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APPLICATION OF REMOTE SENSING AND GIS FOR ASSESSING LAND COVER RESOURCES VARIABILITY IN THE SELOUS GAME RESERVE, TANZANIA

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Abstract

Purpose*:* The study was conducted in Selous Game Reserve, with intention of developing GIS and Remote Sensing based wildlife management system in the protected area.

Methodology*:* All habitats were digitised using ArcGIS9.3 in which five scenes of Landsat TM and ETM+ digital images were acquired during dry seasons of the year 2000 and 2010. Band 3 and 4 of the Landsat images were used for calculation of normalized difference vegetation index (NDVI) for determination of vegetation spatial distribution

Results*:* The NDVI maps of year 2000 to 2010 revealed the vegetation density depletion from 0.72 (obtained in 0.46─0.72 value interval and covering 46.5% pixel area) in 2000 as compared to 0.56 (found in 0.38─0.56 value interval and covering 8.04% pixel area) in 2010 NDVI maps.

Unique contribution to theory, practice and policy: It was recommended that there was a necessity to integrate applications of remote sensing and GIS techniques for the assessment and monitoring of the natural land cover variability to detect fragmentation and loss of wildlife species.

Keywords: *GIS, Remote Sensing, land cover, wildlife management system*

1.0 INTRODUCTION

1.1 Background of the Study

Global research on biodiversity has noted an increase in the magnitude and spatial changes in land use land change (LULCC) of global biophysical resources due to increasing demands from humans (Meyer & Turner 1994). Continuous pressure and unsustainable utilization of biophysical resources to acquire life-sustaining needs has resulted in increasing and considerable impact on the Earth's ecosystem functions (Lambin *et al*., 2001). However, drivers of LULCC vary across the local, regional and global scale (Ramankutty & Foley 1999), but the ultimate implication for these rapid LULCC changes has significant impact across all three scales. For example the consequences of LULCC changes includes global climate change (World Bank, 2008), natural resources depletion, species loss, habitat encroachment around protected areas buffer zones (Kintz *et al.,* 2006). Ecologically, Selous Game Reserve forms a continuous ecosystem by connecting Niassa protected area (42,000 km^2) in Mozambique, Mikumi, Udzungwa mountains National parks and community managed conserved areas with an estimated area of more than 154,000 km^2) (Baldus *et al.,* 2003). The Selous Game Reserve (SGR) is dominated by miombo woodlands which vary in their density depending on soil, topographic characteristics and other associated human activities (Caro *et al.*, 2009).

The rapid acceptance of the use of remote sensing for conservation and nature protection coincides with frequent reporting of wide spread modification of natural systems and destruction of wildlife habitats during the past three to four decades. Concerns about the increase in adverse environmental conditions prompted the remote sensing experts and users to quickly catch up with the evolving technology. The parallel advance in the reliability of Geographic Information System (GIS) has allowed the processing of the large quantity of data gene rated through remote sensing (Muzein, 2006).

According to Salem, (2003) geographic information system (GIS) is an important tool for monitoring biodiversity is a, which accommodates large varieties of spatial and a spatial (attribute) data. The information embedded in a GIS is used to target surveys and monitoring schemes. Data on species and habitat distribution from different dates allow monitoring of the location and the extent of change. Conservation (Sigh, 2015) is considered to be "maintaining of nature as it is, or might have been before the intervention of either human beings or natural forces." Natural resources including wild animals and their environment are getting depleted and environmental problems are increasing. It is, thus, necessary to conserve and protect our environment, therefore, applications of geospatial technology today is inevitable as a more comprehensive tool for assessing, managing, protecting and measuring wildlife resources variability.

Tanzania is blessed with diverse natural resources and thriving wildlife including large mammals, but no longer roam the entire landscape freely, and their populations are no longer completely governed by the laws of nature. Economic growth, modernization, and human population expansion has resulted in conversion of natural communities and habitats to other uses for meeting national and world demands of goods and services while ensuring sustainability of natural resources has become increasingly complex (Mark *et al., 2010*). Vegetation indices offer ideal measures of amounts of vegetation and variations in vegetation distribution, both over space and time. The established relationship between vegetation indices and biomass forms the basis of land cover analyses, which rely on vegetation indices to provide a continuous representation of land cover.

Identification of species` potential habitats, distributions and variability over time is of great importance as far as sustainable utilization of natural land cover resources are concerned. Inadequacy of aerial survey method used in assessing the natural resource variability, wildlife migration pattern and the underlying causes in Wildlife Division has led to the following problems: low or no inventory of vegetation health variability and detected habitat changes over time scale in the protected areas. Natural resource inventories have historically been conducted through field survey a time-consuming and expensive, particularly when study sites are large and/or remote, and when long-term monitoring is a concern to resource managers (Rogan *et al*., 2004). Integrated Remote Sensing and GIS in spatial and temporal data collection for protected areas ecosystem monitoring and sustainable use decisions are vital for mapping, clarifying and modeling species migration; as well as provision of information needed for scientifically valid ecological mapping and monitoring needs (McDermid *et al*., 2005).

