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Extrapolation of Land Use Land Cover Changes in Menisa Watershed Using GIS based Markov Chain Analysis

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Abstract:
Background*: Land Use/ Land Cover (LU/LC) Change is one of the major human induced global changes. Information on LULC Change and the forces and processes behind such changes are essential for proper understanding of how land was being used in the past, what type of changes have occurred and are expected in the future. This study was carried out to examine expected land use/land cover changes in the Menisa watershed in Offa Woreda, Southern Ethiopia.*
Materials and Methods*It was conducted using satellite image of Landsat5 TM 1989 and 1999, Landsat7 ETM+ 2019 to investigate LULC within the study area during 1984-2014 and the resulted LULC maps in 1999 and 2014 were used to predict future LULC map based on Markov Model. ERDAS Imagine 2014 and ArcGIS 10.3 software's were used for satellite image processing and map preparation respectively.*
Results*: The study revealed agricultural land decreased with a mean annual rate of 76.91ha/year, followed by 15.2 ha/year drop in forest lands. During the 30 year period, degraded land was continually increasing as it was 680ha in 1989 and 3346ha in 2019, about 2666ha brought under degraded land. In addition, built up and shrub land were continuously increasing as it was 972.7 ha (113.17%) and 607.2ha (44.81%) change respectively in the period under study. Built up and degraded LU/LC categories are expected to gain 54% and 74% from other LU/LC categories in 2049. This implies that shrub land and forest will have a net loss of 34% and 2% respectively.*
Conclusion:*Thus, the findings revealed to witness expansion of urban and degraded land in 2049; hence, the right policy packages are required to control the expansion of built up and degradation at the expense of other resources in the study area.*
Key Word*: LULC Change, Markov Chain Analysis, GIS & RS, Gesuba, Menisa Watershed*

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I. Introduction

Land is a vital resource and is the basis of the existence of mankind. It is a base on which all life depends. It provides ecosystem services such as conserving biodiversity, storing carbon, purifying and storing water and regulating the Earth's climate by absorbing the heat as well [1] [2]. These services will continue if only the land is not destroyed or degraded by human induced actions. According to [3] increase in atmospheric carbon dioxide concentrations; alterations in the biochemistry of the global nitrogen cycle; and on-going Land Use Land Cover (hereafter LULC) change are the three major human induced global changes. LULC change is an endless process taking place on the earth's surface starting from ancient time [4] [5].

Several natural and human factors cause LULC changes within the confines of social, economic and political circumstances [6] [7]. Human activities are responsible for the conversion and transformation of plentiful of the world's natural land covers [8]. For instance, over the last 10,000 years, about 50% of the ice-free land surface has been changed by human activities [9]. Accordingly, since 1850 around 6 million km² and 4.7 million km² of forest/woodland and grassland areas have been converted to agricultural land worldwide in that order, to meet the demand for food and fiber. These drivers are a complex mixture of political, social, economic and biophysical factors that add force to environmental changes [10] and intensified through high population growth rates [11]. Furthermore, the conversion and modification of the LULC that are induced largely by human activities and natural processes create problems that influence the environment [12].

Like many other developing countries, Ethiopia is experiencing enormous LULC changes[13][1]. The LULC change problem is more severe in the highland parts of Ethiopia. It is because these areas were characterized by high population pressure and cultivated for long period of time [14]. Different studies have been conducted to quantify LU/LCC in both highland and lowland parts of Ethiopia [15] [16] [17] [18] [6]. Accordingly, the country is characterized by reduction of forest, woodlands, grass and shrub lands, but a remarkable expansion of agricultural land, settlements and bare lands in space and time. The mounting pressure of residents and intensive use of resources coupled with global market drive unprecedented land use and land cover changes in Menisa area too [19]. These changes lead to transformations in the hydrological, ecological, geomorphologic and socioeconomic systems and which are often neglected by both rural and urban administrations. Hence, the study site is a reflection of degradation in many ways and studies made in this site may have wider implications. Thus, timely and accurate change detection of the natural resources (such as vegetation cover, water, and soil) provides a foundation to clearly comprehend the prevailing interactions between people and the environment. This, in turn, enables the people to manage and use the resources sustainably [18][20].

