Changes in Land-use, Land-cover and The Urban Sprawl in Gurage Zone, Ethiopia - A GIS and Remote Sensing Approach

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Abstract

Land-use and land-cover change (LULC) is a major issue in global environment change and is especially significant in rapidly developing regions in the world. With its economic development, population growth, and urbanization, Gurage, a major zone in Southern Nation Nationalities People Region (SNNPR), Ethiopia, has experienced a dramatic land-use and land-cover change-over from the year 1973 to 2010. LULC changes have resulted in degradation of its ecosystems and affected the environment. It is instantly needed to monitor its land-use and land-cover changes and to analyze the consequences of these changes in order to provide information for policymakers to support sustainable development.

KEYWORDS: urban sprawl; land-use, land-cover, LULC.

1. Introduction

Ethiopia is an agricultural country. The country is divided into zones. Gurage zone is in the southern part of the country. Most parts of Gurage Zone are heavily eroded. Farmers protect their enset (a banana type which is the staple food) fields with stone and soil bunds. During the 1930s, about 20% of the land in Gurage was covered with natural forests, which have since been almost completely cut down; the removal was especially fast during the years 1991 and 1992. In the early 1960s eucalyptus was grown on an increasing scale, which has increased the amount of land being covered with trees (Environmental Protection Authority, 1997).

The Central Statistical Agency (CSA), 2013 reported that 7,624 tons of coffee was produced in Gurage, Hadiya and Kembata Tembaro combined in every year, based on inspection records from the Ethiopian Coffee and Tea authority. That represents 3.36% of Ethiopia's total output. Mother Nature has to be occupied and used / utilized in the process. She has to be maneuvered sensibly, properly and optimally. This is give and take. We take responsibility in striking a balance between our needs for development and not disturbing our nature to a larger extent. Because it is our duty to create a better place for our future generations who will have to live and let live.

GIS (Geographical Information System) and (RS) Remote Sensing technologies are used to map and analyse the urban sprawl, LULC (land use and land cover) in Gurage Zone during 1973, 1986 and 2010. The research will supplement the offices of Urban Development, Agriculture, Forestry, Water and Municipality in course of urbanization and infrastructure development. For example, the satellite images and statistical data will enhance decision makers in Agriculture Department to identify suitable waste/scrub lands to be converted to suitable agriculture land.

Section 2 is a review of the works regarding LULC carried out previously. Section 3 focuses on the data collection and analysis methodology. The findings and interpretations are discussed in section 4. Section 5 and 6 provide a conclusion with an insight into the future possible work.

2. Literature Study

Information with respect to land-cover, their types, classes, density, quality and distribution, is of prime need for adopting conservation measures, eco-balance and planning-cum management aspect (Pant et al., 1992). These applications referred to urban expansion, and vegetation loss. At the same time, in the past decade, a major international initiative to study land-use change, the land-use and LULC (land-use and land-cover change) project, had gained great momentum in its efforts to understand driving forces of land-use change (mainly through comparative case studies), developed diagnostic models of land-use change, and produce regionally and globally integrated models (Lambin, 1997; Lopez and Bocco, 2001). As Houghton (1994) pointed out, the major reason of land use change was to increase the local capacity of lands to support the human enterprise. Yet, together with the "positive" changes – i.e., those that made land more productive- there were also unforeseen impacts that could reduce the ability of land to sustain the human enterprise. Today, localized changes around the world added up to massive impacts. Thus, it could be argued that even modest changes in land-use had some unintended consequences. So it was necessary to discuss the impacts of land-use change on society, environment and economy, especially economic growth in developing countries such as India, Ethiopia, China, etc.

Satellite remote sensing had been widely applied on detecting LULC change (Weng, 2002; Weng et al., 2003) especially urban expansion (Schneider et al., 2003; Weng, 2001), urban planning (Yeh and Li, 1998) and vegetation loss (Li and Yeh, 2004; Prenzel, 2004). Many change detection techniques, which were the processes of identifying differences in the state of and object or phenomenon by observing it at different times (Howarth, 1986; Singh, 1989), were used in these studies, such as image differencing, vegetation index differencing, selective principal components analysis, direct multi-date classification, univariate image differencing, image rationing, change vector analysis and post-classification and so on (Mas, 1999; Cho, 1999). At the same time, these were available in achieving different level of success in monitoring a variety of LULC changes (Fung, 1990; Dai and Khorram, 1999; Kaufmann and Seto, 2001).