Measuring or monitoring habitat quality requires complex integration of many properties of the ecosystem, where traditional terrestrial data collection methods have proven extremely time-demanding. Remote sensing has known potential to map various ecosystem properties, also allowing rigorous checking of accuracy and supporting standardized processing (Zlinszky *et al*., 2015). Remote Sensing and Geographical Information Systems (GIS) can deliver area-covering information on variables influencing habitat quality, but also allow optimization of fieldwork by detection of change and pre-selecting sites of interest. Furthermore, by standardizing the interpretation of digital remote sensing data, quantitative habitat parameters can be determined more reliably than in the field, and subjectivity can be reduced substantially (Zlinszky *et al*., 2015).

Identification of species' potential habitats, distributions and variability over time is of great importance as far as sustainable utilization of natural land cover resources are concerned (Rogan *et al*., 2004). Lack of effective and sustainable measures to utilize forest resources in villages and general land has resulted in deforestation and degradation in the study area (Nyanda, 2015). Land cover changes and degradation is still a challenge facing natural resources management in Selous Game Reserve and other places in Tanzania. Thus, assessment of land cover for a specified period of time is very crucial in monitoring, conservation management, understanding the status of LULC and the main drivers for changes of natural resources (Fisher, 2011). Few studies have documented information of land cover and its implication on biodiversity in the study area. Some researches for example, (Nyanda, 2015) which, have studied LULC in relation to Selous Game Reserve have however, focused on the drivers of land cover change in the adjacent villages surrounding the study area. This study therefore, intended to fill a research gap which seemed not to be addressed by other scholars, who previously conducted their studies in the study area, as they have not paid attention in documenting land cover changes (i.e. pattern of land cover resources variation) using the normalized difference vegetation index (NDVI).

1.2 Research Objectives

To determine land cover resources variation pattern

To evaluate the impact of land cover resources variation to wildlife resource distribution and abundance

20 RESEARCH METHODOLOGY

2.1 The Study Area

Selous Game Reserve lies in central south-eastern Tanzania between 130 and 500 km southwest of Dar-es-Salaam at 7° 20' to 10° 30'S, and 36° 00' to 38° 40'E. Selous contains a third of the wildlife estate of Tanzania. Large numbers of elephants, buffaloes, giraffes, hippopotamuses, ungulates and crocodiles live in this immense sanctuary which measures almost 50,000 square kilometres and is relatively undisturbed by humans (UNEP & WCMC, 2013). The Reserve has a wide variety of vegetation zones, from forests and dense thickets to open wooded grasslands and riverine swamps. The study area has an altitude from 80m in the north-east to 1,300m in the south-west (Mbarika Mountains) (UNEP & WCMC, 2013)

The centre of the Reserve is a flat to rolling landscape with alluvial valleys and protruding inselbergs largely underlain by the Karoo sandstone and metamorphosed upper PreCambrian schists and gneisses with granite outcrops. It is covered by thickets and closed woodland; the south is hilly, rugged and forested (Stephenson, 1990). Large part of the Reserve is drained by the Rufiji River, the largest river in east Africa, which, with its tributary the Ruaha, drains most of south-central Tanzania and is formed where the Ruaha and Luwegu Rivers join above the Shughuli Falls. Tributaries in the southwest include the Kilombero, Luhombero, Mbarang'andu and Njenje Rivers which are the main permanent streams. Below the Rufiji-Ruaha confluence there is a stretch of lakes and swamps (UNEP & WCMC, 2013). The southeast border is drained by the Matandu River, the northern border by the Mgeta (Figure 1).

