Article

Evaluation of land use/land cover changes in Mekelle City, Ethiopia using Remote Sensing and GIS

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Abstract
Land use is a dynamic phenomenon that changes with time and space due to anthropogenic pressure and development. Evaluating the existing land use and its periodic change is useful for urban planners, policy makers and natural resource managers. Land use and land cover changes in Mekelle City, Ethiopia (north east Africa) over a period of 25 years was studied using remotely sensed data. Multi temporal satellite data of Landsat was used to map and monitor urban land use changes occurred during two point of time of 1985 and 2010. A pixel base supervised image classification was used to map land use land cover classes for maps of both time set. A positive changes of 200% was recorded in urban features of Mekelle, whereas, an area of 6 km^2 was added in grasslands. On the other hand a loss of 92.86% was estimated in bare land and all farm lands available in the area were converted into other feature and it declined from 3 km^2 to nil. Since forest land is protected so that no change in sparse forest was recorded.

Keywords Remote Sensing; land use; land cover; GIS; Mekelle City.

1 Introduction

Analyzing the land cover changes and understanding the subsequent trends of change contribute to present complex dynamics of land cover and is important for policy making, planning and implementing of natural resource management (Ioannis and Meliadis, 2011; Knorr et al., 2011; Reddy and Gebreselassie, 2011). Land-use shifts are caused by external and internal drivers and have been influenced by many traditional and modern resource management practices (Campbell et al., 2005).

The information about the change in landscape may be obtained by visiting sites on the ground and/ or extracting it from remotely sensed data. But traditional methods are time consuming and do not provide a holistic picture. Monitoring forests from the space or airborne platforms, in contrast, can provide relevant information quickly, as well as repeatedly and at regular intervals of time. This makes it possible to detect changes in the land cover quickly and efficiently.

Considering the importance of remote sensing and geographic information system (GIS) in evaluating the changes in landscape cover, this technique is used for the present study. Remote sensing offers an important means of detecting and analyzing temporal changes. Since early 1970s, satellite data have been commonly used for detecting these changes over large landscapes. Pitt and colleagues (1977) described aerial photographs as one of the simplest methods for detecting forest changes because of their easy availability and interpretability. As time progressed, digital methods were developed for detecting change using satellite imagery to take the advantage of the new repetitive, synoptic digital data (Saint, 1980; Howarth and Wickware, 1981). Hame (1988) used visual interpretation techniques to detect forest changes from satellite scanner imagery, whereas Sugumaran et al. (2003) were successful in using satellite imagery to delineate the boundaries of planted forests that were converted under various programmes.

Land use land cover (LULC) is perhaps the most prominent form of global environmental change phenomenon occurring at spatial and temporal scales. The change in the land use in cities is the result of urbanization and different developmental activities. Most of the metropolitan areas face the growing problems of urban sprawl, loss of natural vegetation and open space. The process of urbanization often leads to haphazard growth in metropolitan cities, deterioration in living conditions and worsening of environmental scenario having detrimental impacts on human health. It is, therefore, desirable to plan for the city and its peripheral areas in an integrated manner (Pathan et al., 1991). The United States Geological Survey's project on Urban Dynamics Research studies the landscape transformations that result from the growth of metropolitan region over time. An understanding of the growth dynamics of urban agglomeration and land use changes is essential for ecologically feasible developmental planning. Thus there is an obvious need for continuous monitoring of the phenomena of growth and mapping and analyzing LULC changes. The inventory of urban changes is required not only to have up-date information of existing land use but also to record the recent improvements as well as to monitor the changes that are constantly occurring in different parts of the town (Jain et al., 1991). It is expected that million hectares of productive agriculture land in the urban peripheral regions are lost due to urbanization and urban sprawl. Thus it is important to plan and control the urbanization process in a systematic way that would give the people maximum benefits (Pathan et al., 1991).

The development of spatial data infrastructure is a key to sustainable land development (Mohan, 2005). Information on exiting LULC, its spatial distribution and change are essential prerequisite for planning (Jaiswal et al., 1999). Remote Sensing and GIS technologies now provided the potential for mapping and monitoring the spatial extent of the built environment and the associated urban land use changes. Chauhan and Shailesh (2005) have analyzed LULC changes in Hazira area near Surat, Gujarat using IRS-LISS-III data. Urban land use mapping of greater Bombay was carried out using Land Sat TM data by Pathan et al (1989). The main objective of land use analysis is to provide a balanced pattern of land use for the people.