Land-use land-cover classification is a time consuming and expensive process. Remote sensing though costly, offers a quick and efficient approach to the classification and mapping of land-uses/land-cover changes over space and time. Such studies are particularly important because the spatial characteristics of LULC are useful for understanding the various impacts of human activity on the overall ecological condition of the urban environment (Yeh and Li, 1999). LULC change due to human activities is currently proceeding more quickly in developing countries than in the developed world, and it has been projected that by the year 2020, most of the world's mega cities will be in developing countries (Sustainable Development Unit, 2007). In developing countries, where urbanization rates are high, urban sprawl is a significant contributor of the land-use change.

Information on changes in resource classes, direction, area and pattern of land-uses/land-cover classes form a basis for future planning (Sudhira and Ramachandra, 2007).

Major land-cover changes have also occurred at the local level for all land types. For instance, a significant increase in cultivated land at the expense of forestland was found to have occurred between 1957 and 1995 in the Dembecha area, northwest Ethiopia (Gete, 2000). Kebrom and Hedlund (2000) reported increases in open areas settlements at the expense of shrublands and forests between 1958 and 1986 in the Kalu area, north central Ethiopia. On the other hand, deforestation trend was reduced through appropriate interventions by promoting planting of local tree species in the Chemoga Watershed, Blue Nile basin, Ethiopia (Woldeamlak,2003) between 1957 and 1998.Similarly, Aklilu (2006) concluded that in the Beressa watershed (central Ethiopia), there were substantial land use changes in the area during the second half of the 20th century. The most important changes were destruction of the natural vegetation, increased plantations and expansion of grazing land. Cropland increased slightly in the 43 years period. Moreover, Bezuayehu and Geert (2008) reported that the decline of natural forests and grazing lands due to conversion to croplands between 1957 and 2001. In this respective period, crop lands increased from 403km2 in 1957 to 607 km2 in 2001- a net increase of 51% in Fincha' watershed. In addition, in Chirokella Micro watershed of South Eastern Ethiopia, the dense forest cover decreased by over 80%, the moderately forest land was completely transformed into other land-use and land-cover systems, cultivated and settlement lands increased by 62.8% and bushes and degraded land-cover categories showed increasing patterns of 49.9% and 100%, respectively between 1966 and 1996 (Mohammed and Tassew, 2009).

Keeping this in view, this research will focus on the urban sprawl, land-use and land-cover change in Gurage Zone using remotely sensed satellite data from 1976 to 2010. The survey will be conducted from 1973 to 2010 which will give an insight into the future development, urbanization and its impact on the geographical land of the study area.

3. Materials and Methods

3.1 Study Area

The study area covers about 5893.4 square kilometer and features altitudes between 1800 and 4000 M. Geologically, the region belongs to Ethiopia's south east highlands. The major soil classifications are Cambisols, silts, and Lithosols (Anonymous 1988). Mean annual temperatures range between 15 and 24°C. The study area (Figure 1 & 2) is located in Gurage Zone, one of the most densely populated zone in Ethiopia, with not less than 260 persons/km^2 (Socio economic bureau, 2014). Except for a small percentage of the population living in the urban area, the inhabitants are farmers engaged in crop production and livestock rearing. (Anonymous 1988). The study area is located between 7° 81' 0"N and 8° 27' 0"N latitudes and between 37° 25' 0"E and 38° 45' 0"E longitudes. This area forms a part of SNNPR, Ethiopia.

Fig. 1: Physical Map of Ethiopia

Fig 2: Gurage zone

3.2 Data Sources

Spatial data like toposheets and LANDSAT images of Gurage zone were collected from Ethiopian Map Authority (EMA), Addis Ababa. Non-spatial data were collected from Central Statistical Agency (CSA), Addis Ababa, Department of Urban Development, Wolkite,Department of Agriculture and Water, Wolkite, Department of Forestry, Wolkite, Municipal Corporation, Wolkite and Socio-economic Bureau, Wolkite.