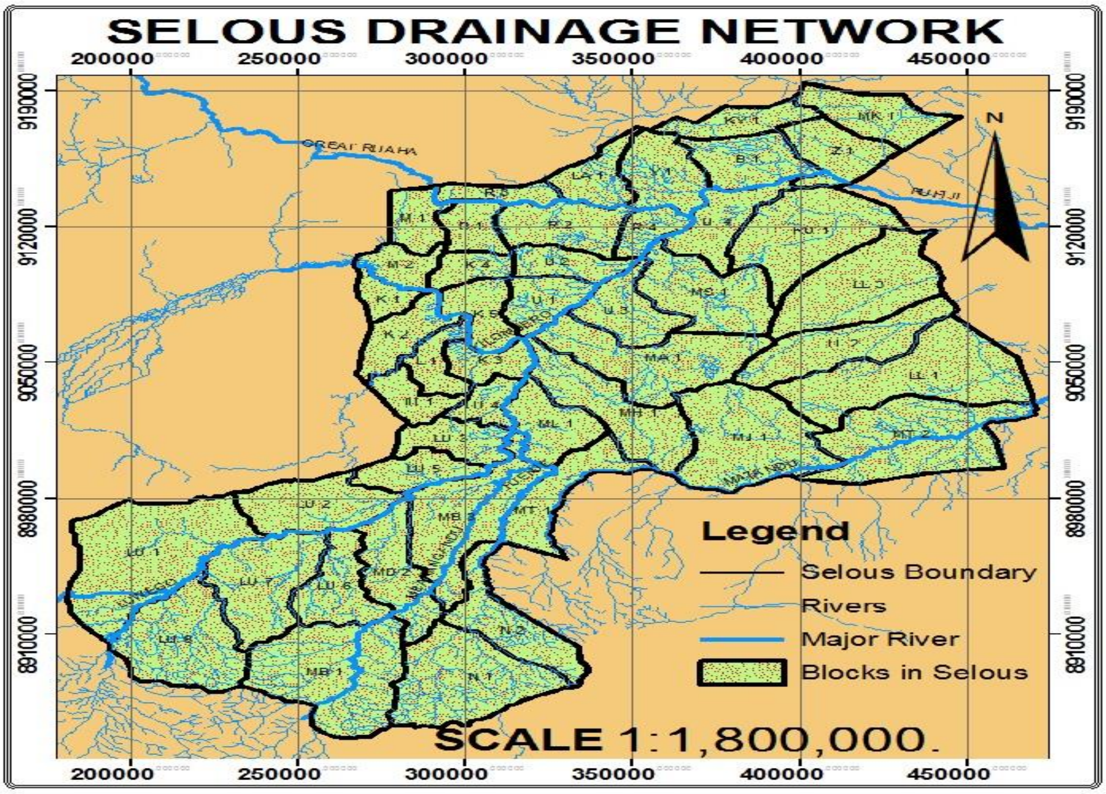

Figure 1: Drainage System of Selous GR: Source Base Map

Source: MNRT (2010)

2.2 Types of Data Used

Several datasets were essential for this research; these included the topographic map covering the study area at a scale of 1: 450,000 obtained from the Ministry of Natural Resource and Tourism, Division of Wildlife. The features were digitised from the topographic map using ArcGIS9.3. The Landsat TM and ETM+ images were acquired from Glovis and Earth Explore websites. Five Landsat satellite path-rows (167-65, 167-66, 167-65, 166-65 and 166-66) were necessary to cover areas of Selous Game Reserve and its adjacent ecosystem. Landsat images used during the study are indicated in Table 1. These image scenes were joined (mosaic) and then reprojected band-wise using ERDAS IMAGINE prior to classification. Band 3 and 4 of the joined images of the same period were used for calculation of normalized difference vegetation index (NDVI) (Figure 2 & 3) using ILWIS for determination of vegetation densities and their consequence variation over time interval. Reprojection involved transforming and rectifying the image to a standard Universal Transverse Mercator (UTM) projection system. Reprojection (USGS, 2013) allows the determination of geographic coordinates for features identified in the analysis and facilitates integration with other geographic data sets.

Table 1: Landsat Images Used in this Study

Sensor name	File name	Acquisition date	Cloud Cover	Path/Row
ETM+	LE7167065200182EDC00	18-2-2000	<10%	166/065
TM	L5166065_06520110707	07-07-2011	<10%	166/065
TM	p166r066_7t20000630_z37	06-30-2000	<10%	166/066
TM	L5166066_06620100517	05-17-2010	<10%	166/066
ETM+	L71167065_06520000707	07-07-2000	<10%	167/065
ETM+	L71167065_06520110706	07-06-2011	<10%	167/065
ETM+	L71167066_06620020510	05-10-2002	<10%	167/066
ETM+	L71167066_06620110722	07-22-2011	<10%	167/066
TM	p167r067_7k20000707_z37	07-07-2000	<10%	167/067
TM	L5167067_06720100711	07-11-2010	<10%	167/067

The Digital Elevation Model of 90m resolution obtained from the Shuttle Radar Topographic Mission (SRTM). Altitude of the landforms of the study area as depicted by the Digital elevation model (DEM) map, classified land cover images of 2000 and the datasets used in the study were composed of 20 images acquired during 2000 and 2010. Satellite data in digital form were utilized for analysis to characterize the land cover (classification), and NDVI calculation. Mapping of different landform features (habitats) were possibly through the use of base and Digital Elevation Model (DEM). Interactive digital analysis procedure and operational software used included but not limited to the following: ERDAS IMAGINE 9.1, ILWIS 3.6, ArcGIS 9.3 and Arc SWAT, Microsoft Excel and Microsoft Word.

2.3 Digital Images Processing

More than twenty digital images of the Landsat TM and ETM+ were acquired for this study but only those with cloud cover less than 30% were utilized. Since Selous Game Reserve, comprises of five Landsat image scenes for its entire coverage, a total of ten images were used, five of which were for 2000 and the other five were of 2010. The procedures adopted for digital image processing, classification, calculating NDVI and topographic feature mapping in this study are detailed in the following sub sections.

2.4 Merging Data Bands into a Single File and Projecting

Digital image composed eight bands; each composed of different radiance characteristics of the reflecting surfaces. Band 1 to 5 and 7 were used for land cover properties while band 6L and 6H (not used in this study) are used for temperature (thermal) of the geological nature. The classification of land cover features required combining together band 1 to 5 and 7 (Figure 2) ready for classification and were the layout of the procedures followed in ERADS IMAGINE 9.1.