Determining the effects of land-use and land-cover change on the Earth system depends on an understanding of past land-use practices, current land-use and land-cover patterns, and projections of future land use and cover, as affected by human distribution, economic development, technology and other factors (Tom, 2003). The land cover change, in many parts of the world has become a global issue, as a result contributed to the present complete transformation of land cover types. Natural disasters such as droughts, floods caused by climatic change, as suggested in many literatures is not a commonly occurring phenomenon, human interventions are, however cause dramatic changes in a society. FAO (2001) suggested that, such human induced processes are advancing at much faster rate. The most potent forces affecting natural vegetation arises from the direct effect on an expanding human population (Grime, 1997). In Ethiopia approximately, 150,000 to 200,000ha of forest are lost each year mainly for the expansion of rain fed agriculture and also for fuel wood and through over grazing (EFAP, 1994).

Mapping spatial changes using remote sensing tools gives quantitative descriptions (Olson et al., 2004). However, studies on evaluation of land use land cover changes in Mekelle city are scanty. Therefore, considering this the present study was undertaken. The goal of this study was to map and to offer an increased understanding of the patterns of land-use/cover changes over time. The objective was first to explore the dynamics of the land-use/cover and to investigate what are the main drivers which brought most important transitions (i.e., conversions) among the land use/cover classes between 1985 and 2010.

2 Materials and Methods

2.1 Study area

Mekelle, the regional capital city of the Tigray region, is located in the northern Ethiopia high lands at 777 km drive north of national capital city, Adiss Ababa. Geographically it is located between $13^{0}24'30''$ to $13^{0}36'52''$ Latitude and $39^{0}25'30''$ to $39^{0}38'33''$ Longitude (Fig.1). It has an average altitude of 2200 meters above sea level with a mean minimum, mean maximum and mean average monthly temperatures of 8.7, 26.8 and 17.6° C, respectively (Kibrom, 2005). Amount of rainfall is variable in Mekelle; on average about 600 mm, and more than 70% of it falls between July and August, followed by long dry season (Kibrom, 2005). Mekelle has an estimated total population of 215,546 (CSA, 2008). Mekelle which was founded as a national capital during Emperor Atse Yohannes the 4^{th} era in the nineteen century and subsequent years, as a regional city of Tigray has been developed as political, economic, and cultural center characterized by its spontaneous growth. Mekelle is one of rapidly growing city in terms of human settlement, Industrial and Institutional establishment and at present city has a built up area of 3500 hectares.

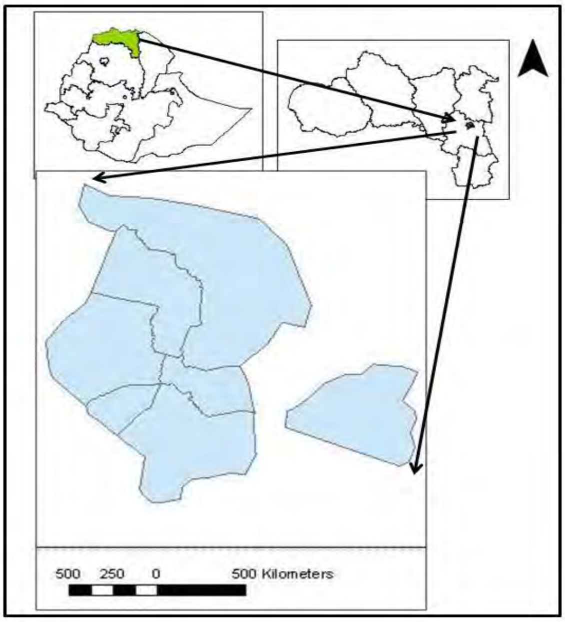

Fig.1 Study area (Mekelle), Ethiopia

2.2 Methodology

The study was carried out in three phases. In the first phase satellite and collateral data were collected and processed, while during the second phase, field survey was conducted for ground truthing to perform supervised classification. The third phase included database creation and geospatial evaluation of landscape changes. *ERDAS IMAGINE 8.7* (2004) and ArcView 3.2 (1999) computer software were used for data processing and GIS analysis.

