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Monitoring of Land Use and Land Cover Change using Remote Sensing and GIS Techniques: A Case Study of Mt. Kilimanjaro, Tanzania

Selassie D. Mayunga[1], Semeni Anastazia[2]

[1]Botswana International University of Science and Technology, Palapye, Botswana

[2]Ardhi University, Dar Es Salaam, Tanzania

Abstract: ***Change detection techniques using Remote Sensed imagery and Geographic Information System (GIS) is useful in understanding qualitative and quantitative Lands use and Land cover patterns. Mount Kilimanjaro is one of the highest mountains in Africa with various attractive scenes including the flora, fauna and glaciers at the peak. The forest cover of the mountain has been disappearing very fast for the past two decades. As a result the living organisms are exposed, causing a great threat to the ecosystem of the mountain. This study presents evidence showing land cover and land use changes around Mt. Kilimanjaro for the period of twelve years from 2000 - 2012. Landsat 7 satellite imageries of three different periods were acquired to quantify the changes of the mountain for 2000, 2006 and 2012. Supervised classification method has been used by employing maximum likelihood technique in ArcMap Software. The Landsat 7 images were divided into nine different categories namely glacier, rock type1, rock type 2, thick forest, medium forest, farms, water body, built-up and bare land. The results indicate that for the past 12 years, about 6712 hectares of medium forest of the mountain have been converted into settlements amounting to 6.11%. Agriculture, barren land and water body has been decreased by 1.52%, 5.46%, and 0.08% respectively. The paper finally emphasizes the need to use remote sensing and GIS technologies to monitor land use and land cover changes more frequently as deforestation and illegal logging are threatening the existence of Mt. Kilimanjaro ecosystem.***

Keywords: Land use/cover, Remote Sensing, GIS Change detection technique

1. Introduction

The terms Land use and Land cover are two terms, often used in remote sensing to describe different phenomena. Land cover is defined as how much of part of the earth is covered by different features such as forests, wetlands, agriculture, land, water types etc. Land use on the other hand is defined as how the apportioned land is being used by the people for various applications being socially or economically. Information on land use and land cover and possibilities for their optimal use is essential for planning and implementation of various land use schemes to meet the increasing demands for basic human needs and welfare. This information also is used to monitoring land patterns resulting from changing demands from the increasing human activities and population. Land use usually affects land cover and land cover changes affect land use positively or negatively [1]. The positive and negative land cover changes include proper utilization of the Land while negative includes land degradation. However, Land cover changes are caused by various factors, including human activities which affect the environment and biosphere [2]. The determination of Land use and Land cover changes is very important for better understanding of lands patterns during a known period of time for the management of the environment. Also, Land use patterns between human and the nature are important for managing land, protection and improved decision making.

Mount Kilimanjaro, with its with various attractive scenes including the flora, fauna and glaciers at the peak and three volcanic cones, "Kibo", "Mawenzi", and "Shira", is a dormant volcano in Tanzania. It is the highest mountain in Africa, and rises approximately 5895 m above sea level. For the past three decades the forest cover around Mt. Kilimanjaro has been affected by presence of human activities, including agriculture, illegal logging and construction of houses. These activities to a great extent, have been affecting living organisms which cause great threats to the ecosystem. Mount Kilimanjaro ecosystem is fragile and is susceptible to over-exploitation. Population increase, human activities and land fertility have forced more people to seek livelihoods on the limited areas. At the same time, migrating to previously protected and uncultivated area is becoming a norm for people living around the mountain.

The forest cover around Mt. Kilimanjaro has been over-exploited by deforestation, soil erosion, and land degradation, which have greatly affected the nature of the mountain. For example, the southern slopes of the mountain have been seriously affected by erosion due to excessive creation of coffee plantations and planting of annual crops on steep slopes [3].

Related Studies on Land Cover and Land use Changes

In the past decades, mapping and monitoring of land use and land cover changes has been conducted using conventional ground methods. Conventional methods of mapping and monitoring of land use and land cover changes are labour intensive, expensive, time consuming and are not done more frequently. For example, [4] found that monitoring changes more frequently using conventional methods such as field surveying is very difficult, time consuming and expensive. Also, the maps produced using these methods soon they become out of date particularly in rapid changing environments.