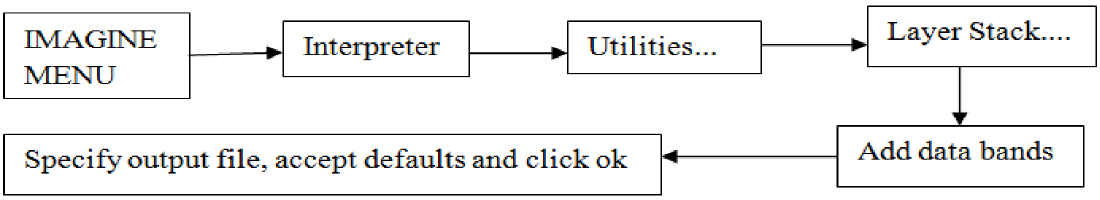

Figure 2: Image layer stacking using ERDAS 9.1

After the bands were stacked together, the reprojection was conducted under data preparation in the ERDAS main menu so as to give the stacked image its actual projection. The stacked and reprojected adjacent image scenes were then joined.

2.5 Satellite Image Classification

Stacked, reprojected and joined adjacent scene image important for the coverage of all areas of Selous Game Reserve, were necessary for classification process undertaken so as to classify different land cover features. These classified habitats provided information of the land cover classes present in the study area, which are the basic need of the wildlife species found in that location. The steps in Figure 3 were involved for digital image classification process using ERDAS Imagine 9.1.

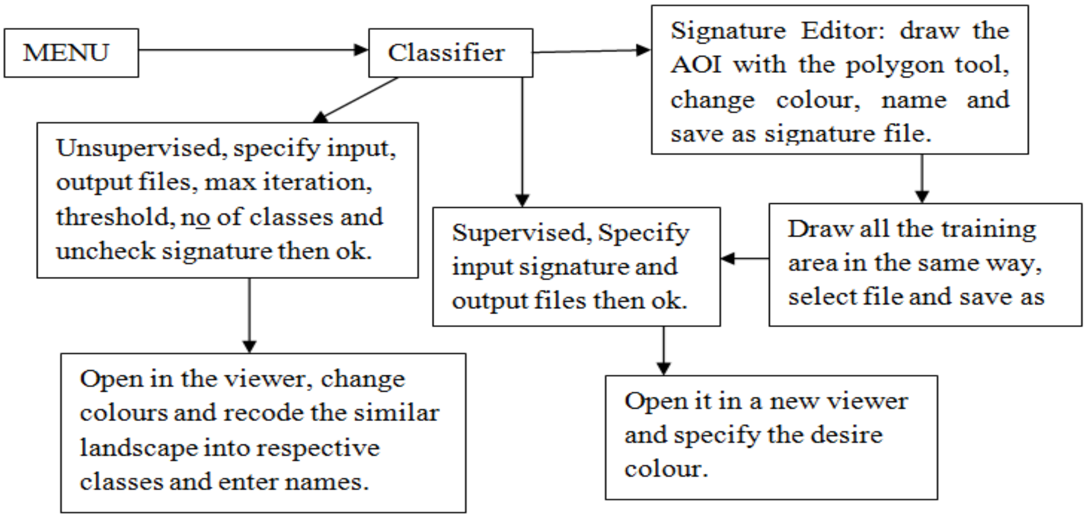

Figure 3: Image Classification Procedures Using ERDAS IMAGINE 9.1

2.6 Calculating NDVI

Vlek *et al*. (2008) revealed that land degradation should be reflected in the productivity of the land and thus in its vegetation. The most common Remote Sensing derive indicator associated with vegetation productivity is the Normalized Difference Vegetation Index (NDVI). The NDVI is successful in predicting photosynthetic activity (Govaerts & Verhulst, 2010), because this vegetation index includes both near infrared and red light. Plant photosynthetic activity is determined by chlorophyll content and activity. Justice *et al*. (1991) further reported that Satellite-based NDVI are influenced by a number of non-vegetation factors: atmospheric conditions (e.g. clouds and atmospheric path-specific variables, aerosols, water vapor), satellite geometry and calibration (view and solar angles), as well as soil backgrounds and crop canopy.

The Normalized Difference Vegetation Index (NDVI) utilizes the combination of red (Band 3) and near-infrared (NIR) (Band 4) wavelengths. The NDVI is calculated as: NDVI = (NIR Band4 – RED Band3) / (NIR Band4+ RED Band3). NDVI ranges from −1.0 to 1.0, with higher index values being associated with higher levels of healthy vegetation cover, while index values near zero can be due to clouds and snow reflecting less green vegetation. The NDVI function in Map Calculation was used in the calculation of the NDVI. In addition to calculated NDVI map, ILWIS generated histogram, which shows graphical display of the histogram as well as a numerical display of the histogram.

2.7 Preparation of a Topographic Map

In the ArcMap feature’s boundaries were demarcated by on-screen digitization of the base map and when the digitization of the maps were ready the frame, legend, title, scale, grid reference and north direction were added and then exported and saved ready for use. Furthermore, classified digital image and NDVI map were also added into the arc map for finalizing the analysis process. Different maps including drainage network map were prepared in ArcGIS 9.3 from on-screen digitization of added and geo-referenced scanned base map. Map shape file were prepared in ArcCatalog, projected at Arc 1960 UTM Zone 37S projection and all were added to ArcMap ready for digitization process. Moreover, the

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DEM was processed in the embedded ArcSWAT and the in-built of 3D Analyst of Extension in the ArcGIS 9.3 in order to produce the topography map.

