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GIS AND REMOTE SENSING BASED FOREST CHANGE DETECTION FOR SUSTAINABLE FOREST MANAGEMENT IN BENCH MAJI ZONE, ETHIOPIA

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Abstract

Forest cover change analysis was calculated and estimated using Landsat imageries of the area. Nowadays, forest cover change is the major and the most widespread form of environmental problems in southwestern parts of Ethiopia. Population pressure due to re-settlement, overgrazing, deforestation and uncontrolled exploitations of natural resource for firewood, construction and other household uses often ultimately leads to severe forest cover changes. Therefore, the overall objective of this paper is to assess the extents of forest cover changes for sustainable forest management. This study had integrated Geographic Information System (GIS), Remote Sensing (RS) and Global position System (GPS) technologies to assess and map forest cover changes from 1986 to 2001. The data were collected and analyzed from Landsat satellite imageries and ground control point verifications using GPS technologies. The result of the study discourses that, forest cover is drastically decreasing through time especially in the resettlement areas of northwestern tip, central and northeastern parts of catchment. Quantitatively, forest cover was diminished from19.55% in 1986 to 11.8% by 2001.

Key words: GIS, Remote Sensing, GPS, Forest Cover Change, Land use/land cove change and Ethiopia

Introduction

People in developing countries are increasingly forced to use more marginal and sensitive lands for agricultural purposes in every aspect to sustain their living. These uncontrolled and unmanageable uses of land due to population growth ultimately leads to deforestation, land over cultivation, overgrazing and exploitation of biomass for firewood, construction and other household uses which often causing severe forest change and land degradations cycle. The economic implication of forest change and other resource degradation is more serious in Ethiopia because of mainly its rugged topographical features and lack of capacity to cope with it to replace lost nutrients (Gete, 2000).

Even though, forest cover change is recognized as a severe problem in every corners of the country, nowadays the study area has been severely affected by severe forest cover change and land degradations due to the aforementioned problems. Currently, because of population pressure due to re-settlement, unplanned land use management and uncontrolled exploitations of natural resources, the southwestern parts of Ethiopia have been characterized by severe deforestation and environmental degradation cycle (Bench Maji Zone Bureau of Agriculture, 2013). Studies reported that, cultivation without using specific control techniques and unplanned land use such as deforestation, over grazing and mal-agricultural practice are fundamental factors of land use/land cover change and land degradations.

The formulation of proper land use management for sustainable development requires an explicitly assessed and identified land use maps. The classification and mapping of vegetation are fundamental tools for obtaining knowledge about vegetation cover and its relationship to the environment. A number of methods have been used to identify different phenological stages of vegetation including the application of the normalized difference vegetation index (NDVI), which is used as an indicator of vegetation condition (Ramamoorthi et al., 1991).

Mapping of land use/land cover using the integration of GIS, RS and GPS technologies can identify areas that are at potential risk of land cover change and extensive land degraded areas (Moore and Wilson, 1992). This information is very useful in the decision making context to avoid land acquisition in environmentally degraded areas or alternatively, to recommend natural resource conservation measures in a highly degraded areas (Yusof and Baban, 1999). On the other hand, assessment and mapping of land use/land cover and their consequences plays a significant role for natural resource management and/or sustainable environmental planning processes. Thus, by this research GIS, remote sensing and

GPS technologies were employed to assesses forest cover change and its environmental implications for the planning and implementations of sustainable land use management in the area in particular and at country level in general.

Objectives of the Study

The general objective of the research is to assess and map the extents of forest cover changes for sustainable forest management.

Scope of the Study

The study was conducted in Bench Maji Zone, which is located southwestern part of Ethiopia in Southern Nations National and Peoples Regional State. The area covers a total land area of 24, 500.05 km^2. The competition between demand and supply of land for different activities (especially agricultural practices) are playing crucial role in forest change and environmental degradations.