2.3 Data collection and data processing

Data are generally classified as either primary or secondary. The primary data was obtained by field surveys and by actual measurements recorded during the fieldwork. A global positioning system (GPS), rangers compass, binocular and camera were used during the field visit(s). Secondary data was obtained from various sources like topographic maps, Municipality and satellite imageries.

Satellite data of Landsat of 1985 and 2010 were acquired form Department of Geography and Environmental Sciences, Mekelle University, Ethiopia. Satellite data (imageries) were used for creating False Colour Composite (FCC) that served as the basis to develop the Land Use/Land Cover maps for both time sets of 1985 and 2010.

The satellite data were imported into ERDAS IMAGINE software in an image format for geometric correction. Geometric distortions in a satellite image are introduced by the sensor system. In order to use these data in conjunction with other spatial data, it is needed to georeference the distorted data (raw data) to a coordinate system. The Imageries of 1985 and 2010 were georeferenced using ground control points with a root mean square error (RMSE) of less than one pixel. The Universal Transverse Mercator (UTM) geographic projection, Clarke 1880 spheroid, and Adindan (Ethiopia) zone 37 North datum were used in geo-referencing the images. To make these images compatible (Lillesand and Kiefer, 2000), both images of 1985 and 2010 were re-sampled to a 30m×30m pixel size using the nearest neighbor re-sampling technique after Serra et al. (2003). Five land-use/cover classes viz; Urban feature, Grass land, Sparse forest, Bare land and Farm land were identified for image classification for both the imageries (Fig. 2). A pixel based supervised image classification with maximum likelihood classification algorithm was used to map the land-use/cover classes (Lillesand and Kiefer, 2000).

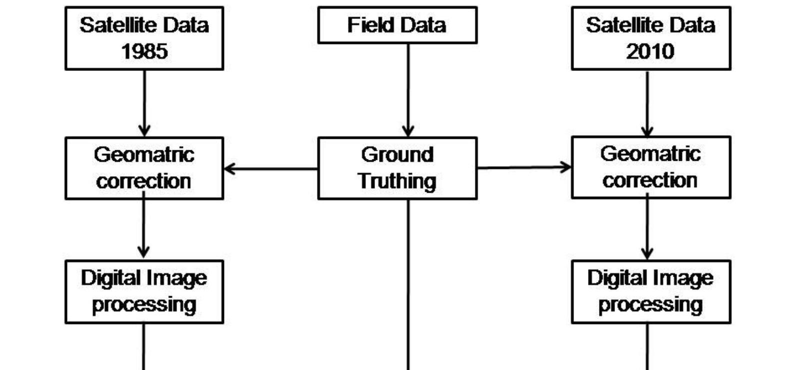

Fig. 2 Paradigm of Landscape cover type change for Mekelle city, Ethiopia (1985-2010)

After creation of shapefile (the format Arc View uses) "attributes' were attached. Each class was given unique identity and assigned a particular colour to make them separate from each other. The vector maps were polygonized using a clean-build operation. The aggregated area of different classes were calculated and verified with the total area of the study area. After preparation of Land Use/Land Cover maps of 1985 and 2010, area of each class were compared to analyze the changes in the landscape cover type (Fig. 3 and 4, Table 1).

Table 1 Changes in land use land cover in Mekelle city, Ethiopia during 1985-2010.

Land use type	**Area in km^2 (1985)**	**Area in km^2 2010)**	**Changes in km^2 (%)**	**Description**
Bare land	14	1	-13 (336%)	High rate of urbanization, Industrialization and rural urban migration and natural increase in human population
Urban features	5	15	+10 (200%)	High rate of urbanization, Industrialization and growth in academic institution
Farm land	3	0	- 3 (100%)	Increase in human settlement, holding of lands by city administration for various purposes.
Sparse forest	1	1	No change	Conserved by forest department under law
Grass land	1	7	+ 6 (600%)	Grasses are grown naturally in those agriculture and bare land which were acquired by government agencies for future development and are still lying vacant.

3 Results and Discussion

Land cover maps from Landsat imageries of 1985 and 2010 were produced and trend analysis was carried out to compare the land cover type (Fig. 3 and 4, Table 1). Regardless of the proportion of changes in size of the cover types, significant changes have been observed between 1985 and 2010. The various land cover types; urban feature and grassland show almost a similar trend with dramatic increase in their areas. An increase of 200% was estimated in urban features from its previous area of 5 km^2, whereas, 6 km^2 was added as grass lands from its previous area of 01 km^2.