3.0 RESULTS

The results presented include; altitude of the landforms of the study area as depicted by the Digital elevation model (DEM) map, classified land cover images of 2000 and land cover resources variation pattern represented by the NDVI maps**.**

3.1 Topography/Landforms

The digital elevation model (DEM) map representing the topographical features (landforms) as well as the drainage network and elevations of different animal habitats of the Selous Game Reserve revealed that the study area has an altitude ranging from 0m to 2600m (Figure 4).

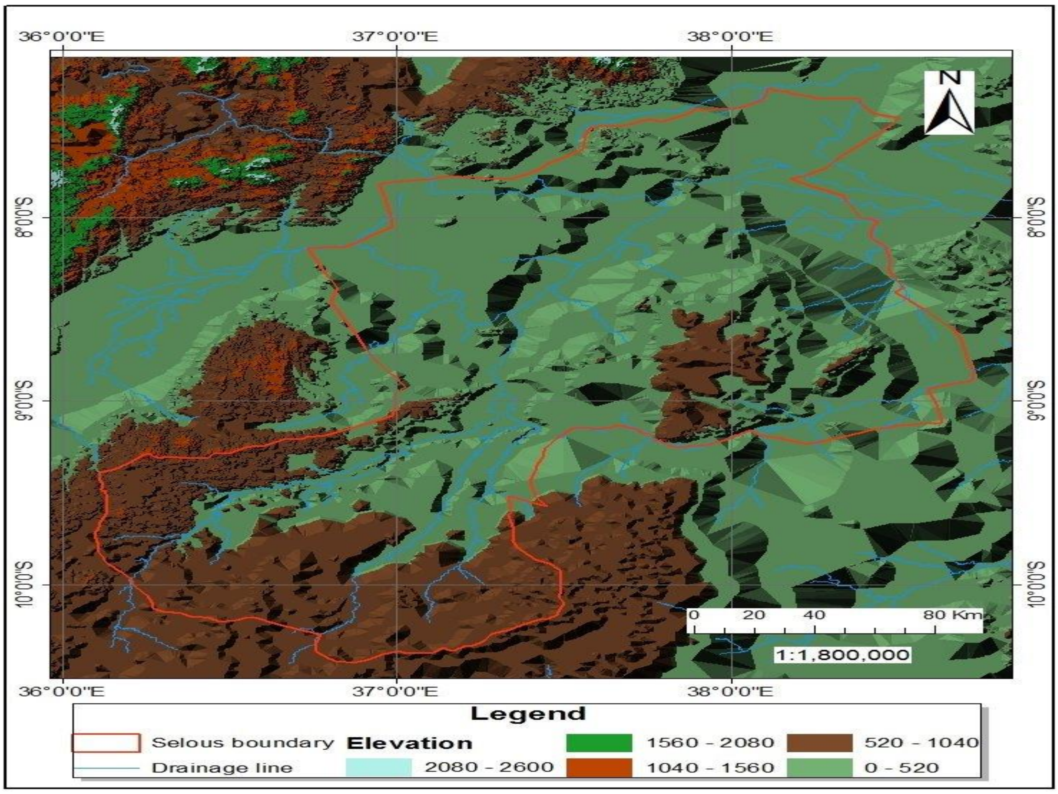

Figure 4: The Topological features (Landforms) of Selous Game Reserve

3.2 Land Cover Classification

Based on the unsupervised classification of satellite image, the following four major classes of landscape elements were identified as forests, woodland (open, closed wooded land, thickets, swampy, dry and scattered tree grassland), water (flooded plains, ponds and wetlands), and bare soil or rocks (Figure 5). All these landscape elements are spatially well distributed in the Game Reserve. Most of the evergreen forest lies in the northwest joining Udzungwa and Mikumi National Parks, southwest towards Kilombero valley and at centre to the east. The central part and far south of the reserve are dominated by the mixed type of open woodland and scattered tree grassland. The west towards northeast is the lowland of

Kilombero joining Rufiji valley subjugated by open woodland, swamp, riverine forest to dense woodland.