According to article II of the International Society for Photogrammetry and Remote Sensing (ISPRS), remote sensing is defined as a science and art of acquiring information about the Earth's surface without actually being in contact with it. Remote sensing technology provides continual and consistent synoptic view of the Earth surface making, the ability to monitor the earth natural and manmade features more easily. The development of satellite has improved collection of remotely sensed data and provides information over a large area. The capability of the remote sensing technology to identify and monitor the earth's surface has dramatically increased in the last few decades and has become an important technology for monitoring and management of natural resources. Therefore, remote sensing has given scientists a remarkable capability to determine Land use and Land cover changes caused by natural phenomena and human activities [5]. In recent years, remote sensing and GIS techniques have reached an advanced stage of development and have proved to be useful in preparing accurate land use and land cover maps and monitoring changes at regular intervals of time. The techniques are quick and suitable for mapping inaccessible areas at lower cost.

In addition, remote sensing and GIS techniques have proved to be useful technologies for agriculture, settlements and industrial areas [6]. Also, remote sensing and GIS have made possible to study the changes in land cover in less time, at low cost and with better accuracy [7]. Therefore, remote sensing and GIS provide suitable environment for data analysis, update, retrieval and prediction more effectively.

For the past two decades, extensive research efforts have been conducted on land use and land cover change detection using remotely sensed images. [8] compared traditional post-classification cross tabulation, cross correlation analysis, neural networks, knowledge-based expert systems and image segmentation and object-oriented classification techniques to classify land use and land cover changes. The comparison revealed that there are advantages and disadvantages to each method and that no single approach can solve all land use and land cover change detection challenges. [9]carried out a study on land use land cover mapping of Panchkula, Ambala and Yamunanger districts, Hangana State in India. The study revealed that the heterogeneous climate and physiographic conditions in these districts has resulted in the development of different land use and land cover and the analysis of satellite imagery indicated that a large area was useful for agricultural purpose. However, the hilly areas indicate fair development of forests and land use and land cover pattern in the areas controlled by agro – climatic conditions and the potential of ground water.

[10] Investigated the land use and land cover changes in Lagos for the period of two decades, caused by the rapid increase of population and urbanization. A post-classification approach was adopted utilizing a maximum likelihood technique. It was revealed that maximum classification algorithm is capable of categorizing land at a higher accuracy. Also, they recommended that for effective management and control of the land use and land cover changes there is a need to strengthen the trained urban planners and related professionals on the use of remote sensing and GIS to monitor and to manage changes. Therefore, land use affects land cover and changes in land cover affect land use. A Land cover changes by land use do not necessarily indicate land degradation of the land. However, it has been reported by [1] that Land use changes is always driven by human activities which causes Land cover

In Tanzania, studies have been conducted to monitor the changing situation of Mount Kilimanjaro using different techniques. [11] investigated the plant biodiversity component of the Land use Change Impacts and Dynamics of the Mountain. In his research he concluded that some of the plant species around the mountain had disappeared due to economic gain as some dominant species was highly needed. In addition, crop cultivation was replacing forest cover in search for more nutritious land. Population increase is the main factor contributing to these changes and destruction of biodiversity. [12] determined Land use and Land cover changes on Soil degradation and biodiversity on the slopes of the mountain. It was found that soil degradation was severe in the lower part than in the middle and upper part of the mountain. The soil degradation is mainly caused by wind and tillage erosion on agricultural land. However, the upper zone was likely to be degraded due to intensive agriculture. [13]investigated the dynamics of land use changes and their impacts on the wildlife corridor between Mt. Kilimanjaro and Amboseli National Park. The findings revealed that there were many changes in the wildlife corridor, which were associated with the expansion of agriculture, settlements and livestock grazing.

Since the launch of Landsat program in 1972, the images and data have been available for free to the public around the world. Landsat images are used for various applications such as mapping, monitoring of forest loss and urban growth as well as measuring population changes. For example, Landsat-TM images represent valuable and continuous records of the earth's surface for the past three decades. Moreover, the Landsat archive is available free-of-charge to the scientific community and represents abundant information for monitoring environmental changes.