Significant negative changes were observed in Mekelle during past 25 years. Bare lands which were spread over in 14 km^2, transformed into other land features and reduced to only 01 km^2 showing a changes of 336%. Farm lands which were spread over in 3 km^2 in Mekelle during 1985 reduced to zero in 2010, showing a negative change of 100%.

Land cover changes are caused by a number of natural and human driving forces (Meyer and Turner, 1994), which is also true for Mekelle city. A significant change has been observed in land cover type between 1985 and 2010. The magnitude of land cover change reflected in the city was basically due to an increase in the human population density coupled with an increase in residential, industrial and institutional building at the expense of bare lands and agriculture lands. It seems that from the point of resource conservation, degraded and bare lands have less value due to thin soil cover for crop production. Therefore, government has allotted/acquired the land for other development/construction works.

Ethiopia has experienced rapid urbanization and increasing urban population in the last few years due to more rural-urban migration and rising per capita incomes (FDRE PCC, 2008). Similarly Mekelle city is expanding by engulfing the rural farm lands in different time periods with the increase in human population.

The population of the study area has increased from 96938 to 215914 in 1994 and 2007 respectively. The spatial trend in expansion of Mekelle city is shown in Fig. 5. During 1984, the total area of the city was 1,600 hectares then after ten year in 1994 the total area of the city reached upto 2,304 hectares. The spatial growth trend of the city has become rapid after 2005, which was 13,000 hectares. This spatial growth is probably due to increased demand of land for the construction of residential housing as well as the provision of infrastructures in the city. The city is growing in to different directions without following any comprehensive planning guidelines. It is growing towards south, southwest, west and northwest directions. However, growth is limited in the east direction because it is shadowed by mountain Endayesus (Fig. 6).

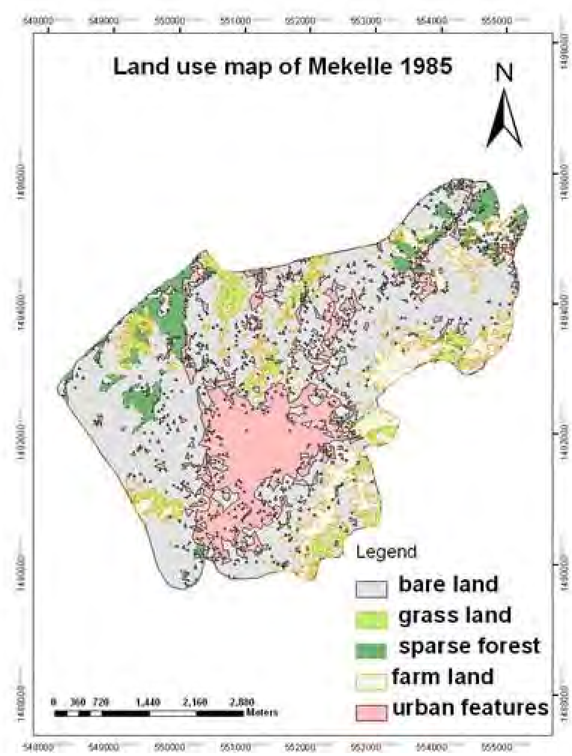

Fig. 3 Land use land cover map of Mekelle, Ethiopia during 1985.

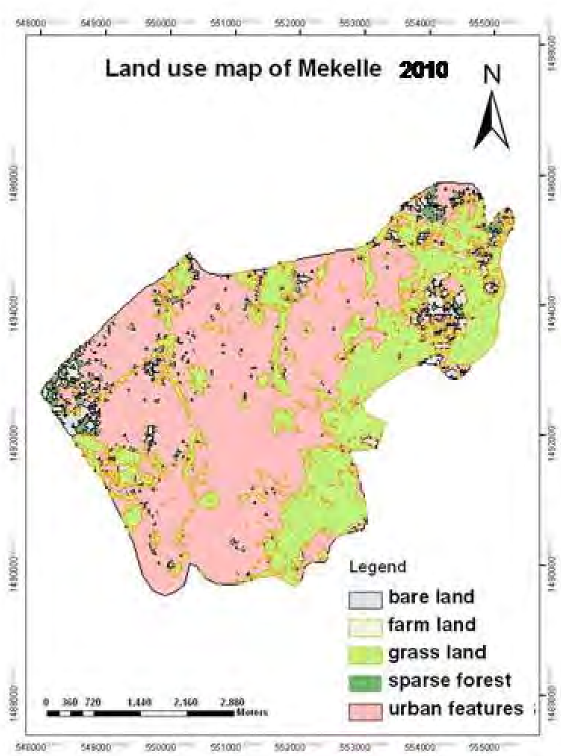

Fig. 4 Land use land cover map of Mekelle, Ethiopia during 2010.