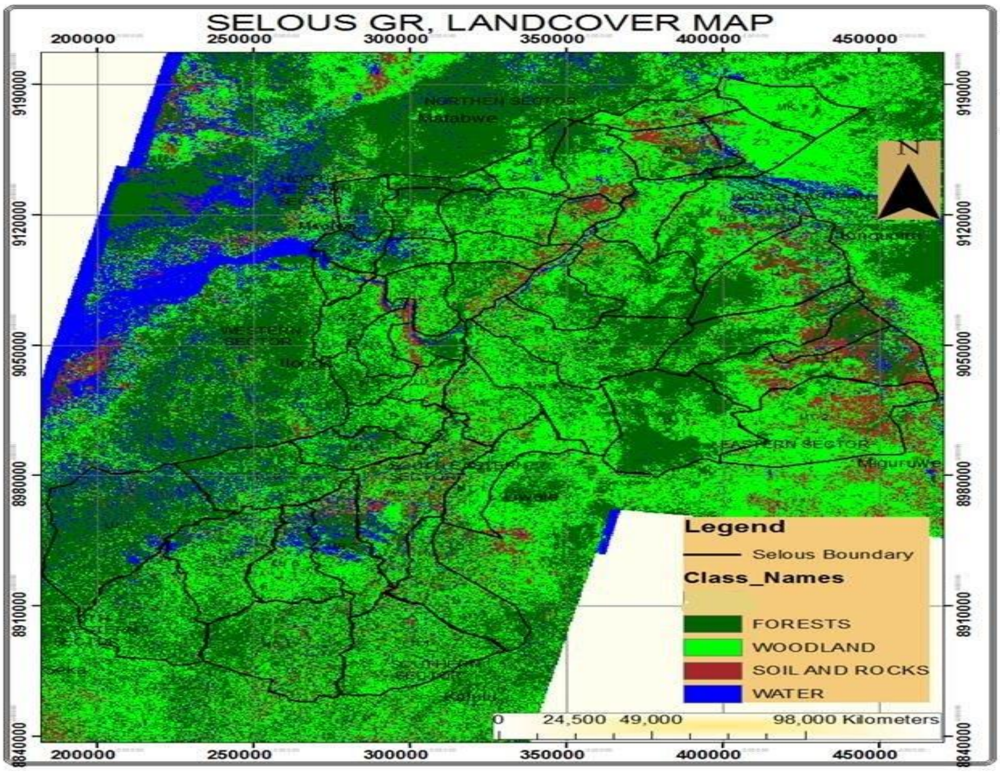

Figure 5: Land cover classes of Selous GR: Source Landsat images of 2000.

Land cover and landforms classification in the study area played a great role to wildlife as it was observed during field data collection. Such land covers provide preliminary information on the type of game animal that can possibly be found in such habitats as summarized in Table 2.

Table 2: Game Animal and Their Possible Habitat in Natural Environment

Land Cover and Landform	Possible Animal Species Found
Flat ridges of woodland, Steep stream beds, Riverine forests and grassland.	Elephant, buffalo, and waterbuck predominate in the valleys, Sable and greater kudu on the hills. Hartebeest, impala and wildebeest are confined to short grass ridges near rivers.
Mountainous, dense forest and thickets	Large mammal densities elephant, buffalo, and sable predominate
Low-lying land, open flood plain, lakes, rivers, dams, swamps riverine and dense forest.	Buffalo, elephant, hartebeest, waterbuck, Hippo, crocodile, and birds predominate, while kudu are absent
Undulating open woodland with some hills	Elephant, buffalo, impala and hartebeest, wildebeest are scarce on the open grassland near sand rivers.
Scattered tree grassland	Herbivores predominate at high densities.

Source: UNEP & WCMC (2013)

3.3 Pattern of Land Cover Resources Variation

Resource variation was examined in this study by using vegetation index comparison of the spatial distribution of vegetation cover/density mapped from Landsat images of 2000 and 2010 NDVI maps which was beneficial in assessing the variation of area covered by health vegetation. Healthy vegetated areas were successfully mapped on the NDVI maps with the output maps showing distinct colour variations related to land cover classes in the range of -1 to 1 values whereby health vegetated areas were represented by NDVI values closer to 1 (Figure 6).