In this regard, remote sensing and geographic information systems are powerful tools in change analysis and simulation of LULC [21][22][23]. Continuous data from Landsat imagery provides valuable information that can be used as input for prediction studies [12]. Numerous previous studies have examined the simulation of land use changes pattern by using a CA-Markov model [24][25]. It is an application of change detection that can be used to predict future changes in one area based on the rates of past change in the area [26]. Thus, one can realize that LULCC is a complicated process and the Markov based cellular automata model for prediction offers a wide understanding about the complexity of the components of spatial systems. Therefore, in view of the literature gaps indicated above, this study estimated the trend of LULC changes and predicts the future changes that will occur in Menisa watershed during the period from 1989 to 2019 using GIS based approach.

II. Material And Methods

Study Area

This study was undertaken in Menisa watershed in Offa Woreda which is one of the 16 Woredas of Wolayta Zone and located in the Southern Ethiopia. It is found at about 29 kilometers from zonal city WolaitaSodo on the way to GofaSewula road. Offa woreda is located at 60 37’08’’-- 6o50’06’’N, latitude and 37o24’18’’-37o59’13’’E Longitude. The slope position of the study area is categorized in to gentle sloping (3-15%), moderately sloping (16-30%) and steep sloping (26-50%). Offa Woreda is composed of 16 Kebeles (which are the smallest local government unit). However, the intervention kebeles for LULC analysis of this study were only six, namely Okto Sere, Busha, Sere Esho, Gelda, Gesuba, and Gelko cover 40,716 hectares. Hence, hereafter Menisa watershed in this study refers only to these six Kebles (Figure 1).

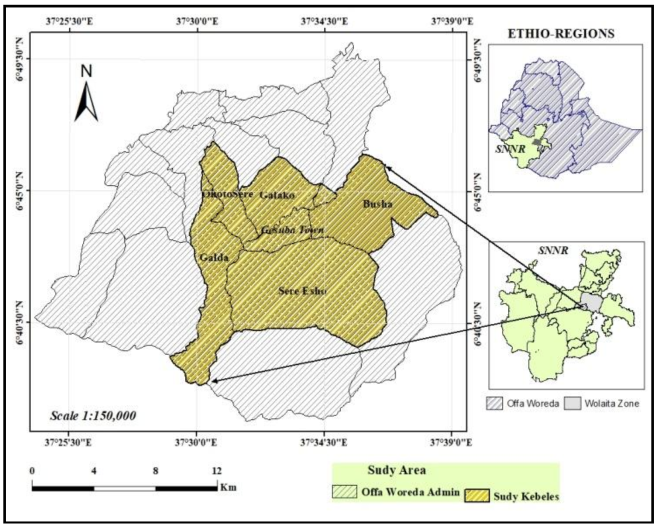

Figure 1: Location map of the study area

According to CSA (2013) the woreda ranges 1200 -2800 meter above sea level. Agro-ecologically, Offa woreda consists of Kola, Weynadega and Dega (22, 62 and 16%) respectively. The woreda’s annual average rainfall, 800-1400 mm and annual average temperature lies b/n 14 0C-34 0C. There are numerous small permanent and seasonal streams flowing in the area to join the main river called Menisa[27]. These Rivers are namely Hintala, Urula, Gassa and Woyo. The forests in Menisa are home of diverse fauna and flora, including a significant number of rare and endemic species. The Dew and Olke forest including its large genetic pool of biodiversity of plant species and vast carbon store is response of the area. Main soil types in the area are Cambisols, Vertisols, Luvisols, Lithosols and Nitosols[27]. As per the CSA projection [28]Offa woreda where Menisa is situated together have a total population of 120694 of which 51% are male 59136 and 61558 female. About 110871 (92%) and 9823 (8%) of this population live in rural and urban areas respectively. Small-scale subsistence agriculture using traditional technologies is the major sector that supports the livelihood of households and communities in the area[29][30]. Agriculture in the Menisa involves two major activities: farming and livestock husbandry. As it's indicated in [31] farmers in the region grow cereal crops (e.g. Corn, Barley, Teff and Wheat), cash crops (coffee and cassava), pulses (field peas, haircot been, fabieen been etc), permanent crops like avocado, mango, banana and enset), root crops (potato, sweet potatoes, cassava) and horticultural crops particularly vegetables (e.g. onion, potato and cabbage). Cattle, Goats, Sheep, Horses, Mule and Donkeys are important livestock species reared by farmers in the Menisa watershed.

