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Land Use Land Cover Change Dynamics of Jigjiga Town and Toga Watershed: Using GIS and Remote Sensing Technique

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ABSTRACT

Understanding the current land use and land cover dynamics will help to project the future changes and to initiate more appropriate policy interventions. This paper mainly focused on examining the land use land cover change dynamics of Jigjiga town and Toga watershed, of Somali regional state of Ethiopian by using GIS and remote sensing techniques. A qualitative and quantitative approach method was applied and satellite images of LANDSAT-7 and LANDSAT- 8 for the year 2003 and 2017 were downloaded from Earth Explorer website. Agricultural land, bare land, shrub/bush/tree, grass land, built up area and water body are the major land use land cover classes exist in the area. The LULC change detection map of both Jigjiga town and the study watershed show similar trend in most LULC change. However, the decreases in grass land and shrub/bush/tree cover were observed in the town as opposed to the study watershed. The expansion of built up area indicates the population number is increasing highly and the current urbanization policy is contributing for its expansion. On the other hand grass land and shrub land areas of the study watershed shows fluctuations and this ismay bethe similarity of spectral reflectance patterns of the grass lands and bare lands or the bare lands changes to grass lands and shrub lands. Population pressure, urbanization, fuel wood extraction and charcoal making, agricultural land expansions and overgrazing are the most drivers of land use and land cover dynamics of the study town and watershed. This shows major changes in the socio-ecological driving forces will affect the landscape dynamics of the study area. Therefore proper land use planning in both urban and rural areas of the study area is important to consider in the future.

Keywords: *Jigjiga town, LULC, GIS, Drivers*

Introduction

Land cover is the physical and biological cover of the surface, while land use is the total of arrangements, activities and inputs that people undertake in a certain land cover type. Land use and land cover changes have significant environmental consequences at local, regional, and global scales. These changes have intense implications at the regional and global scales for the loss of biodiversity, distresses in hydrological cycles, increase in soil erosion, and sediment loads [1].

LULC dynamics are widespread, accelerating, and significant processes majorly impelled by human actions and at the same time resulting to changes that impact human livelihood [2]. Human beings modified natural environments to obtain food, fiber and other essentials for several thousands of years. But today, the rates, extents and intensities of human pressure on land is by far greater than before, affecting the status, properties and functions of ecosystems, which in turn affect the provision of ecosystem services and hence human well-being [3].LULCC interrupts the ability of natural systems to support human needs and increase the exposure of people and resources to climate change, socio-economic crises, and political worries by reducing ecosystem services [4,5]. Additionally, local and global LULCC has increased in recent years [5, 6]. Due to those reasons, the study of LULCC has become an important research topic in recent years [7-11]. Studies have shown that LULCC has been intense in the highlands of Ethiopia. In particular, the expansion of intensive agriculture, urbanization, and extraction of forest products are accelerating over time to meet the requirements of an increasing population [7,9,12]. Because of the rising population over the years, lots of pressure has been imposed on the land resources in Ethiopia where approximately 80% of the population engages in agriculture but only 15.1% of its land is arable. As a result, the shortage of arable land has led to expansion of cultivation into the wetter margins of rangelands, deforestation and decline of grassland as a result of overgrazing, charcoal burning and other unsustainable land uses. The drivers of LULCC include social, economic, biophysical, and political factors [7, 13].

The human and livestock population, different agricultural practices, urbanization, drought prevalence, and poor land-use planning have been reported as the main drivers of LULCC in Ethiopia. However, different places have different driving factors and consequences. For example, overgrazing and charcoal productions are the dominant driving factors in Afar and Somali regions of Ethiopia [11], while forest grabbing for investments, settlements, poor law enforcement, shifting cultivation and land tenure policy has been significant drivers in south western Ethiopia. Therefore LULCC analysis has become an important tool to generate evidence for decision-makers, spatial planners, local communities, or actors, who are operating within a given landscape to formulate appropriate policies and strategies, generate data for spatial planning, and develop detailed land use plans as well as understand agents of change. Therefore, this study tries to provide an in-depth understanding of the patterns of LU dynamics, for planning appropriate land management in the study area.

