of gully development.

ENVI Ex software identified differences between images of different times (1985-2000, 2000-2011 and 1985-2011) with a resultant classification image and statistics. The area of land under different land uses and cover were used to calculate percentage changes in land use and land cover change using Excel software. The results were then analyzed using Chi-square test in order to determine if there were significant changes in land use and land cover changes (shrubland, grassland, bareland, agricultural land and settlement). Future projections of land use and cover change were established through linear regression analysis. The analysis was conducted using Microsoft excel. The three data points were plotted on a xy scatter plot. A trend line was then fitted displaying both the equation and R^2. Using this equation, estimates for 2021, 2031 and 2041 were conducted. These periods are ten year projections of land use and land cover change in Suswa Catchment from 2011 (the year of focus of this current study).These points were then plotted on the final graph. This resulted in a new equation and R^2.

3. Results

3.1 Land use and land cover changes between 1985 and 2011

Land use and land cover changes were observed on grasslands, shrubland, settlements, agricultural land and bareland as shown in the classified land use and land cover maps (Figures 2- 4). Land use and land cover change for 1985, 2000 and 2011 for Suswa Catchment were analyzed as shown in Table 1. Major changes in land use were observed in shrubland, settlements, bareland, grassland and agricultural land. Built up area (settlements) increased by 18.18% by 2000, and further increased by 42.86% by 2011. Built up area change (1985-2011) however increased by 68.83%. Shrubland decreased by 26.18% in 2000 and increased by 39.39% in 2011. Shrubland change (1985-2011) increased by 2.90%. Bareland increased by 928.10% in 2000 and increased by 405.69% in 2011. Bareland change (1985-2011) increased by 103.31%. Grassland increased by 13.32% by 2000 and decreased by 27.12% by 2011. Grassland change (1985-2011) decreased by 17.41%. Agricultural land increased by 1433% by the year 2000 and further increased by 51.08 % by the year 2011. Agricultural change (1985-2011) increased by 2216%. To determine whether the observed land use/land cover changes were significant, results of chi square goodness of fit test are shown in Table 2. There were no significant ($p < 0.05$) changes in built up areas, agricultural land, grassland, bareland and shrubland.

Future projections (2020) of land use and land cover change in Suswa Catchment are shown in Figure 5-9. Projections for land use and land cover trends were based on the assumption that there were no interventions and the status quo remained the same.From the projections (Figure 5), a significant increase in built up area will characterize the land use in the coming ten year period in the Suswa Catchment possibly due to increased settlement. Therefore there is a high association (97.3%) between built up areas and gully formation and development in the coming ten year period.Future projections (Figure 6), indicate that an increase in the area under agricultural land will occur in ten years in the Suswa Catchment probably due to increased cultivation. Therefore there is a high relationship (99.85%) between agriculture and gully formation in the next ten year period.From the projections (Figure 7), indicates no significant changes in shrubland in the coming ten year period in the Suswa Catchment, which probably indicates that exploitation may be minimal. Therefore there is a minimal association (0.004%) between shrubland and gully erosion risk in the coming ten year period. Future projections (Figure 8), indicate a significant increase in bareland which will be characterized in the coming ten year period in the study area probably due to increased soil erosion due to lack of vegetation cover. Therefore there is a minimal association (18.89%) between bareland and gully development in the next ten year period. From the projections (Figure 9) a significant decrease of grassland will characterize the land use in the coming ten year period in the Suswa Catchment possibly due to overgrazing. Therefore there is a high relationship (66.19%) between grassland and gully formation in the coming ten year period.