Data sources and Image analysis

Time series of Landsat satellite imageries were the main source of input data for the LULC analysis in this study. Landsat images were downloaded from Global Land Cover Facility (GLCF) in the USGS archives at Glovis(http://glovis.usgs.gov)[32]. Seven images were downloaded at about ten years' interval to easily visualize changes in spatiotemporal LULC patterns. However, some discrepancy ±1 year was considered due to the availability and quality of Landsat images from USGS archives for the study area. Therefore, Landsat TM of 1989 (30 m × 30 m), Landsat ETM+ of 2004 (30 m × 30 m) and Landsat OLI of 2014 (30 m × 30 m) at path (169 and 170p), and row (52r) images were used. These were preprocessed such as layer stacking, sub-sampling the study area by MOI file, re-sampling of all time-series images into similar ground resolution (30 m × 30 m), gap filling for Landsat 8 (1989 and 2019 images), and spectrally enhancing the images before actual image classification process. The major LULC classes considered in the classification are as given in Table 2. About 101 ground control points (GCP) representative of the different LULC classes were taken by a GPS receiver to improve accuracy of classification and to produce thematic land cover maps representative to the entire study period. Field observation was also conducted to substantiate the image classification and analysis. Based on the correlation between the collected field data and the preliminary visual interpretation, the entire area was delineated from the ortho-rectified and geometrically corrected historical aerial photographs of 1998 using on-screen digitization by "Spatial Analysis Tool" of Arc- GIS 10.3.

Accordingly, supervised classification was done using training areas obtained from ground truth data combined with spectral signatures in false color composite images by maximum likelihood classifier. Subsequently, the accuracy assessment was conducted for all the classified Landsat images (maps) using accuracy assessment tool in ERDAS IMAGINE 2014 software to evaluate the user's and the producer's accuracy. Thus, the accuracy assessment result indicated that most of the maps met the required minimum 82.86% accuracy in LULC analysis as reported in Table 4. This showed a strong agreement between the classified LULC classes and the geographical data (ground truths) and made it possible to use the output maps for change detection analysis. As a result, the rates of change of LULC classes were determined in terms of percentage by:

C = At2 – At1/At1 × 100…………………………………………Equation 1

Where At1 is the area of one type of land use in t1 time; At2 is the area of the same type in t2 time and C is the rate of change in percent.

Future projection

A Markov process is one in which the future state of a system can be modeled purely on the basis of the immediately preceding state. Markov chain analysis describes land use change from one period to another and uses this as the basis to project future changes. The conditional probability images report the probability that each land cover type will be found at each pixel after the specified number of time units [33]. This is used to predict the land use land cover situation in each LULC type for the year 2049 based on the 1989–2019 scenarios.

The projection for2049 = 1989–2019 annual rate of change*12 (2049-2019) + 2019 magnitude (area coverage)……………………………………………………………Equation 2

Thus, the general procedures of using Markov Change Detection Techniques (MCDT) are: first to create a transition matrix of pixels in each class for two time periods—this is basically the same as the cross-tabulation matrix that can be used for accuracy assessment. The main diagonal of the matrix contains pixels that have not changed, while other cells contain pixels that have changed. The next step is to generate probabilities of change between classes. This is accomplished by dividing each cell value by its row total. The result is the probability that a given class in date 1 will convert to another class in date 2 out of all possible changes [34].

III. Result and Discussion

Land Use and Land Cover Dynamics in Menisa watershed

The LULC map for 1989, 1999 and 2019 were produced by supervised classification using the maximum likelihood classifier of ERDAS IMAGINE v.2014. The LULC classification was employed from the prior knowledge of the study area and based on the system developed by [35]. The images were classified into seven LULC classes, namely agriculture, built-up, degraded land, dense vegetation, graze land, shrubs, and Water body.

Table 1: Land use/cover classification scheme

Land use/cover	Description/Associate Class
Shrub lands	Areas covered with mature trees and other plants growing close together.
Water body	Rivers lakes, reservoir, dams and wetlands.
Agriculture	Crop cultivation both annuals and perennials, mostly in subsistence farming and the land covered by rural villages and scattered rural settlements
Built-up	Land covered by buildings and other man-made structures. Residential, commercial services, industrial area, mixed urban or built up lands, transportation, communications, and utilities.
Degraded land	Land with exposed soil, sand or rocks, and never has more than 10% vegetated cover during any time of the year. Bare ground, future land use, bare exposed rocks, strip mines, quarries and gravel pits
Grazing land	Pasture both communal and\or private grass lands that are used for livestock grazing. The land is basically covered by small grasses, grass like plants and herbaceous species.
Dense forest	Dense natural vegetation (forest, plantation), woodland, thicket forest, sparse vegetation