In this study an attempt is made to map out the status of land use and land cover of Mt. Kilimanjaro aiming at detecting the rate of change of 9 categories including forest, agriculture, population, glacier, rock type 1, rock type 2, thick forest, medium forest, farms, built-up areas and bare land which have taken place during the past twelve years, using remote sensing and GIS techniques.

2. The Study Area

The study area (Fig. 1 and 2) of Mt. Kilimanjaro is located at about 300 km south of the Equator in Tanzania on the border with Kenya, between 2°45'00" and 3°25'00"S and 37°00'00" and 37°43'00" E. It is the highest mountain in Africa composed of three extinct volcanoes namely Kibo, Mawenzi and Shira, which are 5895, 5149 and 3962 metres high respectively [14].

The largest part of Mt. Kilimanjaro is in Rombo district. Based on the population census report of 2012 Rombo district had a population of 260, 963 [15]. The population is distributed in 5 divisions 24 wards and 65 registered villages. This gives a population density of 471 per sq. km of the available land. Land carrying capacity has been increasing to 7 people per hectare instead of the approved 5 people per hectare [16].

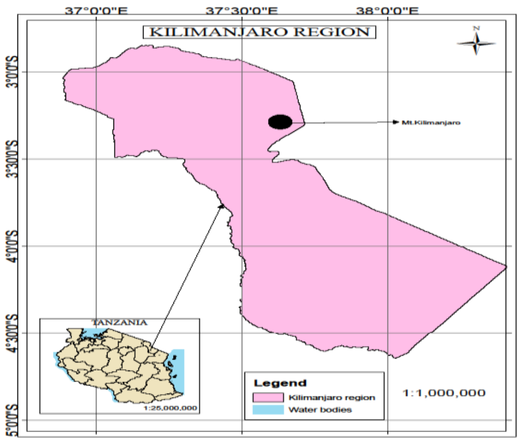

Figure 1: Location map of the study area in Tanzania

Figure 2: An image of the study area

The temperatures around Mt. Kilimanjaro are related to altitude whereby between 700m and 1200m above the mean sea level the monthly temperature varies between 220 and 260 C. The warm season is from October to March and is accompanied by high humidity with maximum temperatures of 35°C. The cool season starts from June to September, and has monthly temperatures in the range of 120 to 18°C. The average temperature ranges between 18°C and 20°C. The climate of Mt. Kilimanjaro is classified as Tropical Savanna characterized by two rainy seasons - from March to June, and during November and December. Rainfall varies with altitude and exposure to the dominant wind from the Indian Ocean but reaches a maximum of around 3, 000 mm annually and reaches 2, 100mm on the central southern slope in the lower part of the forest belt [17]. Rainfall decreases at 2, 400, 2, 700 and 3, 000 higher elevations amounting to 90, 70 and 50 per cent, respectively. The northern lee slopes of the mountain receive less annual rainfall.

3. Material and Methodology

Landsat Thematic Mapper (TM) with a resolution of 30m of 2000, 2006 and 2012 were used for land use and land cover classification. The satellite TM images of Mt. Kilimanjaro were obtained by downloading from USGS website *http://glcfapp.glcf.umd.edu:8080/esdi/*. The imageries were imported into ArcMap processing software whereby a False Colour Composite (FCC) was created. The layer stacking process was done to generate the FCC for the mountain. The landsat TM imageries were extracted from both images after sub setting the images. Extraction of images was performed by taking the outline of the geo-referenced images. To improve the classification process, a Normalized Difference Vegetation Index (NDVI was used. The normalized difference vegetation index (NDVI) is a simple graphical indicator that can be used to analyze remote sensing measurements. The advantage of NDVI is on its capability to distinguish vegetated areas from other feature types.