4. Discussion

Satellite image analysis showed that land use and land cover changes have occurred in the area between 1985 and 2011. Between 1985 and 2000, built up area, bareland, grassland and agricultural land continued to expand, while shrubland decreased. Shrubland was therefore converted to built up area, bareland, grassland and agricultural land. Between 2000 and 2011, built up area, shrubland, bareland continued to expand, while grassland decreased. Grassland was therefore converted to built up area, bareland and agricultural land. Although built up areas, agricultural land, bareland, grassland and shrubland did not change significantly for the period under investigation, it was observed that the overall change of built up area, shrubland, bareland, agricultural land expanded between 1985 and 2011, while grassland decreased during this period. Grassland was therefore converted to built up area, shrubland, bareland and agricultural land during this period. An increase in built up area, bareland and agricultural land and a decrease in grassland are probable drivers of gully erosion. An increase in built up area results in a decrease in grassland. In a Participatory Geographic Information Systems (PGIS) study in the area (by this author) it was observed that between 1985 and 2011 (26 years), there was an overall increase in built up area and bareland and decrease in shrubland and grassland in the 4 villages (Olepolos, Enkiloriti, Eluai and Olesharo). Therefore remote sensing and PGIS analysis both showed that a decrease in grassland was a driver of gully erosion in the study area. Although there was an overall increase in shrubland (an increase by 39.39% in 2011), due to invasion by invasive species due to soil deposition as was observed in the field. Invasive species were observed in areas of soil deposition which had very little grass and shrubs. Checheet *et al.,* (2015) in Narok observed similar results to this study in that, about 30% of the encountered species were exotic species that might have been introduced in the rangelands by human activities. Exotic species were common in degraded areas with less than 40% vegetation cover.Invasive alien plant species affect grasslands by lowering yield and quality of forage, further leading to soil degradation.

Literature reveals increases in gully erosion as a consequence of land use and land cover changes. Agricultural practices can accelerate erosion through soil compaction, reducing water holding capacity and increasing soil erodibility (Van-Camp *et al*., 2004). Agricultural practices without adequate conservation measures such as in the case of Suswa area can be directly linked to greater water erosion. Cultivation exposes bare soil to rain, which could be the case in the study area. Overgrazing is one of the main drivers of gully erosion in rangelands, such as the Suswa Catchment. According to Veblen*et al.,* (2014) livestock grazing reduces pasture and shrubs hence, affecting rangeland health. Poor rangeland health could be due to historic grazing intensity which is the case in the Suswa area. In the study area grassland decreased by 17.41% between 1985 and 2011 indicating poor rangeland health. Land-use and land cover change is associated with a series of transitions, which reinforce each other. According to Lambin et *al.,* (2003) transitions in land use/cover must be viewed as multiple and reversible dynamics. Transitions can also be viewed as possible development paths where the direction, size, and speed can be influenced. Historical land use and land cover changes therefore may have significant impact on erosion, which could be the case in the study area.

Similar results to this study were observed by Duvert*et al*., (2010) in the Mexican Central Highlands, indicating that traditional cropping practices with cattle grazing leads to severe soil degradation in the Cointzio basin. Therefore the formation of gullies in Huertitas and Potrerillos was triggered by these practices, which could be the case in Suswa Catchment. Okoti*et al,* (2006) observed a similar relationship in Marsabit district, where there is an increase in gully erosion, especially near settlement areas due to animal trampling and cutting of vegetation. As a result eroded places hardly support any vegetation. Observations by Yannelli*et al*., (2013) in Argentina showed that grazed fields and abandoned crop fields were much more susceptible to potential gully erosion. Results by Wessels*et a*l., (2007) in South Africa showed that long-term heavy grazing was the cause of range degradation. Vagen*et al*., (2013) in Ethiopia observed that soil erosion was due to overgrazing further exposing the soils. Leh*et al.,* (2011) in Arkansas showed that increased erosion risk in barren areas was not surprising because larger barren coverage meant larger areas without protective soil cover and therefore increased the risk of soil erosion. Results by Tesfahunegn*et al*., (2014) observed similar relationships in the Northern Ethiopia catchment, indicating that the highest rates of soil detachment occurred in marginal lands, and subsoil exposed soils having low soil resistance to detaching forces.