Materials and Methods

Study Area Description

The study area is located within the Shebelle Basin, Jigjiga town, and its area is about 8500 ha. It is located at 9.420 N to 9.270 N latitude and 42.740 E to 42.840 E longitudes. The elevation of the study area ranges from 1597 m to 1750 m above mean sea level. The Shebelle Basin includes the Jigjiga sub-watershed, whose tributaries originate from the upper escarpments of the Bale Mountains and West Hararghe of Oromiya National Regional State (ONRS) and the highland parts of Ethiopian Somali Regional State.

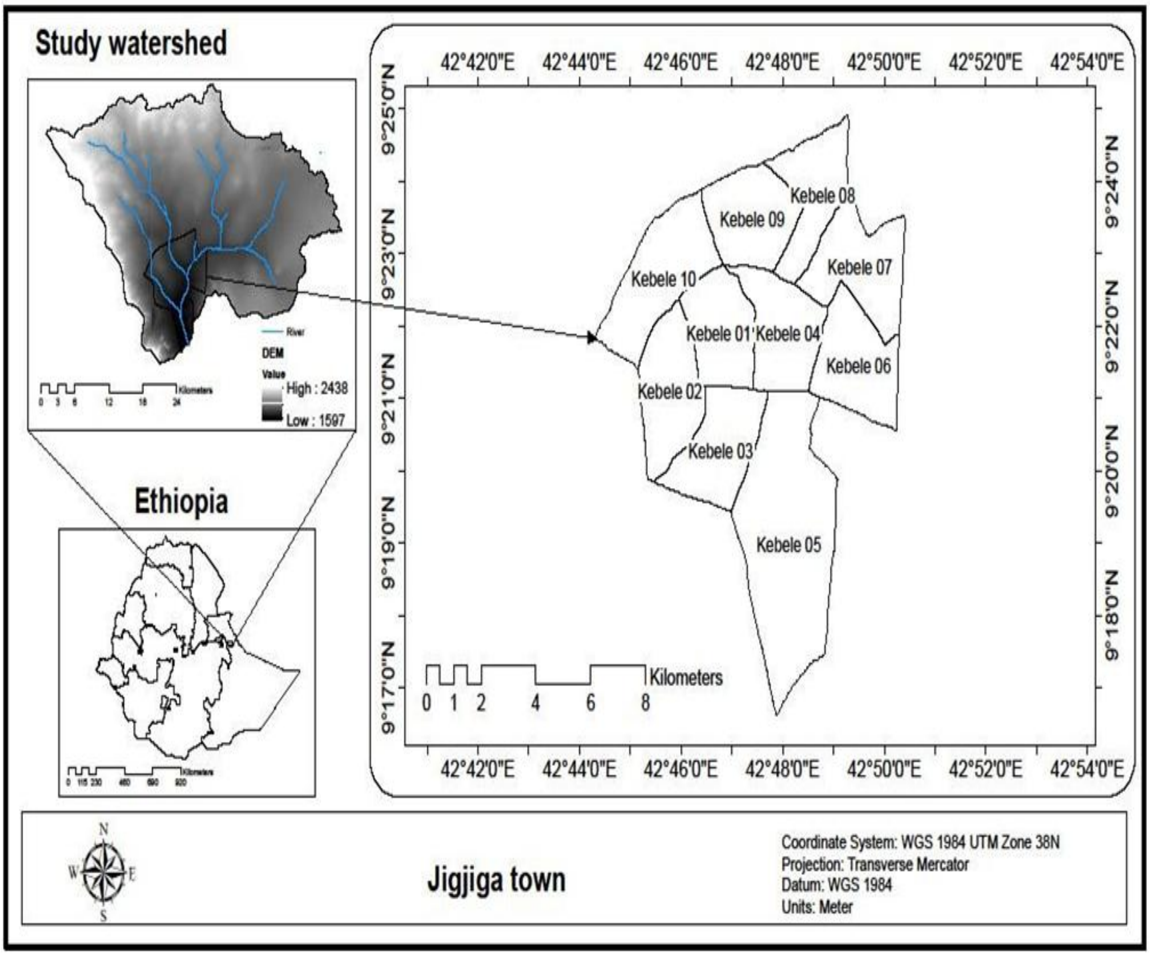

Figure1. *Map of the study area*

Based on projections made by the Central Statistical Agency (CSA), the 2017 population of Jigjiga town has been estimated at about 169,390 (Ministry of Urban Development, Housing and Construction [MUDHCo, 2015]. The mean monthly temperature of Jigjiga town varies from 15.2°C to 27.73°C in December and April respectively. The hottest month is May while December is the coldest month. The average annual temperature of the town is 20.4°C. The mean annual rainfall of Jigjiga town is 523.48 mm. The mean monthly amount of rainfall varies between 7.13 mm and 103.11 mm in December and April respectively (NMA, 1984- 2016).