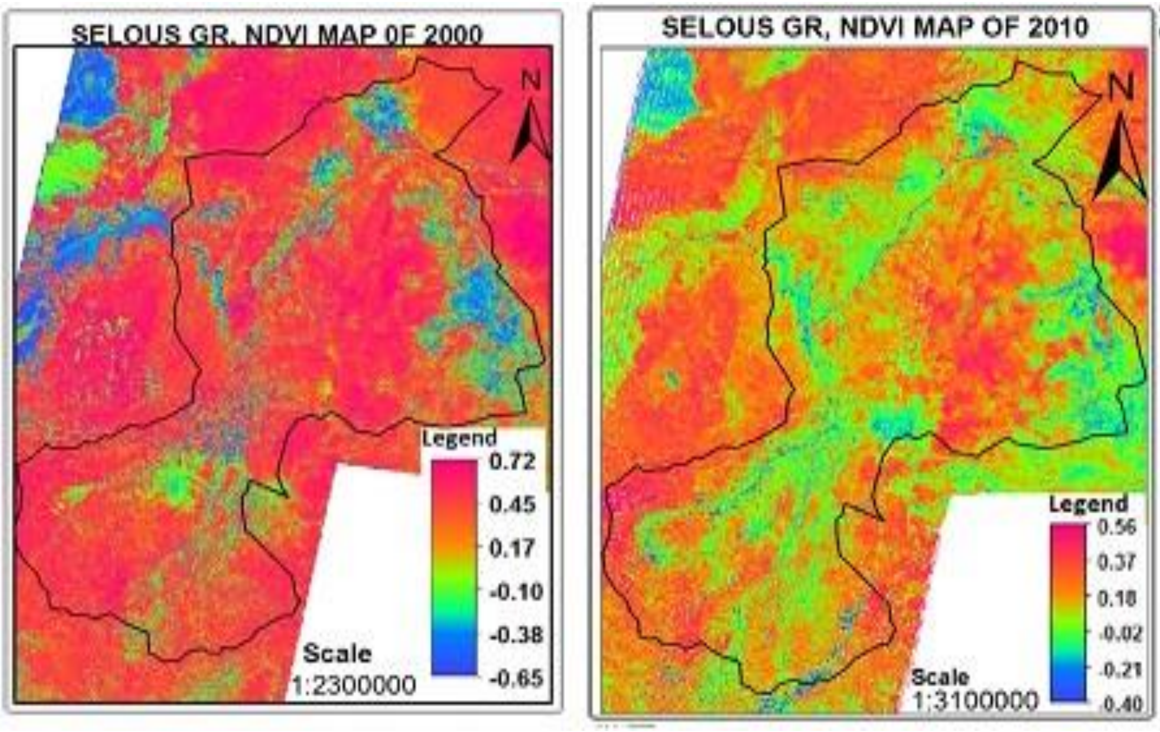

Figure 6: Calculated NDVI Map of Selous Game Reserve

Based on the NDVI map results of 2000 and 2010 (Figure 6) it was possible to note the variation of large areas with much health vegetation of at least 0.72 higher NDVI value in the 2000 NDVI map contrary to 0.56 high value depicted in NDVI map of 2010. This means that from 2000 to 2010 there was a decrease of 0.16 NDVI value, such that the trend in the size of the area covered by health vegetation has decreased with time. This study also revealed higher predominant (mode) NDVI value of 0.49 covering large pixel area of about 46.5% on the 2000 NDVI map as compared to lower 0.2 predominant NDVI value encompassing small pixel area of 37.74% on the 2010 NDVI map (Figure 7 & 8).