3.3 Methodology

Multi-temporal images have been used for land-use mapping and change detection LANDSAT images were enlarged in ArcGIS and projected on the viewing table as false colour composite images on 1:50000 scale for interpretation. The land-use land-cover categories interpreted were verified in the field and boundaries of the different land-uses land-covers finalised. The boundaries of land-use and land-cover classes for the years

1973 and 2010 have been compared from the images (Adeniyi, 1980) and the differences were identified. The new boundaries indicated the changes in land-uses and land-covers which have been mapped separately. Using digital image, areas under each category (Settlement, water-body, vegetation and dryland) have been calculated (Bhagawat, 2011). Thus, the trends, patterns and direction of changes in land-use land-cover have been detected.

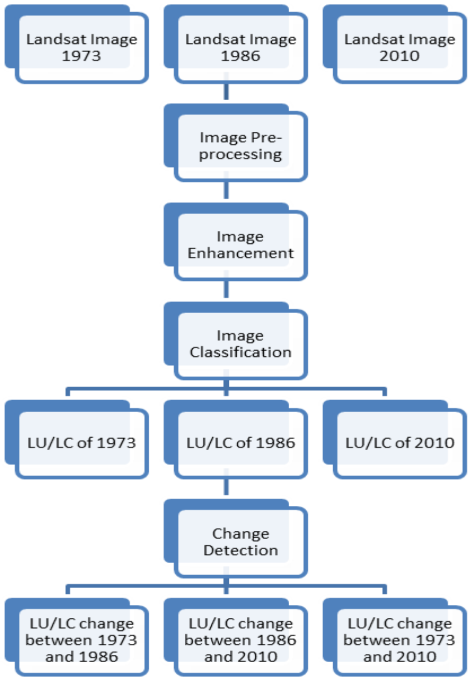

Fig: 3 Architecture diagram of the general methodology of LULC

3.4 Research tasks

The images were geo-referenced. The area of Gurage zone is approximately 5893 $Km^{2.}$ The changes in land-use and land-cover changes were analyzed on the image. Also, the task is to analyze and compare spatial and non-spatial data. We will investigate the impact of urbanization and land sprawl on natural resources. Finally to portray digitized maps and consolidated data comparing 35 years of land-use and land-cover change in study area.

3.5 Data analysis

The implementation tool is MS – ArcGis 10.0. LANDSAT multi-temporal images of Gurage Zone were classified using ArcGis 10.0 software. The Spatial-data / Satellite images of the study-area were geo referenced using ArcGis 10.0 software (Rawat and Manish Kumar, 2015). Using the images, thematic layers were prepared by ArcGis 10.0 software. Geo-Data-bases were created for the data collected using ArcGis 10.0 software (Elgammal *et al.,* 2010). Urban sprawl, land-use and land-coverage Gurage Zone, Ethiopia had been estimated for the years 1973 and 2010. Digital Maps, charts and tables had been generated on natural resources and the land-use and land-coverage of the study area.

4. Results and Discussions

Areal estimates obtained from the LANDSAT for 1973. Table presents the changes detected using the remotely sensed data for 1973, 1986 and 2010.

Vegetation area: During the period between the three photographs (1973–2010), a major portion of the study area was under cultivation (Table 1 , Figure 4,6 & 8). However, contrary to general expectations, there was a drastic reduction in the cultivated areas (with decrease of 23.1%). Transformation was largely into remaining dryland and settlements areas (Table 4). However, the loss of cultivated areas was partially explained either the areas left uncultivated were not suitable for cultivation or they were under settlement for rural and urbanization. There has also been a decline in the vegetation areas, from 2209.78 Km2 (year 1973) to 1699.045 Km2 (year 2010).