Data Source and Methodology

Due to the complex nature, it is difficult to use a single research design to analyze LULC change. Hence, a mixed design that includes qualitative and quantitative approaches was applied for this research due to its importance for triangulation of sources and interpretation. The primary data from the satellite images of LANDSAT-7 and LANDSAT- 8 for the year 2003 and 2017 were downloaded from Earth Explorer website. After acquiring the required images, band stacking and removing background color were conducted and normalization were done for change detection analysis. Conducting unsupervised classification were done to select sample locations for supervised classification and these locations were selected from each class and recorded in to hand held GPS. Then, a classification scheme was developed for the study area and image enhancement was done by using Normalized Difference Vegetation Index (NDVI), Normalized Bare Land Index (NBLI) and combination of the two enhancements. The secondary data were generated through interview and Maximum Likelihood Classification (MLC) method was performed to collect valuable data.

Table1. *Characteristic of Landsat used*

No	Data type	Date acquired	Resolution	Source
1	LANDSAT7	2003-02-15	30m^{ETM}	USGS Earth Explorer
2	LANDSAT8	2017-01-12	30m^{OLI}	USGS Earth Explorer

Radiometric correction

Before performing image classification and change detection analysis of remote sensing data, it is important to pre-process (normalize the images) the data to correct the error that may occur during scanning, transmission and recording of the data [14].

Hence, radiometric correction method is the most appropriate technique to correct the data sensor irregularities and compensating the effects of atmosphere through histogram equalization, haze and noise reduction.

The method involves two steps, taking the Digital Number (DN) values in each pixel and converting them to radiance and reflectance. This also helps to make comparison between images.

In order to improve the quality of the image, the spatial resolution of each year image was enhanced using panchromatic image by applying a High Pass Filter (HPF) algorithm as proposed by [15]. Then suitable band selection of different false color composite images was done to enhance the raw satellite image for identification of different land cover classes in the study area.

Post Classification

After conducting supervised classification, some errors were cleaned by post classification techniques. These include, for instance, majority filter change the classification of small, isolated patches in the classified layer to that of the majority of neighboring cells.

Whereas boundary clean tool will smooth the boundaries between patches of the classified images. Then small patches are removed and assigned values to the nearest cell using region group, nibble and set null tools.

Image Classification and Accuracy Assessment

Supervised and unsupervised image classification systems were performed to produce land use and land cover maps of the study area from land sat images. Land use and land cover classes of the study area were determined based on the information acquired from unsupervised classification and field observation. Then the Landsat images of each study year were classified independently with supervised classification technique. Based on data collected from field, Google Earth map, and interview, which were not used for classification purpose, error matrixes were produced. This matrix helps to compare the relation between known reference data (ground truth) and the corresponding results of the classification. Based on the confusion matrixes overall, user's and producer's accuracies were calculated. Similarly, omission and commission errors and kappa coefficient also calculated based on these matrixes using Cohen (1960) formula.

Results and Discussion

Accuracy Assessment Result

The overall accuracy assessment and Kappa coefficient of the year 2017 Jigjiga town classified image is found to be 87% and 0.81 respectively. Classification and accuracy assessment have also been conducted using ENVI 4.7 and the result shows that similar overall accuracy and Kappa value as Arc GIS classified image. The overall accuracy assessment result of the year 2017 study watershed image is found to be 83% and Kappa coefficient of 0.75. Land use land cover classification result of the year 2003 town and watershed images show that an overall accuracy of 86.9% and 83.5% and Kappa coefficient of 0.79 and 0.71 respectively.