3.1 Land Use and Land Cover Classification

To determine the Land use and the Land cover changes, a supervised classification technique was used employing Gaussian Maximum Likelihood Classifier was applied in the ArcMap Software. Maximum likelihood algorithm (MLC) is one of the most popular supervised classification algorithm used with remote sensing image data. This method is based on the probability theory that a pixel belongs to a particular class. The theory also assumes that these probabilities are equal for all classes and that the input bands have normal distributions. However, the method requires intensive computation time, relies heavily on a normal distribution of the data in each input band. Also, it tends to over-classify signatures with relatively large values in the covariance matrix. The spectral distance method calculates the spectral distance between the measurement vector for the candidate pixel and the mean vector for each signature and the equation for classifying by spectral distance is based on the equation for Euclidean distance. The supervised classification method uses less computational time as compared to other supervised methods and it does not entertain class variability. Ground truth is necessary where features are not clearly verified. During the classification process, misclassified areas were corrected using the ground truth data. The error matrix and Kappa coefficient were calculated and used to assess the classification accuracy.

Nine land use and land cover categories were identified in the study area viz., (i) vegetation (ii) agricultural land (iii) barren land (iv) built-up land (v) water body.

3.2 Land Use and Land Cover Change Detection Analysis

After supervised classification process, a post classification approach was performed followed by pixel based comparison so as to provide changes of the images on pixel basis that interprets changes more easily. The classified images for the period of 2000 and 2006 and from 2006 to 2012 were compared using tabulation to determine the qualitative and quantitative changes for the period of 12 years. A change detection matrix was computed with the assistance of ArcMap software. In addition, the overall land use and land cover changes indicates the increase and decrease of areas and rates in each category.

Normalized Difference Vegetation Index (NDVI) being the most widely used vegetation index to distinguish vegetation from others features or categories. NDVI was derived using the expression given in Equation (1):

$$NDVI = \frac{(NIR-R)}{(NIR+R)} \quad (1)$$

Where NIR = Near Infra Red (band 4 for Landsat TM), R = Red (band 3 of Landsat TM images)

4. Results and Discussions

The results obtained from classification process are illustrated in Fig. 3 – 4 and data are shown in Tables 1 and 2 below. Figure 3 shows the status of land use and land cover while Fig. 3 illustrates the land use and land cover change from different land use categories. Fig. 4 illustrates the rate of change in different land categories. The detailed discussion of the results is discussed in the following paragraphs.

4.1 Preparation of Land Cover Maps

From the classification results, the land cover maps around Mt. Kilimanjaro were prepared using Arcmap interface for 2000, 2006 and 2016 showing different land cover categories and their respective coverages (Fig. 3 - 5).