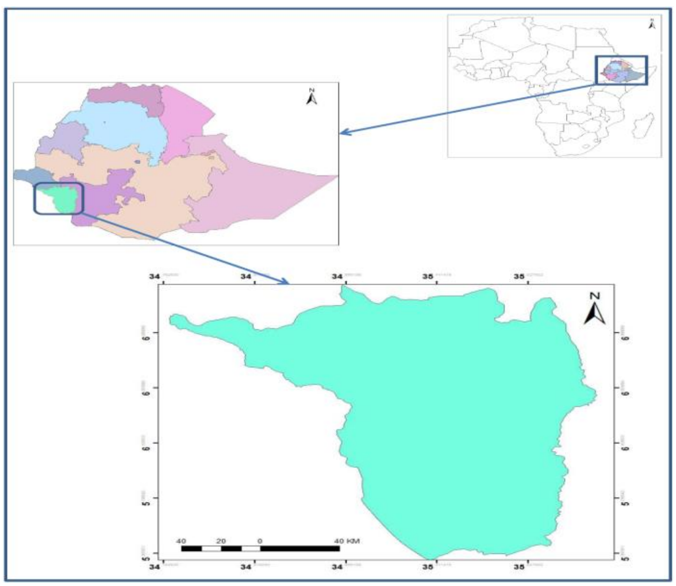


Figure.1. Locational map of the study area

Methods and Data Analysis

Source and Methods of Data Collection

The research have been used both primary and secondary data. Secondary data (Satellite image, aerial photo, topographic map, meteorological data, population data and others) were collected from different governmental and non-governmental organizations. In addition to this, frequent field observations using Global Positioning System (GPS) were carried out to generate primary information regarding the ground truth for image classification. Primary data were collected using key informant discussions and filed survey or ground truth observations and verification using GPS instruments.

Data Analysis

After collecting all necessary data, data analysis and processing were made by digitizing, calculating and classifying the necessary information of each thematic layer using ERDAS IMGINE10 and ArcGIS10.1 software. .Furthermore, some simple statistical methods, such as percentage, average and graphic tabulation were also employed for the analysis and interpretations. The procedure followed during accurate for forest change analysis from landsat imagery followed the following major steps:

Image Rectification and Restoration (Pre-processing)

In their raw form, as received from imaging sensors mounted on satellite platforms, remotely sensed data generally contain flaws or deficiencies (Lillesand and Kiefer, 2000). Some of the distortions are radiometric distortions, geometric distortion and noise or atmospheric effect. Such errors can be corrected by using pre-processing techniques like radiometric correction, geometric correction and noise removal or atmospheric corrections, which should be applied in raw imageries.

The image used in this study is found in three paths and rows and have distortions like mentioned above. Therefore, the image was perfectly corrected by applying the necessary pre-processing techniques. And also all images were georeferenced in to appropriate datum and projections of Ethiopia because datum conflict utmost may distort the data or limit the use of overlay techniques.

Image Enhancement

These techniques were applied to images in order to display more effectively or record the data for subsequent visual interpretation. All spatial, radiometric and spectral enhancements were deemed necessary to increase the interpretability of raw images. Specifically for this study resolution merge, contrast stretching and histogram equalization were applied to enhance the visual interpretability of the image. Contrast stretching is a technique to expand the narrow range of brightness values typically present in an output image over a wider range of gray value (Lillesand and Kiefer, 2000).

Image Classification

Image classification is the process of creating thematic maps from satellite imagery. A thematic map is an information representation of an image that shows the spatial distribution of particular theme (Lillesand and kiefer, 2000). Remotely sensed data of the earth may be analyzed to extract useful thematic information for different purposes. The overall objective of image classification procedures is to automatically categorize all pixels in an image into land use / land cover classes or themes (Lillesand and Kiefer, 1994).

In classifying the images, both unsupervised and supervised image classifications techniques were applied. Unsupervised classification has been done prior to the field survey whereas; supervised image classification was computed after the collection of training sample in filed survey. In supervised image classifications, after assigning the signature value (training area), a spatial merging algorithm was applied to obtain a more homogeneous appearance of the individual classes. This algorithm is used to merge adjacent regions according to their spatial properties. Finally, the different land use/land cover classes were classified (grouped) and maps were composed using ERDAS IMAGINE 10 and ArcGIS 10.2 software.

Accuracy Assessment

Accuracy assessment is a general term for comparing the classification to geographical data that are assumed to be true in order to determine the accuracy of the classification process. The data used to cross-check the accuracy are usually collected from ground truth and calculated using a set of reference pixels. Reference pixels are points on the classified image for which actual data are represented and are randomly selected (Congalton, 1991). Therefore, the confusion matrix method was used to estimate the accuracy of supervised land use/land cover image classification of the study area. The confusion matrix is a table with the columns representing the reference (observed) classes and the row classified (mapped) classes (Rossiter, 2001).

RESULTS AND DISCUSSION

Land Use /Land Cover Classifications

The land use/ land cover classes of the area was classified using Landsat satellite image of 2001 and ground control points taken from different land use/land cover classes. Based on the classification algorism, the area was classified and mapped in to six basic land use/land cover classes as forest land, commercial crop land, bush land, grass land, farm and settlement land and degraded (nearly bare) land as shown in table 1 and figure 2.