Land Use Land Covers Classification result

Based on the 2003 LULC map of Jigjiga town (Figure 2a), the town was dominated by bare land and agricultural land. The bare land covered 54.1 km2 and it occupied 63.73% of the town. Agricultural land was the other class that dominated the study town following bare land. Agricultural land covered about 19.59% of the study area (16.63 km2). The area covered by the remaining classes, grassland, built up area, shrub/bush/tree and water body was 7.40 km2, 5.86 km2, 0.81 km2 and 0.09 km2 respectively. These represent 8.71%, 6.91%, 0.96% and 0.10% respectively.

In 2017 bare land area covered 43.58 km2 and consisted 51.31% of the total study area. Agricultural land, built up area, grass land, and shrub/bush/tree area covered 22.84 km2, 14.01 km2, 3.92 km2 and 0.5 km2 respectively. The class that covered smallest area as similar to 2003 LULC was water body and it occupied 0.09 km2.

Table2. *LULC classification result of Jigjig a town in2003&2017*

LULC	2003		2017	
	Area(ha)	Area (%)	Area (ha)	Area (%)
Agricultural land	1663	19.59	2,284	26.89
Bare land	5411	63.73	4,358	51.31
Shrub/bush/tree	81	0.96	50	0.59
Grass land	740	8.71	392	4.62
Built up area	586	6.91	1,401	16.49
Water body	9	0.10	9	0.10

The major LULC classes identified in the study watershed in 2003 (Figure 2b) was bare land and agricultural land. Interims of area coverage, about 57.31% (552 km2) and 26.13% (252 km2) of the study watershed were covered by bare and agricultural lands respectively. Following these classes, grass land, shrub/bush/tree, built up area, and water body covered the remaining watershed with aerial coverage of 115 km2, 27 km2, 18 km2 and 0.34 km2 respectively.

Whereas in 2017 agricultural land was the major class, which covered about 389 km2, while about 366 km2of the study watershed covered by bare land.

The remaining part of the study watershed covered by grass land (132 km2), shrub/ bush/tree (42 km2), built up area (33 km2), and water body (0.38 km2).

Table3. *LULC classification result of the study watershed in 2003 &2017*

LULC	2003		2017	
	Area(ha)	Area (%)	Area (ha)	Area (%)
Agricultural land	25,166	26.13	38,918	40.41
Bare land	55,190	57.31	36,643	38.05
Shrub/bush/tree	2,701	2.80	4,190	4.35
Grass land	11,445	11.88	13,157	13.66
Built up area	1,771	1.84	3,335	3.49
Water body	34	0.04	38	0.04

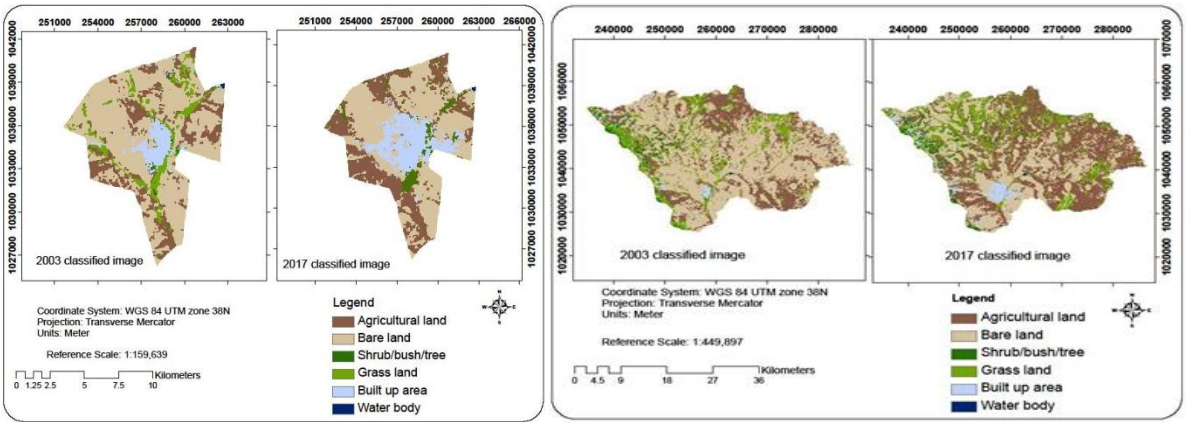

Figure2. *Classified image of Jigjiga town and the Study watershed (2003 and 2017) respectively*

Change Detection Analysis

Change detection analysis has been conducted for both Jigjiga town and the whole study watershed between the year 2003 and 2017. By combining the two year classified images, change detection maps were produced (Figures 4). Aerial coverage of agricultural land and built up areas in Jigjiga town were increased by36.91% (6.16 km2) and more than 100% (8.12 km2) respectively at the expense of bare land, grass land and shrub/bush/tree cover. In contrast, bare land, grass land and shrub/bush/tree cover were decreased by 19.42% (10.5 km2), 46.74% (3.46 km2) and 37.16% (0.31km2) respectively. Water body coverage almost remained constant between the change detection years.