Sakthivel*et al.,* (2011) in India observed high soil erosion hazard zones being found in areas with human habitation where agricultural activities are practiced. Also, high soil erosion prone areas were found at Pattimedu, Jadayagaundan (Southern portion), Kanai and Puttai reserved forests (Eastern portion) and this was attributed to deforestation and human interferences. In the study area built up area 1985-2011) increased by 68.83% between1985-2011 indicating human interferences. Observations by Sulieman*et al.,* (2013) in Eastern Sudan, showed that natural vegetation has been reduced from 26.1% in 1979 to 12.6% in 1999 and further to 9.4% in 2007. The majority of this reduction went into agricultural land. This reduction has exposed the soil surface to accelerated water erosion. The decrease or disappearance of certain plant species and reduced vegetation cover has increased the exposure of soil surfaces to wind and water erosion, which is the case in the study area.

Klaus *et al.,* (2014) in Morocco reported that agricultural practice influenced runoff within the catchment. Agricultural practices therefore lead to accumulation and concentration of runoff which is the case in the study area. Agriculture increased by 2216% between 1985 and 2011 in Suswa. Casasnovas*et al.,* (2009) in Spain showed that agriculture caused an increase in soil loss. Casasnovas et *al.,* (2000) in Spain also showed that the main cause of soil erosion is the uncontrolled transformation of old vineyard plantations through mechanisation. The resulting soils from land transformation are therefore highly susceptible to erosion, which reduces the possibilities of water intake and most of the rain is lost as runoff. Land transformations through the use of farm machines in Suswa catchment could therefore be a probable cause of gully erosion. Xiubin*et al.,* (2004) in the Chinese Loess Plateau also observed that deforestation and cultivation exposed the fragile soil to water erosion. Xin*et al., (*2010) in the Chinese Loess Plateau indicated that there was a critical threshold in the relationship among sediment yield and vegetation cover. Therefore vegetation cover may provide the thresholds required for runoff and soil erosion, which is the case in the Suswa Catchment.Katsurada (2007) in Kendu escarpment, Nyanza province observed a similar relationship with areas with scarce vegetation and steep slope and sedimentation causing rapid runoff and severe gully erosion.

Results Omuto*et al*., (2011) in Somalia, showed that about one-third of the country was degraded because of the loss of vegetation cover, topsoil loss and decline of soil moisture. Overgrazing, excessive cutting of trees, and poor agronomic practices in agricultural areas were the primary drivers of land degradation. Maeda *et al., (*2010) in Taita Hills indicated that if current trends persist, it is expected that agricultural areas will occupy 60% of the study area by 2030, similar to Suswa. These changes will result in accelerated soil erosion. In addition, agricultural expansion will inevitably result in increased soil erosion due to changes in vegetation cover which is the case in the study area. From the projections a significant increase in built up area, agriculture and bareland and a decrease of grassland will characterize the coming ten year period (2020) in the Suswa Catchment.

Liavoga*et al.,* (2014) Yattasub county observed that there was a decline in the area under traditional crops and an increase in introduced crops mainly maize and beans. Results also showed an increase in bare land and a decrease in shrubland. In the study area, bareland increased by 103.31% between 1985 and 2011 also. According to Liavoga et al (2014), the observed trends have implications for food security and dwindling land resources, which could be the case in the study area. Campbell *et al*., (2005) in Loitokitok, Kajiado District, observed that rain fed agriculture and livestock herding were the main causes of land use and land cover change in the area. As a result the ability of the Maasai herders to maintain their long-established livestock system has been curtailed and many now combine livestock and cropping. Ayuyo*et al*., (2014) showed that changes in land use and land cover had occurred in the Mau forest complex, resulting in the reduction of forest cover. This is because the local community depend on forest products for farming, building materials, wood fuel, and charcoal burning which could be the case in the study area. Njoka*et al*., (2003) in Lambwe Valley, southwestern Kenya observed that human settlement caused land-use and cover changes, resulting in a scramble for the remaining high potential land, which could be the case in the study area. Mundia*et al*., (2009) in the Masai Mara Ecosystem, showed that agricultural expansion and an increase in cattle and sheep lead to diminishing pastures.