Table 1. Conceptual descriptions of each land use/land cover type

Nº	Land Use /Land Cover Type	Descriptions	Area in km^2	Coverage in Percentage
1	Forest Land	The area covered by dense forest	2, 881.7	11.8
2	Commercial Crop Land	The ground area is covered by dense commercial crop and sparsely covered by tall trees	2, 300.05	9.4
3	Bush Land	The area covered by tree and shrub	2, 594.78	10.6
4	Grass Land	The area covered by sparse tree and dense grasses	3, 632.67	14.8
5	Farm and Settlement	The area used for farming and settlement	9, 014. 14	36.8
6	Bare Land	Degraded land	4, 076. 71	16.6
	Total		24, 500.05	100

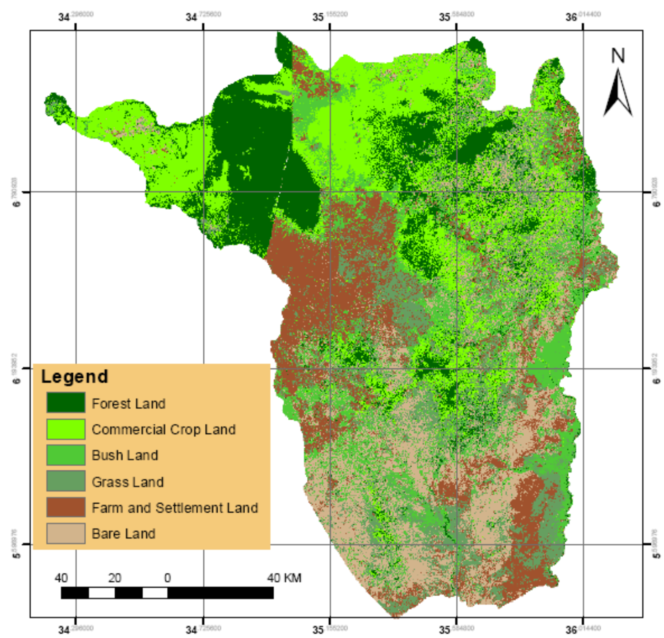
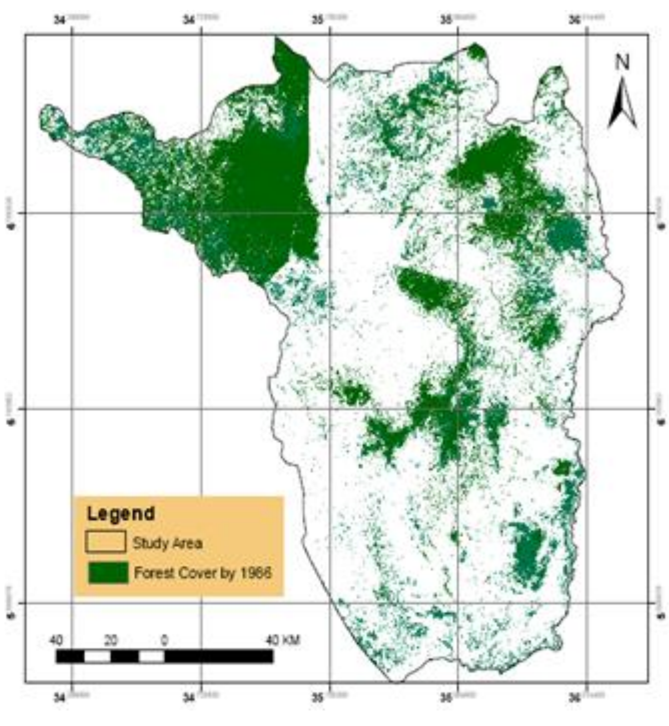


Figure 2. Land Use/Land cover map of Bench Maji Zone

As it clearly depicted on the above maps (figure 2) and tables (table 1), farm and settlement land is the dominant land use/land cover type in the area. It covers a total land area of 9, 014. 14 km2 (36.8%). The second major land use/land cover type is bare (nearly degraded land) which covers 4, 076. 71km2 (16.6%). The remaining grass land, forest land, bush land and commercial crop land covers 3, 632.67 (14.8 %), 2, 881.7 (11.8%), 2, 594.78(10.6%), and 2, 300.05 (9.4%) of the area respectively. Natural resources especially forest resource is becoming scarce due to population pressure and exploitive nature of agricultural practice in the area. Hence, information on land use/land cover and possibilities on their optimal use is essential for the selection, planning and implementations of land use schemes to meet the increasing demands of basic human need and welfares.

Forest Cover Change Detection

Based on the 1986 Landsat satellite image analysis and classification result, the northwestern, central and some parts of northeastern catchments were covered by natural forest resources (figure 3 a). As clearly indicated in figure (figure 4 a) 19.55 % of the area was covered by forest lands in 1986. Through time due to population pressure resulting from resettlement, farmers in the area are increasingly forced to use more marginal and sensitive forest lands for agricultural purposes to sustain their living. Due to these reasons, forest cover is drastically decreasing through time especially in the northwestern tip, central and northeastern parts of catchment (figure 3b). As clearly shown in (figure 4a & b), forest cover was diminished from19.55% in 1986 to 11.8% by 2001. This indicates that 127.24 km2 of forest land was changed in to other land use/land cover types per year.