Table4. *Pivot transition (2003 to 2017) matrix table of Jigjiga town*

	Area (%)	**Final state(2017)**						
	Row Labels	**Agricultural land**	**Bare land**	**Shrub /bush/tree**	**Grass land**	**Built up area**	**Water body**	**Grand Total**
Initial State(20113)	Agricultural land	11.52	5.40	0.10	0.51	2.10	0.00	19.63
	Bare land	11.86	42.40	0.24	1.81	7.30	0.00	63.61
	Shrub/bush/ tree	0.10	0.40	0.11	0.08	0.29	0.00	0.98
	Grass land	3.32	2.23	0.12	2.18	0.90	0.00	8.75
	Built up area	0.08	0.83	0.05	0.09	5.88	0.00	6.93
	Water body	0.00	0.00	0.00	0.00	0.00	0.10	0.10
	Grand Total	26.88	51.26	0.62	4.66	16.47	0.11	100.00

Like the town, the bare land areas of the study watershed were decreased by 33.6% (186 km2). Besides, both agricultural land and built up areas were increased by 57.7% (138 km2) and 89.5% (15.9 km2) respectively. On the contrary to the town, the grass land and shrub/bush/tree cover of the study watershed increased by 14.9% (17 km2) and 55% (14.9 km2). Slight increment in water body coverage was also observed in the study watershed.

Table5. *Pivot transition (2003 to 2017) matrix table of the study watershed*

	Area (%)	**Final state(2017)**						
	Row Labels	**Agricultural land**	**Bare land**	**Shrub /bush/tree**	**Grass land**	**Built up area**	**Water body**	**Grand Total**
Initial State(20113)	Agricultural land	17.75	2.89	0.98	4.01	0.50	0.00	26.13
	Bare land	18.63	30.89	0.46	6.01	1.32	0.00	57.31
	Shrub/bush/ tree	0.14	0.69	1.55	0.30	0.13	0.00	2.81
	Grass land	3.63	3.06	1.13	3.20	0.87	0.00	11.89
	Built up area	0.26	0.52	0.24	0.15	0.66	0.01	1.84
	Water body	0.00	0.00	0.00	0.00	0.00	0.03	0.03
	Grand Total	40.41	38.05	4.36	13.66	3.48	0.04	100.00

Generally, the LULC change detection map of both Jigjiga town and the study watershed show similar trend in most LULC change. However, the decreases in grass land and shrub/bush/tree cover were observed in the town as opposed to the study watershed. The expansion of built up area indicates the population number is increasing highly and the current urbanization policy is contributing for its expansion. Ultimately, this indicates, as the level of urbanization in the town is higher. The spread of this urban area in a horizontal direction has resulted in the loss of scattered trees and a general decline in the spatial extent and connectivity of non-built-up land use classes. Since most part of the study watershed is rural, it is less affected by urbanization. As a result, shrub/bush/tree and grass land were increased in the watershed.