Similar observations to this study were made by Nyariki*et al*., (2009) in the Masai-Mara Ecosystem, in which patterns of land-use have changed from nomadic pastoralism to sedentary pastoralism, agropastoralism, and in some cases pure cultivation. These trends have adversely affected livestock production and diminished grazing areas. According to Maitima*et al*., (2009) land use changes in East Africa have transformed land cover to farmlands, grazing lands, human settlements and urban centres at the expense of natural vegetation. These changes are associated with deforestation and land degradation. Similar results to this study were observed by Gachene, *et al.,* (2015) in Lower Tana River Forest Complex in which forest cover decreased from about 7185.52 km^2 in 1995 to 1852.6 km^2 in 2004, a 74.2 per cent loss. The area under agriculture increased considerably by almost ten times, from 243.87 km^2 in 1995 to 2346.65 km^2 ha in 2004, a 862.25% gain. This means that most of the area previously under forest was lost to cultivation. Opening the forest for cultivation and degradation is still continuing at an alarming rate, which is also the case in the study area. In Suswa, shrubland decreased by 26.18% in 2000 indicating a change to other land uses.

From the projections a significant increase in built up area, agriculture and bareland and a decrease of grassland will characterize the coming ten year period in the Suswa Catchment. This scenario is likely to lead to further gully erosion activity as more areas will be opened up for agriculture and settlement. With no interventions, gully erosion activity will continue resulting in a threat to livelihoods in terms of agriculture and livestock grazing. Scenarios of land-use and land cover change therefore help to explore possible futures and can generate indicators of ecological sustainability or of vulnerability of ecosystems and people. Projections can be used as an early warning system for the effects of future land use changes and pin-point hot-spots that are priority areas for in depth analysis (Verburg, 2006).

5. Conclusions and Recommendations

From this study it was observed that the overall change of built up area, shrubland, bareland, agriculture expanded in 26 years (1985-2011), while grassland decreased during this time period. Grassland was converted to built up area, shrubland, bareland and agriculture during this time period. An increase in built up area, bareland and agriculture and a decrease in grassland are therefore likely to be driversof gully erosion which is affecting the area. From the projections, a significant increase in built up area, agriculture and bareland and a decrease of grassland will characterize the coming ten year period (2020) in the Suswa Catchment. If the present scenario continues, then gully erosion activity will continue. Therefore there is a need for comprehensive land use planning in Suswa Catchment for effective rehabilitation of the gully and also reduce threats to livelihoods. Monitoring of actual soil erosion should be done under different land uses systems in the study area in order to determine hot spots for effective land use strategies. An assessment of invasive alien plant species and their impacts on soil degradation should also be done.