The classified images obtained after pre-processing and supervised classification which are showing the land use/cover of the study area are given in Figure 2. These images provide the information about the land use pattern of the study area. During 1989, it was highly likely that a portion of the land was left abandoned and uncultivated. The areas were low accessed and human population was relatively low with low pressure on the land in general. Analysis of the 1989 image revealed that agricultural land constituted the largest proportion of land in the watershed with a value of 53.5%, followed by grassland which accounts for 17.9 % (Figure 2). Dense forests constituted 4.7%, degraded land 5%, bulit up 6.3%, water body 2.6% and while both bare and open shrub lands showed similar coverage values of 10% each.

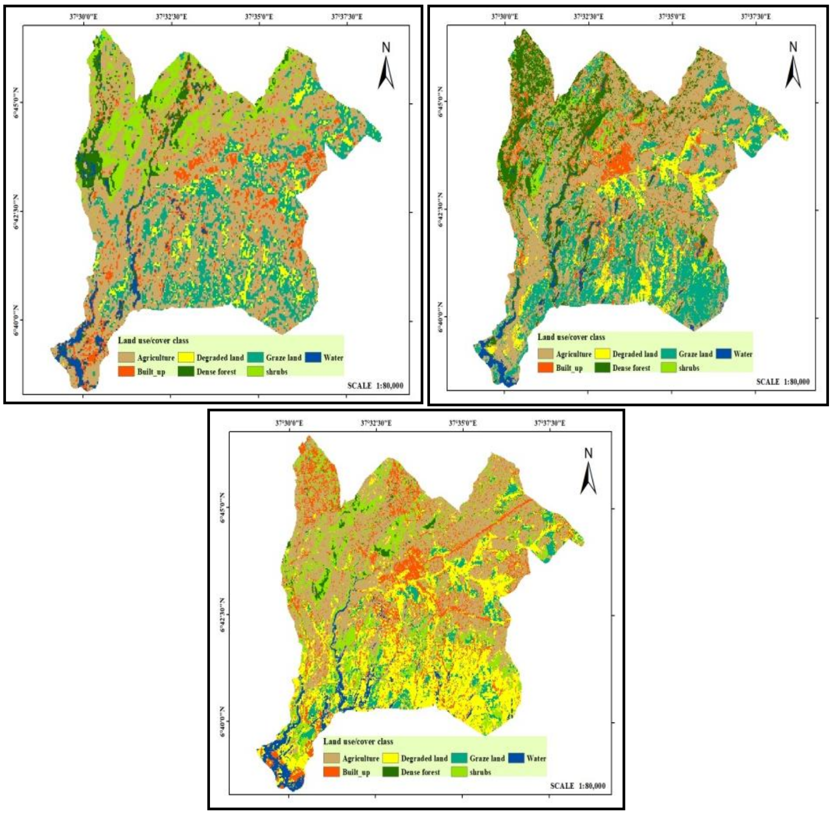

Figure 2: LULC map of the year 1989, 1999 and 2019

Table 2: LULC types and area coverage extracted from land use/cover map

SN	LULC	1989		1999		2019	
		Area		Area		Area	
		ha	%	ha	%	ha	%
1	Agriculture	7262	53.5	5894.4	43.4	4954.7	36.5
2	Built-up	859.5	6.3	1109.9	8.2	1832.2	13.5
3	Degraded	680	5	1166	8.6	3346	24.6
4	Dense forest	642.7	4.7	1757	13	186.7	1.4
5	Grazing land	2416	17.9	2862.7	21	825.4	6.1
6	Shrubs	1355	10	510	3.8	1962.2	14.5
7	Water	356.8	2.6	272	2	464.8	3.4
Total		13572	100	13572	100	13572	100

As can be seen from Figure 2 and Table 2 in the 1999 image, the proportion of land allocated for cultivation and shrubs decreased to 43.4% and 3.8% respectively. However, degraded land, settlement and forests expanded in 8.6%, 8.2% and 13% of the landscape respectively. The 2019 image analysis showed that cultivated landaccounts for 36.5%, while the dense forest, open shrub/bush, built-up, degraded, water body andgrazing lands covered 1.4 %, 14.5%, 13.5%, 24.6, 3.4% and 6.1% respectively (Figure 2).