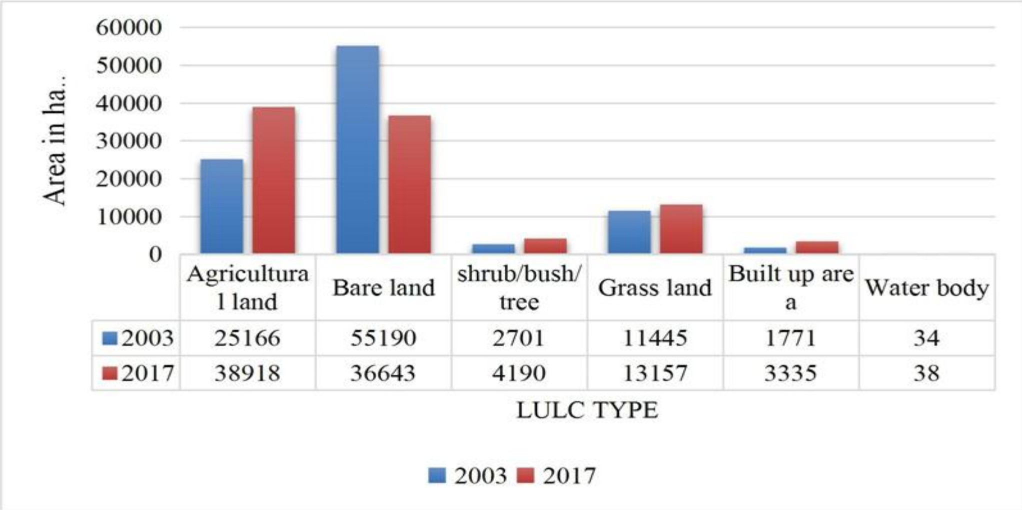

Figure3. *Aerial coverage of LULC in 2003 and 2017(Study watershed)*

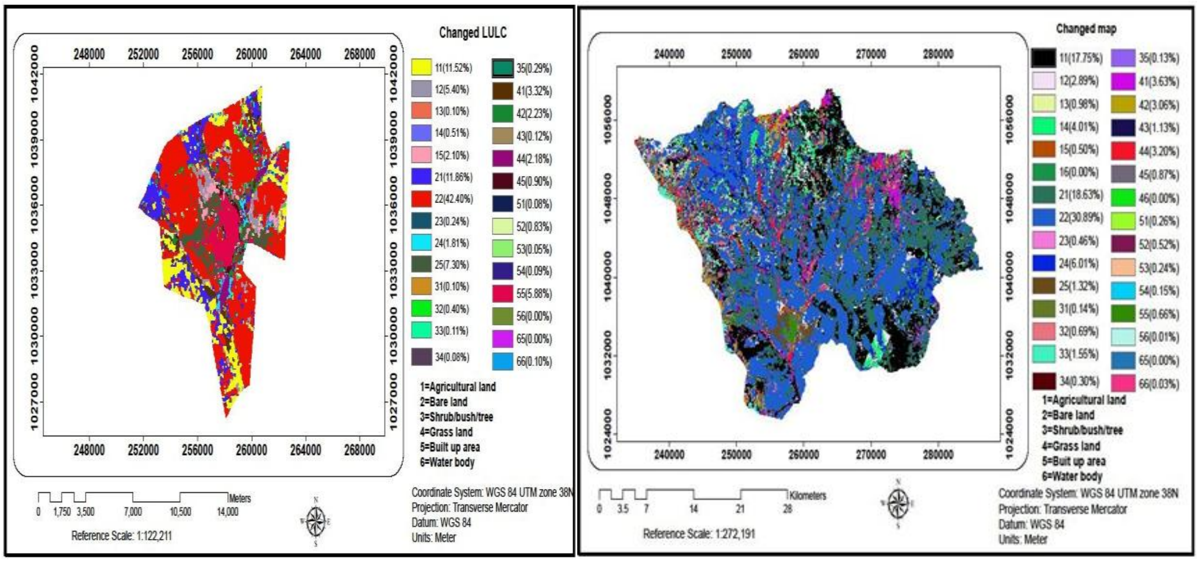

Figure4. *Change detection map of Jigjiga town & the study watershed (2003 and 2017) respectively*

Major Drivers of Land Use and Land Cover Dynamics

The LULC dynamics in the study area largely depend on dynamic relationships among population and policy/ institutional factors, but the effect of natural factors such as climate over small area and short periods of time may not felt as such.

Population Pressure

During 1994 population and housing census of Ethiopia, the total population of the Jigjiga town was 112,345 in 1994 showing an increase of above 70.8% over the population of 65,795 in 1994 whom 33,266 were men and 32,529 women [16]. Based on projections made by the Central Statistical Agency (CSA), the 2017 population of Jigjiga town has been estimated at about 169,390. It is obvious that population growth can directly or indirectly accelerate the action of other drivers on LULC [17]. This means, as the population increases the use of natural resources will increase simultaneously. Therefore the population growth in the study area is certainly the greatest driving force in the observed land use/land cover dynamics particularly built-up areas.