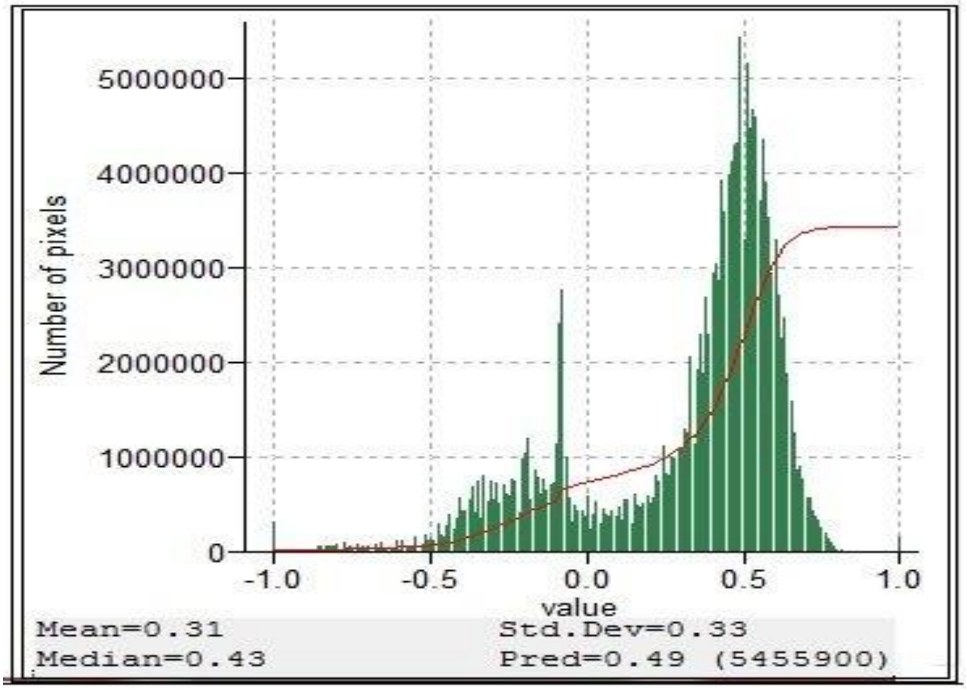

Figure 7: NDVI plot of Selous Game Reserve in the Year 2000

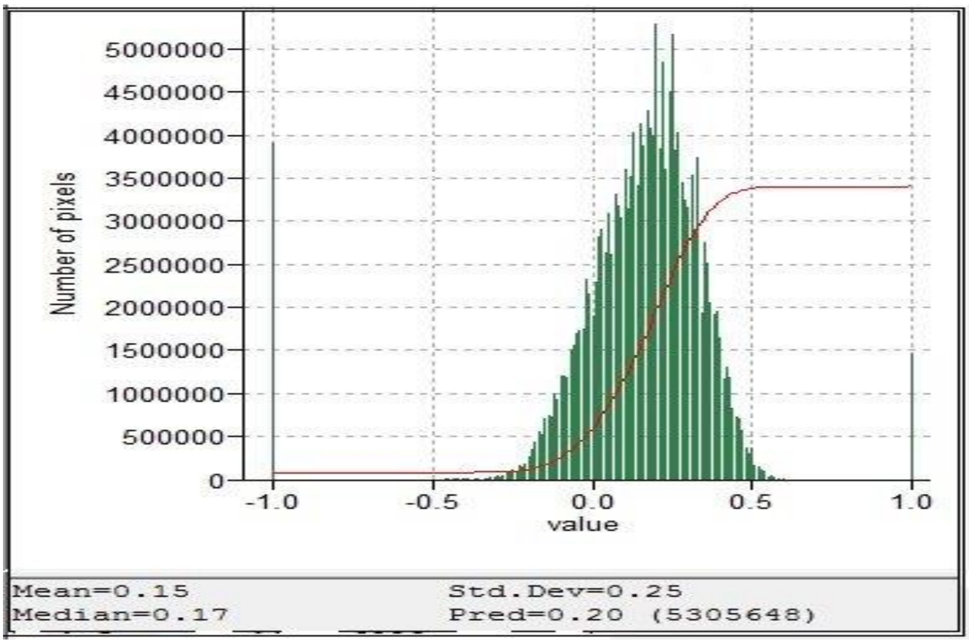

Figure 8: NDVI Plot of Selous Game Reserve in the Year 2010

Furthermore, the findings showed that in year 2000 NDVI class interval of 0.46 − 0.72 higher values occupied larger pixel area of 46.5% depicting more healthy vegetated areas as compared with 2010 NDVI class interval which showed high interval values of 0.38 − 0.56 range revealing less dense vegetation by covering less total pixel area of 8% only (Table 3).

NDVI is based on the principal that green vegetation yields high values for the index in contrast, water yield negative values and bare soil or rocks gives indices near zero.

Table 3: NDVI Values Ranges, Pixel Area Coverage and their Meaning on the Maps

	2010 NDVI Value			2000 NDVI Value			Meaning
S/N	Pixel value interval	Area of pixel	%age Coverage	Pixel value interval	Area of pixel	%age coverage	
1	-0.4 — -0.21	4.73E+09	3.04	-0.65 — -0.38	4.89E+09	3.14	Water, cloud or snow
2	-0.2 — -0.02	1.86E+10	11.96	-0.37 — -0.10	1.82E+10	11.71	Water, clouds or snow
3	-0.01 — 0.18	5.79E+10	37.22	-0.09 — 0.17	1.52E+10	9.96	Bare soil or Rocks
4	0.19 — 0.37	6.18E+10	39.74	0.18 — 0.45	4.34E+10	28.44	Less vegetated areas
5	0.38 — 0.56	1.25E+10	8.04	0.46 — 0.72	7.09E+10	46.50	Highly Vegetated areas
Total		1.55E+11	100		1.53E+11	100	

4.0 DISCUSSION

The decreasing trend in health vegetation coverage of the Selous Game Reserve from 2000 to 2010 (as depicted by the analysis of NDVI) was most likely due to socio-economic changes that led to increased human activities within the Reserve and its buffer zones. Generally, majority of the people venture into wildlife protected areas exploiting wildlife resource for their survival. Adjacent communities used forest resources from the game reserve for charcoal burning, wood-fuel collection, lumbering and logging activities, which were all possible causes of the decrease in the health vegetation observed in the study area, revealed by the calculated NDVI maps of 2000 and 2010.

The above findings (Cui *et al.*, 2013) also cited in (Martiny *et al.*, 2006) pointed out that the amplitude of the change in vegetation can result from the perturbation of the climate system existing in the landscape (in terms of space), present across all land covers and numerically expressed as a drop in the mean NDVI. More than 80% (Stephenson *et al.*, 2006) of the people living in buffer zones depend on charcoal and wood-fuel for cooking, heating and lighting. Charcoal production is having a major impact especially on the growth and existence of forests. Because it is the leading plant biodiversity destructing activities since in the process it does not select what type or size of the plant to be cut down for charcoal. Wildfire was another potential factor for such decrease. Basically, wildfires also results into reduced vegetation regeneration due to reductions in seed germination and disturbing seedling survival and growth (Baldus, 2003). Mineral prospecting in some sites also threatens an influx of illegal miners and lead to serious environmental degradation (Baldus, 2003).

Additionally, wildfires cause threats to ecosystem and adverse effects on soil, vegetation and other living organisms, since in the process of burning, the soil nutrients are reduced and the soil is left bare making it more susceptible to both soil and water erosion. The forest cover is drastically reduced through the death of fire intolerant tree species. Furthermore, animal populations dwindle due to their death and others migrate due to loss of their habitats (Hussin *et al*,. 2008). Timber logging of the miombo belt, as well as poaching and blocking of wildlife migration routes, are all threats to wildlife conservation (Stephenson *et al*., 2006).

5. CONCLUSION

Assessment of natural land cover resource variability as well as wildlife habitation effectively have shown a declining of health vegetated areas within Selous Game Reserve in ten year interval as depicted by the calculated NDVI map of 2000, with high value being 0.72 and 0.46─0.72 value interval covering 46.5% pixel area as compared to 2010 NDVI map which resulted to have 0.56 as high value while large pixel coverage of 39.74% lays in the 0.19─0.37 value interval. These results therefore, quietly encourage immediate present and future integrated applications of remote sensing and GIS techniques for frequent assessment and monitoring of the natural land cover variability in the Selous and beyond in order to detect and manage any radiating change that can lead to fragmentation, loss of wildlife species and their habitats. Conservation of core habitats is thus vital to closely monitor and manage such problems. Moreover, the use of GIS will help to assess temporal and spatial variability of land cover resources. Consequently, it will help determine the dispersal and migration of species between their natural habitats

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