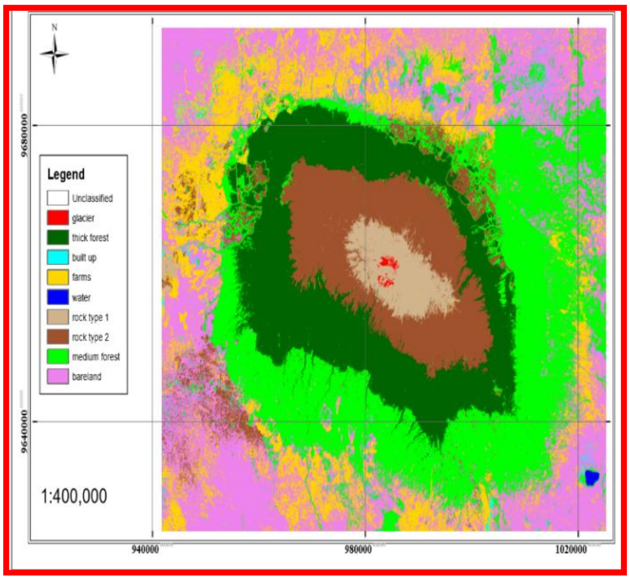

Figure 3: The land cover around Mt. Kilimanjaro in 2000

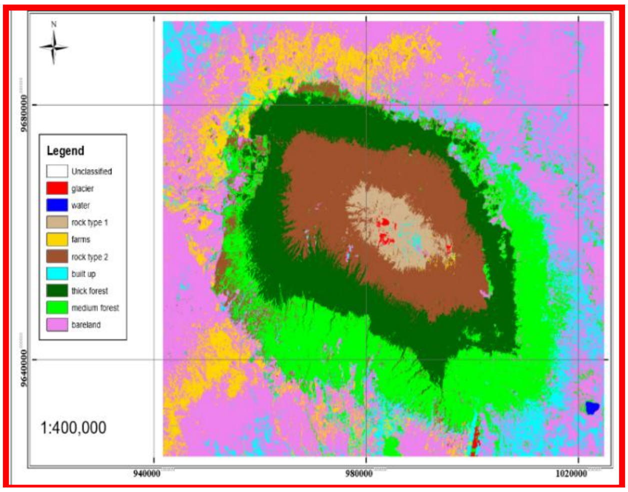

Figure 4: The land cover around Mt. Kilimanjaro in 2006.

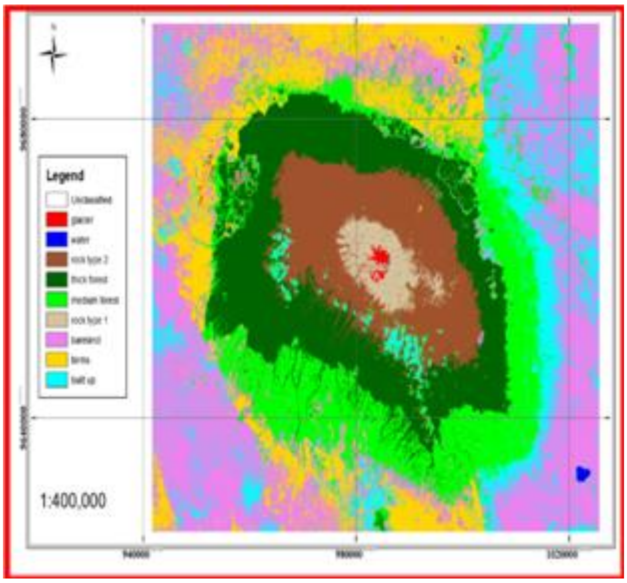

Figure 5: The land cover around Mt. Kilimanjaro in 2012

4.2 Accuracy Assessment

Remote sensing experts and users of Land Use and Land Cover change maps need to understand how accurate the classified maps are so that they can be used more correctly and effectively. According to [18], the minimum classification accuracy should be at least 85%. The error matrix is the most widely classification accuracy assessment, which uses descriptive and analytical statistics. The overall accuracy, producer's accuracy, user's accuracy and Kappa coefficient were used as parameters for accuracy assessment. The errors of commission and omission present show how well the classification process was.

In this study, the accuracy assessment of the land use and land cover classification results show that the overall accuracy obtained was 79.5%, 88.0% and 84.0% for 2006, 2010 and 2012 respectively. The overall accuracy for 2006 and 2012 was below the required threshold due to the fact that during image processing smaller shaded areas were noticed in the image which to a great extent influenced the overall accuracy. The computed Kappa coefficients for 2000, 2006 and 2012 classified maps were 0.74, 0.85 and 0.80 respectively.

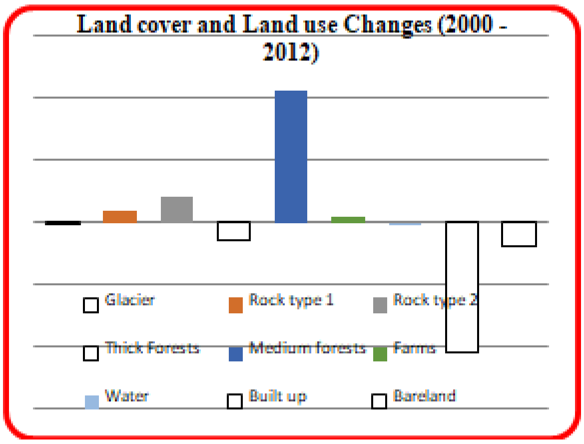

Figure 6: Land Cover Change (2000 – 2012)

Figure 6 above shows that both positive and negative change the occurred in the land use and land cover pattern on Mt. Kilimanjaro. For the past twelve years the thick and medium forest cover of Mt. Kilimanjaro has decreased from 149836 Ha. in 2000 to 189, 246 Ha. in 2012 which accounts for 11.6% of the total study area. The built-up area has increased from 6, 459 Ha. in 2000 to 66, 747 Ha. in 2012 which accounts for 10.5%. The barren land has been increased from 157, 314 Ha. in 2000 to 168, 068 Ha. in 2012. This increase in bareland accounts for about 3%. The water body of the study area has slightly decreased from 407 Ha. in 2000 to 394 Ha. in 2012 which accounts for −0.01%.