Urbanization

The other deriving factor for such high level of land use and land cover is the expansion of urbanization. From the projection in CSA 2013, the total population of Somali region will be 5,748, 000 of whom 14.6% live in urban area whereas the remaining 85.4% live in rural area [18]. This rural-urban migration accelerates the expansion and construction of built-up areas either industrial or residential. From the result in table 2 and 3, the built up area of the town shifts from 586 ha in 2003 to 1401ha in 2017 and in the watershed also the built up area increases 1.65%. Whereas the land holding area of bare land, shrub land and grass land of the Jigjiga town shows a radical decreasing trend from 2003 to 2017. From this we can conclude that, those land uses are changed to settlement areas.

Fuel Wood Extraction and Charcoal Making

Key informants and focus groups also mentioned that access to electricity is almost none in the rural area of the study watershed, and hence as a result of this charcoal making and fuel wood extraction are the key factors contributed to the depletion of forests of the study watershed. Coupled with the lack of access to alternative energy sources, for example, rural electrification, fuel wood extraction and charcoal making are the potential drivers of LULCC in Ethiopia. Studies show that as of 2010, about 89% of energy source in the country dependents on biomass-based sources mainly firewood, charcoal, crop residue, and cow dung [19, 20].

Agricultural Land Expansion

Previous studies shows, population growth and subsequent agricultural land expansions are the major driver of rapid LULC dynamics in Ethiopia [21, 22]. Other studies in developing countries, where the economy is directly dependent on natural resource, similarly reported population growth and resultant cropland expansion as important drivers of LULCC [23, 24]. In line with this argument, 89% of the key informants indicated that, an increase in population from time to time has led to reduced rural farmland holding size and subsistent farming. This, in turn, led to subsequent agricultural land expansion to feed the ever-growing demand for more cultivable lands, which is another driver of LULCC.

Overgrazing

In pastoral areas, livelihoods of the people entirely depend on extensive livestock production with little or no cropping [25]. In Ethiopia, the pastoral production systems are practiced in the arid and semi-arid lowland areas. The numbers of livestock in pastoral areas account for 42% of the country's livestock in the lowland arid and semi-arid regions [26]. The CSA 2017sample survey report indicates that there are 589,503 of cattle's, 1,360,703 sheep's, 2,826,424 Goats and 249,475 Camel in Somali national regional state. As forage availability of the area considers small, the area expected to be overgrazed. Overgrazing refers to grazing of land beyond its carrying capacity that can affect the land by both deteriorating soil physical structures and by removing vegetation coverage which exposes the soil to erosion and excessive drying and expands barren lands [27]. Therefore overgrazing is the other important forcing driver of LULCC in the study area.

Conclusions

This study was conducted to examine the land use land cover change dynamics of Jigjiga town and Toga watershed. Assessing the magnitude, biophysical and socioeconomic driving forces and implications of LULC change of the study area in the past two decades also the other issues addressed in the document. The classification results shows, the techniques and satellite imageries employed for the analysis were effective in extracting land cover classes for change detection. It is possible to behold that the developed Land use land cover schema was appropriate for the study area since there is no significantly unclassified area detected on the developed land use land cover map of the study. Beyond this the accuracy assessment result indicates as the result from the analysis is acceptable making the overall analysis a good indicator of the actual land cover classes in the area. The LULC change detection map of both Jigjiga town and the study watershed show similar trend in most LULC change. However, the decreases in grass land and shrub/bush/tree cover were observed in the town as opposed to the study watershed. The expansion of built up area indicates the population number is increasing highly and the current urbanization policy is contributing for its expansion.

Ultimately, this indicates, as the level of urbanization in the town is higher.

The spread of this urban area in a horizontal direction has resulted in the loss of scattered trees and a general decline in the spatial extent and connectivity of non-built-up land use classes. Since most part of the study watershed is rural, it is less affected by urbanization. As a result, shrub/bush/tree and grass land were increased in the watershed. Population pressure, urbanization, fuel wood extraction and charcoal making, agricultural land expansions and overgrazing are the most drivers of land use and land cover dynamics of the study town and watershed.

This shows major changes in the socio-ecological driving forces will affect the landscape dynamics of the study area. Therefore proper land use planning in both urban and rural areas of the study area is important to consider in the future.

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