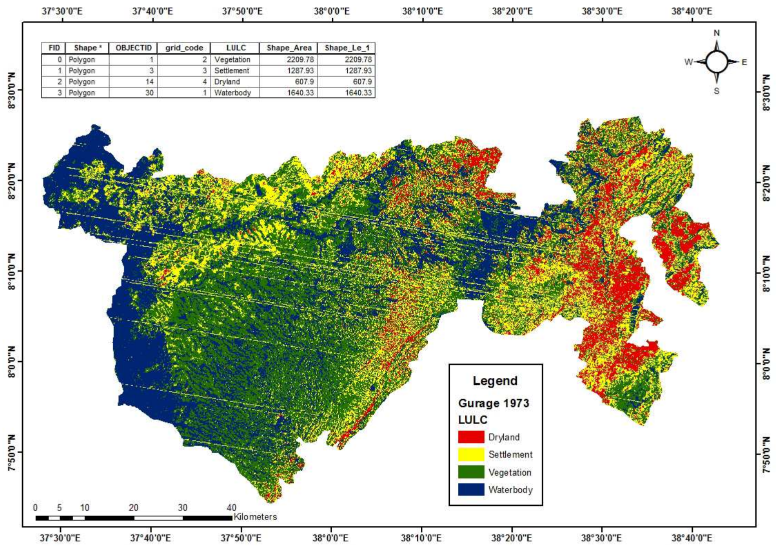

Fig: 4 LULC of Gurage Zone, 1973

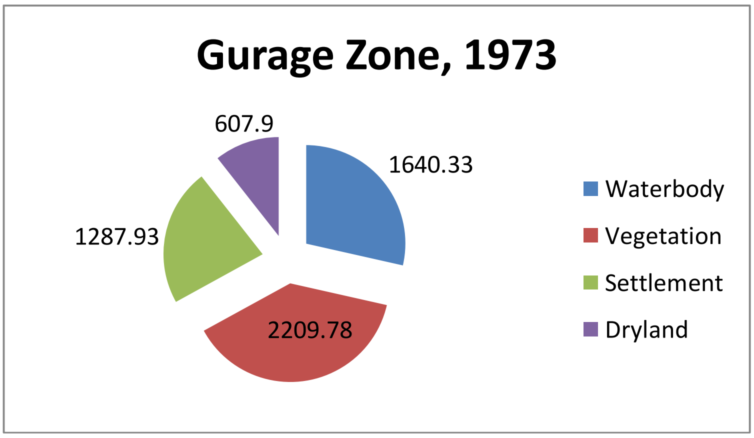

Fig: 5 Percentage of LULC of Gurage Zone, 1973

Dryland area: Considerable change was observed among the dryland areas, with an increase of 322.41 km 2 , or 53.03%, from 1973 to 2010 (Table 1 and Fig. 10). About 10.58% of the dryland areas in 1973, while in the year 2010, it was 16.17% among other lands coverage. Conversely, the total rate of change of other land categories into dryland was so high (53.03%) that it outbalanced this loss by far (Table 1). Harvesting of fuelwood and settlement area must have contributed to the deterioration of vegetation land.