Table 1: Area and amount of change in different land use and land cover categories around Mt. Kilimanjaro from 2000 – 2012.

	2000		2006		Change from 2000- 2012	
	Ha.	%	Ha.	%	Ha.	%
Glacier	476.3	0.1	984.5	0.2	980.446	0.2
Water	406.6	0.1	398.7	0.7	393.989	0.069
Rock type 1	16909.3	2.9	12857	2.2	12090.9	2.104
Rock Type 2	71669.1	12.5	74039.7	12.9	59745	10.396
Thick forest	91904.8	16.0	79581	13.8	100040	17.407
Medium forest	149836.0	26.0	91641.6	15.9	89245.7	15.529
Bare land	157314.0	27.4	222343	36.9	167988	29.23
Farms	79800.8	13.8	46062.5	8.0	77487.6	13.483
Built up	6458.6	1.2	46894.2	8.2	66747.2	11.614
Total	574775.414	100	574802.204	100	574718.835	100

4.2. Land Use/Cover Change

To understand more on forest cover change of Mt. Kilimanjaro for different land categories a change detection matrix (Table 1) was generated which shows that:

i) The built–up area has increased at about 11.61% from 2000 to 2012 and medium forest has been decreasing from 26% in 2000 to 15.5% in 2012. This shows that about 2758.24 Ha. of medium forests were converted into farm land while 13685.3 Ha. were converted into built up areas.

ii) Thick forest remains steady at 16%
In 2000 to 17.1% in 2012 and water has been slowly decreasing at 0.1% in 2000 to 0.69% in 2012. For the forest cover changes from 2006 to 2012, the area that was converted into farm land was 886.922 Ha. while 6712.75 Ha. were converted into built up areas.

iii) Within the period of 12 years (2000
To 2012), 3778.37 Ha. were converted from medium forests into farm land while 29574.6 Ha. were converted into built up areas. The increase in the built-up areas is a result of rapid population growth, which forces the residents to encroach on the forest belt. Economic activities like agriculture have also impacted the forest cover, whereby most of the farms are found around the mountain where the soils are still fertile and productive.

iv) Some land cover classes like glacier,
Rocks and water were not much affected with exception of some cases where the reflectance of the cloud cover and iron sheets altered the results of the glacier. An abnormal difference was noted on glacier cover whereby the 2000 image produced different results from the 2006 and 2012 results. However, the 2000 results were considered more correct because the image was very clear and completely cloud free

5. Conclusion

The study carried out around Mt. Kilimanjaro, Tanzania shows that Landsat 7 satellite imagery plays an important role in quantifying information which was not possible to be determined by conventional mapping techniques. The study also revealed that at present the major land use around Mt. Kilimanjaro is agriculture and settlements. The second major land use is built - up area which has increased by 11.6% (66747.2 Ha) This was caused by conversion of forest and barren land. The third category of land use is water body which has remained steady by 394 Ha. During the study period (i.e., from 2000 - 2012), barren land has been decreased by 29.2% (167988 Ha.) due to conversion into agriculture, vegetation and built-up land. The built-up land has increased by 11.6% (66747.2 Ha.) due to mainly expansion of built-up areas for the past twelve years. Therefore, the present study shows that remote sensing and GIS are important technologies for quantitative and qualitative analysis of spatial phenomena which could not be possible using conventional/traditional mapping methods. Change detection has been made possible by these technologies in less time, at low cost and with better accuracy. Therefore, remote sensing and GIS are potential techniques to monitor frequently land use and cover changes as deforestation and illegal logging are threatening the existence of Mt. Kilimanjaro fragile ecosystem

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