Alike other developing nations, urbanization in Ethiopia particularly in Mekelle is not the product of agricultural and industrial development but due to rural "push" without the associated economic development (Yasin, 1999). Moreover, according to United Nation population estimation, the projected urban population in the country will be 26% by 2015 and 34% by the year 2025 (UN, 1987). This highly aggravated urban growth in Ethiopia and the corresponding demand for shelter and infrastructure will further engulf land available in the area (Mulugeta and McLeod, 2004). For instance, approximately four million unities per year (60%) will be needed in order to address the urban demand (UN-HABITAT, 2010). Likewise, due to high urbanization trend in Mekelle city the demand for land for residential housing will escalate from time to time. This finally causes high housing poverty in the city.

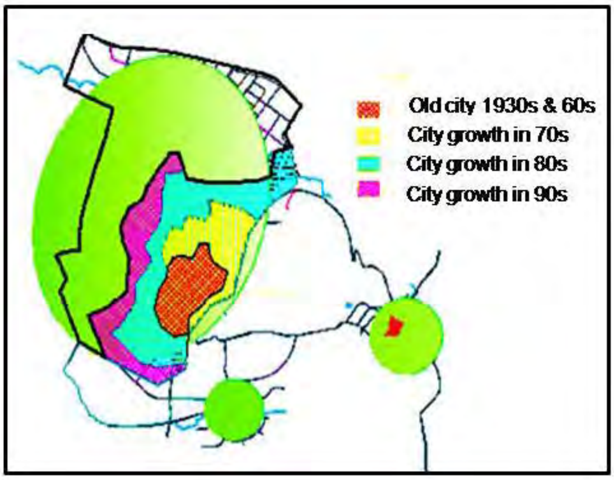

Fig. 5 Growth of Mekelle city, Ethiopia (source, Mekelle Municipality)

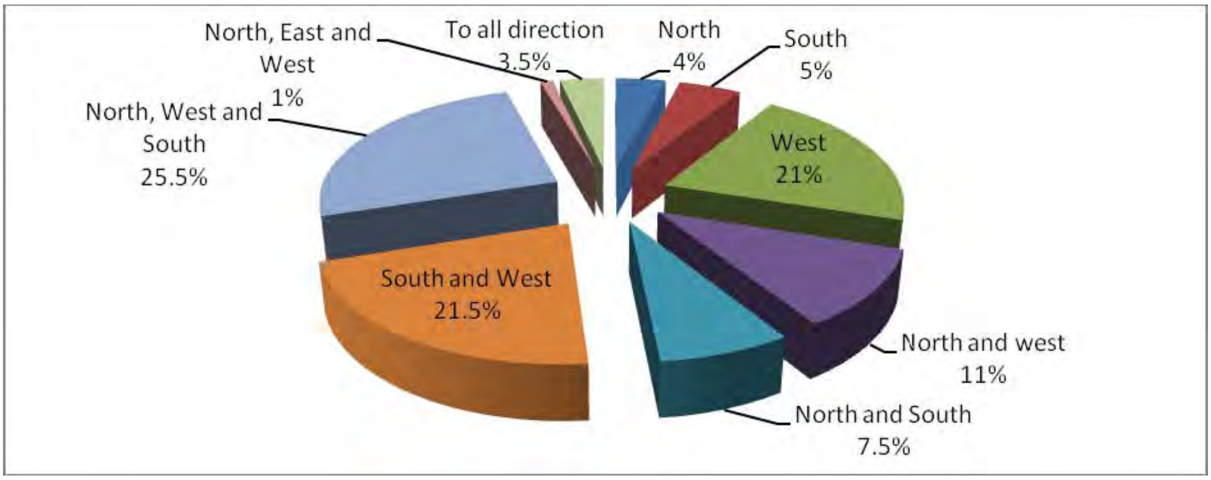

Fig. 6 Growth direction of Mekelle city, Ethiopia (Source: Mekelle Municipality, 2010)

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