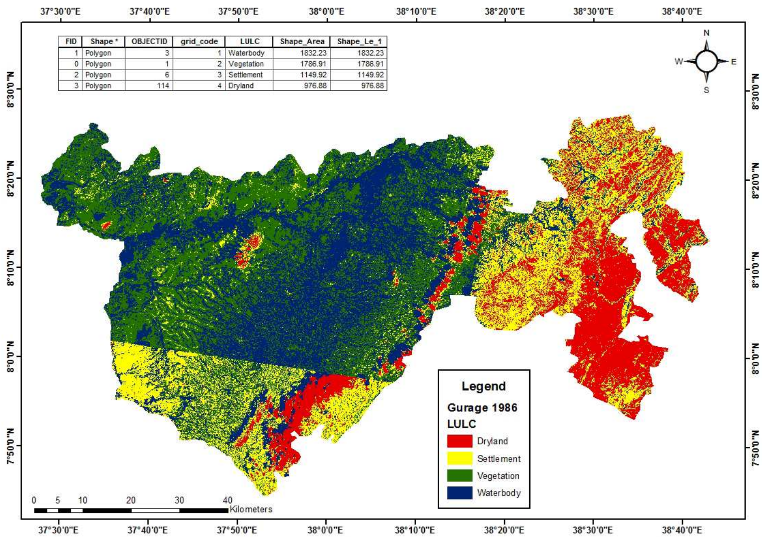

Fig. 6 : LULC of Gurage Zone, 1986

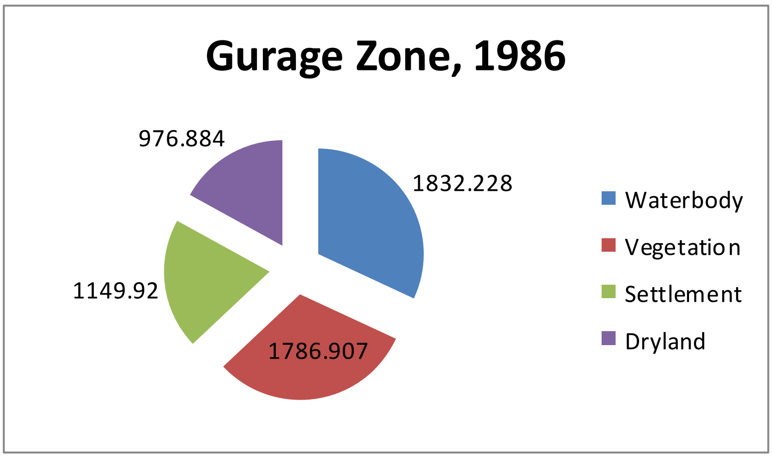

Fig. 7 Percentage of LULC of Gurage Zone in 1986

Water-body: The water-body coverage in the study area between 1973 and 2010 (Table 1) had been observed slightly increased in the percentage of 2.53. Only 28.54% of water-body coverage was in 1973 among other land-coverage. The increase of water body coverage area from 28.54%to 31.99% in the year 1973 to 1986 was observed respectively. But this conversion was low so that, on balance, a net increase of about 2.53% of water body areas was observed (Fig. 4, 6 & 8). The area covered by urban settlements increased by 41.501 km^2 in 37 years (Fig. 10).

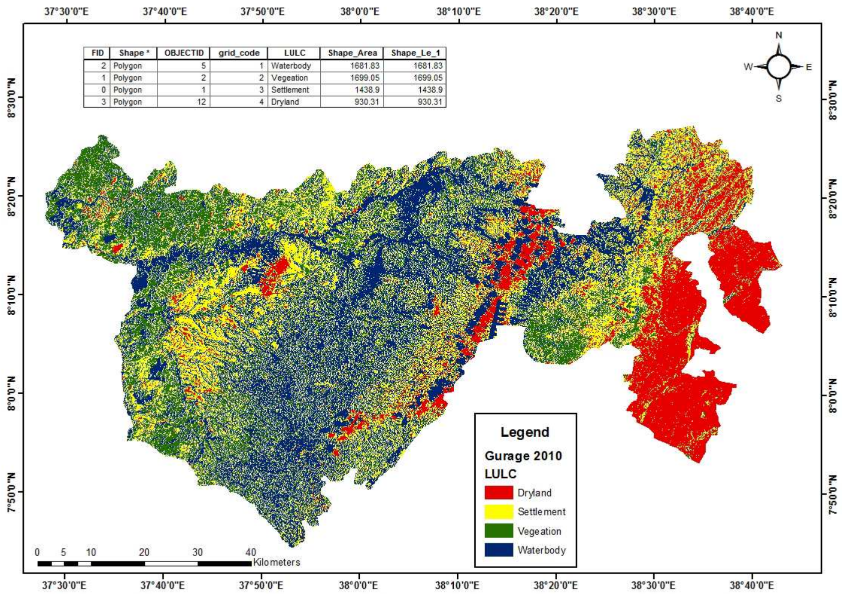

Fig: 9 LULC of Gurage Zone in 2010

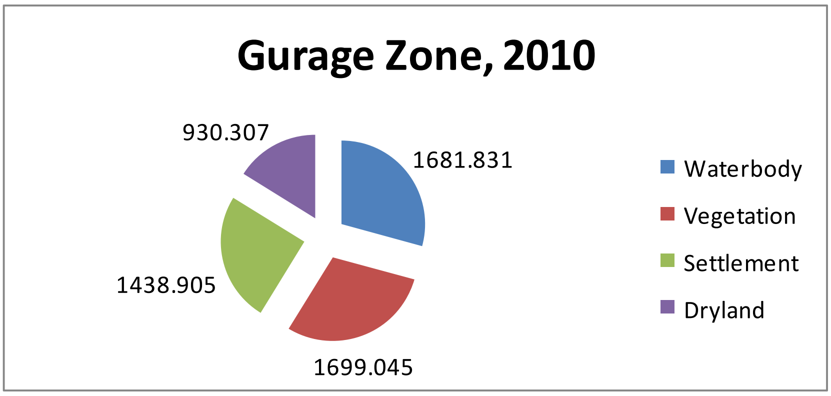

Fig: 10 Percentage of LULC of Gurage Zone, 2010

Settlements: Area covered by during the period settlements increased by 150.98 km 2 (11.72%) between 1973 and 2010 (Table 1). About 22.41 % of rural settlements in 1973 among the land-coverage while in the year 1986, it changed into 20.08 % . On the other hand, conversion of settlements was excess in the year 2010 (25.02% among the land-coverage (Fig. 10). The increase in settlements occurred mostly on hill slopes that are not suitable for cultivation.