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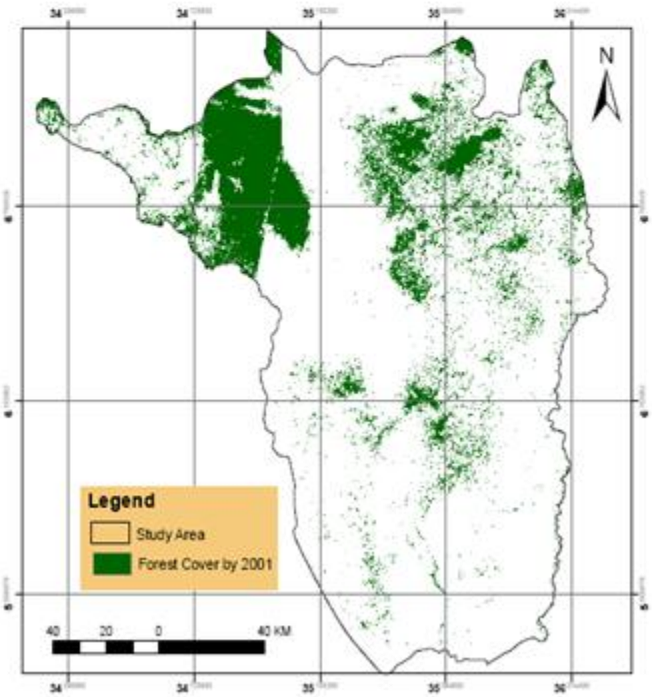

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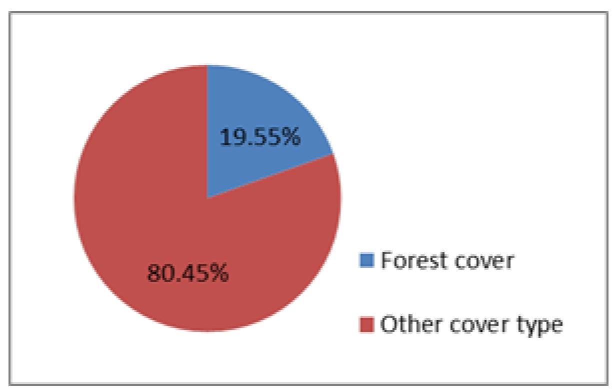
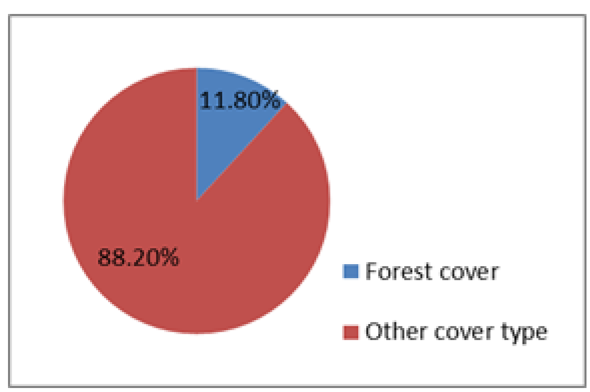
Figure3. Forest cover in 1986 (a) and by 2001(b)



a



b

Figure4. Percentages of forest cover in 1986 (a) and by 2001(b)

The analysis result of the study is in line with the findings of Gete (2000), Gete and Hurni (2001), Markos (1997), Hurni (1993), Hurni (1988b), Solomon (1994), Markos (1997) Belay (1995) and FAO (1984) land use/land cover change and land degradation estimations. According to Gete (2000) due to population pressure, frequent land tenure and unstable institutional set-up, almost all natural forests have been cleared throughout Ethiopian highlands and its environs. The findings of FAO (1984), Belay (1995), Gete and Hurni (2001) also revealed that, a long history of agricultural activity with a high level of population pressure and exploitive nature of agricultural practices has led to existing depletion of vegetation covers and over-utilization of land resources.

Conclusion

Based on the result of the study it is possible to conclude the following important points.

- Forest cover is drastically decreasing through time especially in the resettlement areas of northwestern tip, central and northeastern parts of catchment.
- Landsat satellite imageries are very good popular data for land use/land cover mapping and forest change detections.
- The land use/land cover map and forest change map can be used as one of the main inputs in decision-making support system for sustainable land management particularly for forest resource management.

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Biography

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