Plate 1: Gully in Suswa Catchment

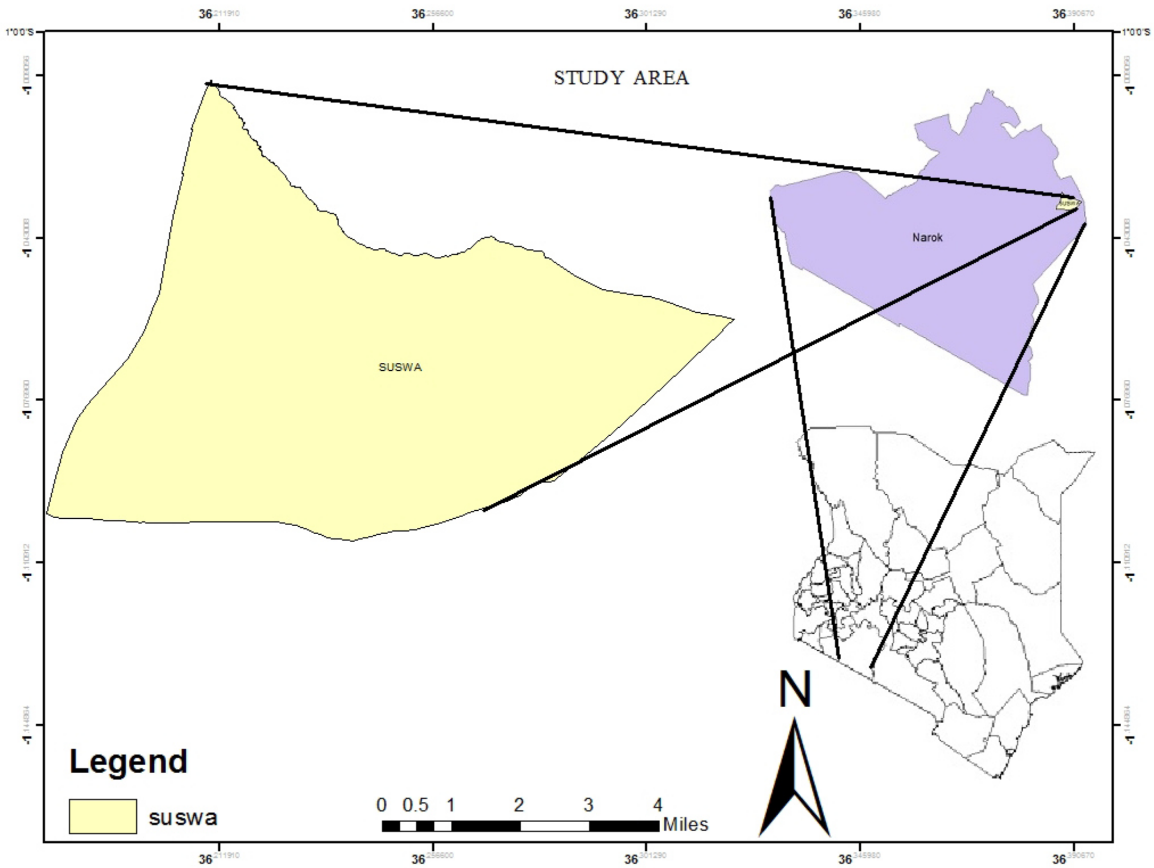

Fig 1: Map showing Suswa, Narok County

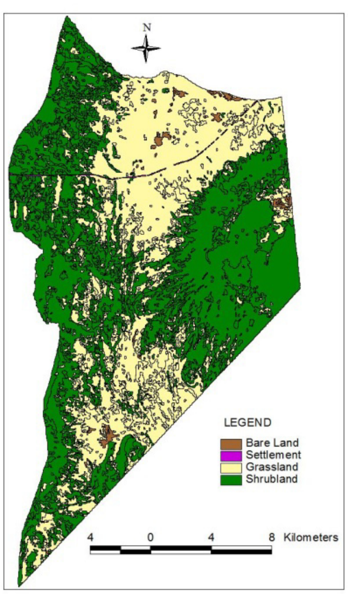

Fig 2: Land use and land cover change (1985)

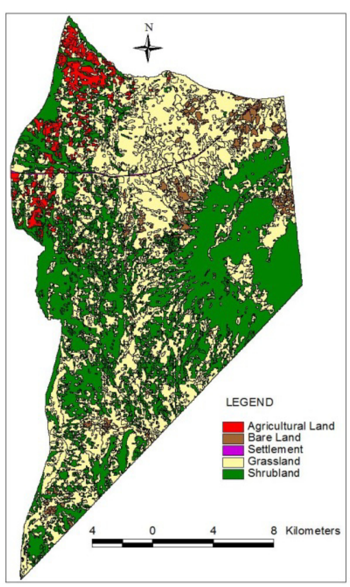

Fig 3: Land use and land cover change (2000)

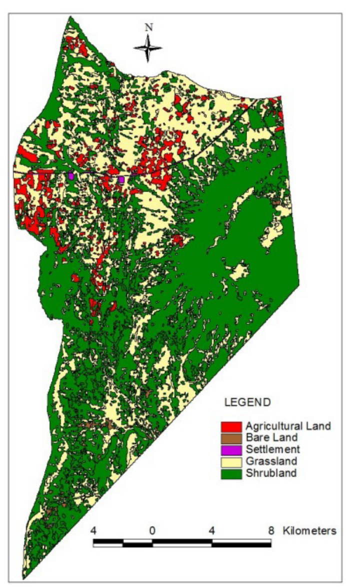

Fig 4: Land use and land cover change (2011)