S.No .	Land-use Land-cover	Years			Rate of Change (Km^2/year)					
		1973	1986	2010	1973 to 1986	%	1986 to 2010	%	1973 to 2010	%
1	Water body	1640.33	1832.228	1681.831	14.76138	0.899903	-11.569	-0.63142	3.192385	0.194618
2	Vegetation	2209.78	1786.90	1699.045	-32.5292	-1.47206	-6.75808	-0.3782	-39.2873	-1.77788
3	Settlement	1287.93	1149.92	1438.905	-10.6162	-0.82428	22.22962	1.93314 5	11.61346	0.901715
4	Dryland	607.9	976.884	930.307	28.38338	4.669088	-3.58285	-0.36676	24.80054	4.079707
	Total *	5745.94	5745.932	5750.088	86.29016		44.13955		78.89369	

Table: 1 Land-use land-cover classes and rate of change in between 1973 and 2003

* Rate of change in percent is calculated as change in between the two study years per total change of these years divided by the time interval times 100.

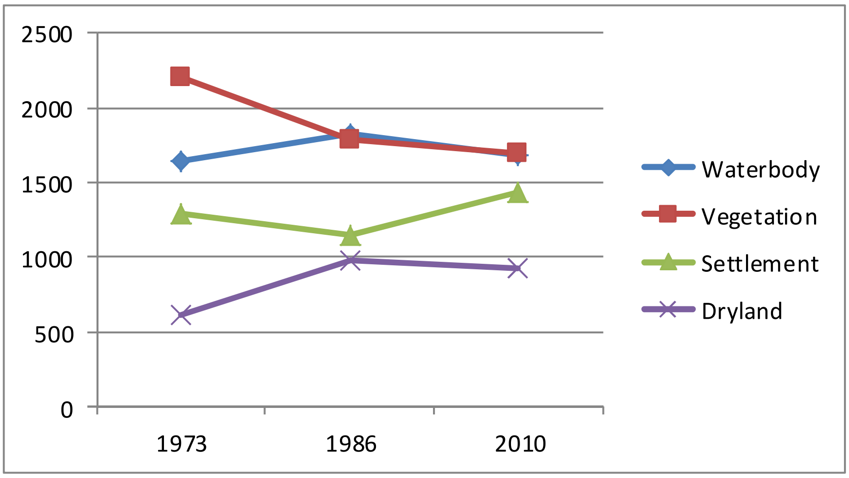

Fig 11: Overall comparison of Gurage Zone LULC from 1973 to 2010

Land transformation is explicitly shown in figure 5,7 & 9. in the which are in Gurage area, the changes detected in vegetation covered area to dryland and settlement areas. Crop land to built up area is wide-spread and is almost found everywhere.

5. Conclusion

The results of the study suggest that the analysis of sequential satellite data offers means of extraction of information on land-use land-cover. In fact, for shorter intervals satellite data are very helpful for the detection of land-use land-cover changes, due to repetitive coverage at very short intervals.

6. Challenges and the Way Forward

Every research is a leap of opportunities with challenges. In this research, we faced so many challenges. We try to point out some of them here,

1. Latest data like Landsat images for 2015 was not available.

2. For better resolution and clarity and interpreted SPOT are preferable. But the cost of SPOT images is too much.

3. The time frame restricted the study to Gurage zone. The study on Wolkite town will be continued in the near future.

Way Forward:

This work is the first step towards web-mapping of Gurage zone. We propose to follow the 'Top down approach' towards analysis and classification of land-use and land-cover and urban sprawl. The individual main cities will be classified on supervision.

The Top-Down approached in proposed to bring down the error rate systematically which will pave way for a web map of Gurage zone with the least error.

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