Table 1:Land use/cover change in Suswa Catchment (1985-2011)

Landuse /cover	1985 Area (km^2)	%	2000 Area (km^2)	%	2011 Area (km^2)	%	Change 1985-2000
Built up Area	0.77	0.19	0.91	0.24	1.30	0.32	+18.1
Agricultural	1.00	0.24	15.33	3.81	23.16	5.67	+1433
Shrubland	231.11	57.43	170.61	42.42	237.8	59.12	-26.18
Bareland	1.21	0.30	12.44	3.11	2.46	0.61	+928
Grassland	166.71	41.45	188.92	46.97	137.6	34.23	+13.3

Table 2:Chi-Square goodness of fit test for land use/cover changes in Suswa Catchment between 1985 and 2011

Landuse /cover	1985 %	2000 %	2011 %	Chi-square test x^2	df	p
Built up Area	0.19	0.24	0.32	0.0	2	1.0
Agricultural	0.24	3.81	5.76	3.455	2	0.178
Shrubland	57.43	42.42	59.12	3.278	2	0.194
Bareland	0.30	3.11	0.61	3.0	2	0.223
Grassland	41.45	46.97	34.23	2.082	2	0.353

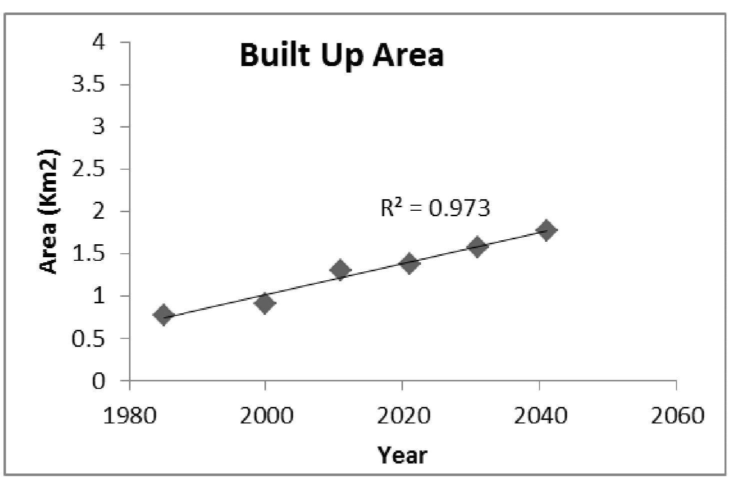

Fig 5: Ten year projections (2020) of built up area change in Suswa Catchment

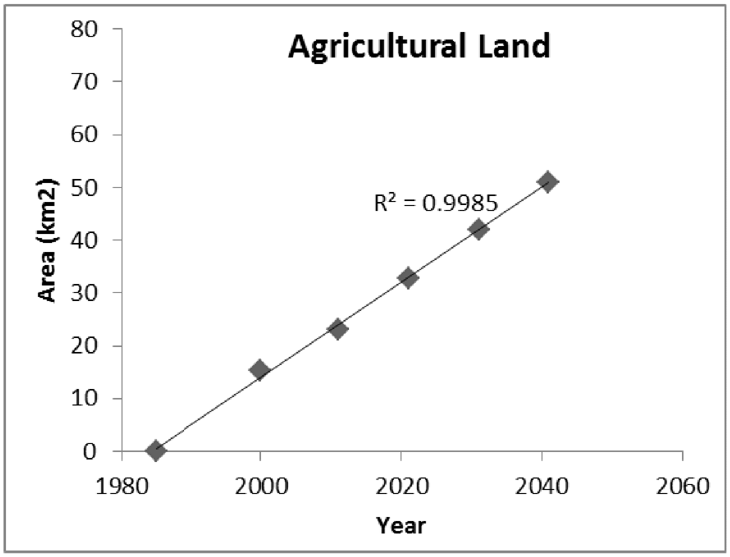

Figure 6: Ten year projections (2020) of agricultural change in Suswa Catchment

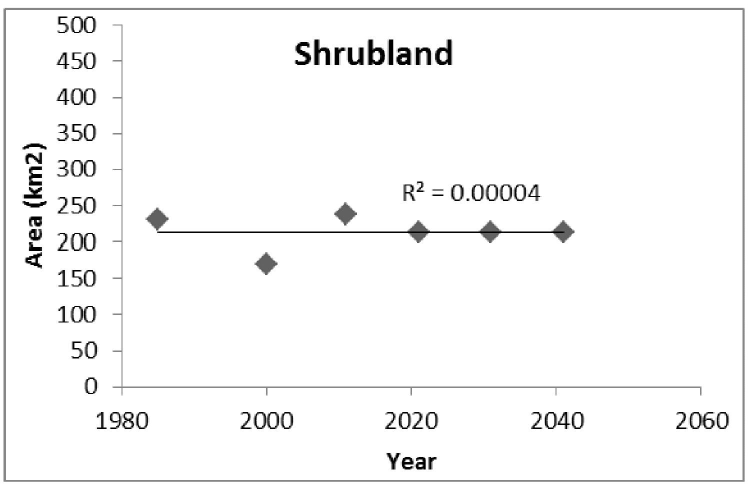

Figure 7: Ten year projections (2020) of shrubland change in Suswa Catchment

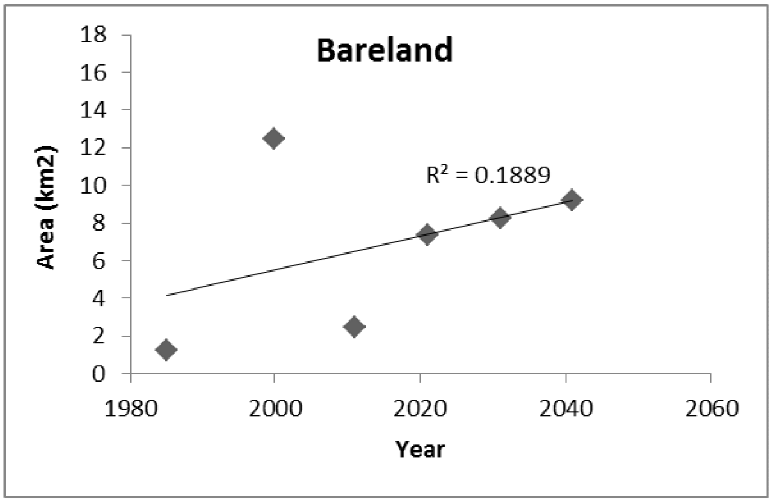

Figure 8: Ten year projections (2020) of bareland change in Suswa Catchment

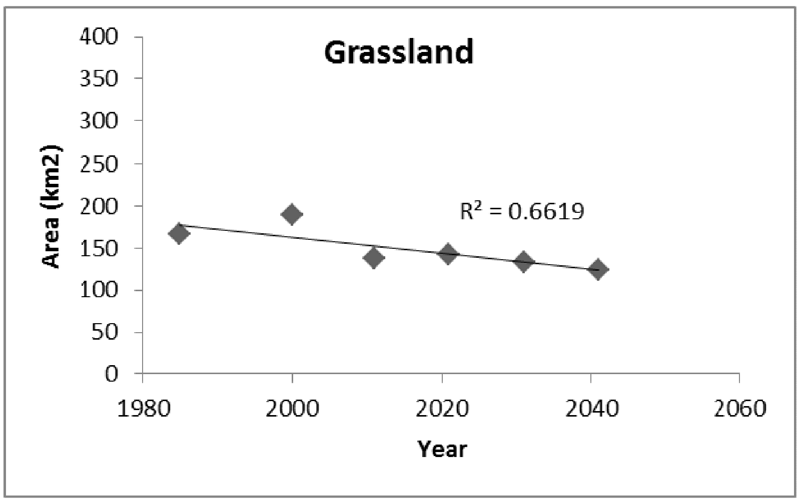

Figure 9: Ten year projections (2020) of grassland change in Suswa Catchment

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