LULC Change Detection Analysis

In the period between 1989 and 2019, agricultural land decreased with a mean annual rate of 76.91ha/year, followed by 15.2 ha/year drop in forest lands *(Table 3)*. During the 30 year period between 1989 and 2019 the proportion of area taken by degraded land was continually increasing as it was 680ha in 1989 and 3346ha in 2019, about 2666ha brought under degraded land (Figure 3). In addition, built up and shrub land were continuously increasing as it was 972.7 ha (113.17%) and 607.2ha (44.81%) change respectively in the period under study (Table 3). As a result, the largest part of land that was covered by agriculture, forest and grazing before were now placed by built-up and degraded lands. Hence, the pattern showed a tendency towards more land being brought under degraded and built up areas at the expense of cultivable and forest lands. Thus, this study was in agreement to the studies conducted in moist dry and semi-dry land parts of Ethiopia such as [31][36][37]that indicated the documented reduction of area under woodland and increase in area under degraded land. Rapid reduction in agriculture, grazing and forest land and increase in degraded land and settlement were also reported by the same authors in Gesuba area. However, it was in contrary to the work of [38].who reported expansion of forest land between 1973 and 2015 with corresponding reduction of cultivated land in Mancha in Offa Woreda of Wolaita Zone.

Table 3: LU/LC Changes between 1989 and 2019 in Menisa watershed over 30 years

LULC	1989		1999		2019		Change between 1989-2019	
	Area		Area		Area		rea	
	ha	**%**	**ha**	**%**	**ha**	**%**	**ha**	**%**
AL	7262	53 .5	5894.4	43.4	4954.7	36.5	-2,307.3	-31.77
BL	859.5	6.3	1109.9	8.2	1832.2	13.5	972.7	113.17
DL	680	5	1166	8.6	3346	24.6	2666	392.05
DF	642.7	4.7	1757	13	186.7	1.4	-456	-70.95
GL	2416	17.9	2862.7	21	825.4	6.1	-1,590.6	-65.83
SL	1355	10	510	3.8	1962.2	14.5	607.2	44.81
WB	356.8	2.6	272	2	464.8	3.4	108	30.27
Total	13572	100	13572	100	13572	100		

Note: -values indicate reduction +values indicate increment

Predicting LU/LCC Based on the Markov Model

As discussed above in the methodology section, Ca-Markov model was used to predict the 2049 LULC based on transition probability matrix records derived from the observed 1989 and 2019 LULC, the probability of each land cover category to change to another category. This matrix is produced by the multiplying each column in the transition probability matrix with the number of cells of corresponding land use in the later image as shown in (**Table 4**). Although the transition probabilities may be accurate for a particular class as a whole but there is no spatial element to the modeling process as we can see in. According to transition probability matrix, the main change occurred on degraded land. Field work investigations demonstrated that forest land and agriculture land with built-up area are transient categories and hence exposed to more changes over time.

Table 4: Transitional probability matrix derived from LU/LC map of 2019 and 2049

		2049						
	LULC	**A**	**BL**	**DL**	**DF**	**GL**	**Sh**	**WB**
2019	AL	0.0000	0.0000	0.3330	0.0800	0.2517	0.1987	0.1366
	BL	0.0000	0.0002	0.0000	0.0002	0.0000	0.0002	0.1223
	DL	0.0000	0.3336	0.1188	0.2650	0.0391	0.1871	0.2436
	DF	0.0000	0.4010	0.1170	0.2352	0.0998	0.1470	0.0000
	GL	0.0000	0.3294	0.2232	0.0395	0.0235	0.3844	0.0000
	SL	0.0000	0.4571	0.1223	0.1873	0.0909	0.1425	0.0000
	WB	0.9996	0.0002	0.0000	0.0000	0.0000	0.0002	0.0000

The predicted LU/LC type of 2049 is dominated by agriculture/settlement, which covers an area of 4985.2 ha (28 %) of the total area. Forest and grassland/rangeland will cover an area of 960.1ha (0.7%) and 730.7 ha (5.4%) respectively, whereas the area coverage of shrub/bush land, water, buit-up and degraded land will be 1131.4.2ha (9.1%), 270.7ha,(2%),1940.7ha (14.3%), and 4985.2ha (40.54%) in that order. This shows that in 2019 more than (187%) of the study area is expected to be changed by degraded land. The forestland and grazing land is decreased about 89.4 and 71.2 % as compared to the initial year (1989) coverage respectively. Therefore, as compared to the base year 1989 in 2019 degraded land was predicted to increase by 397%, while agriculture/settlement, forest and grazing land is predicted to decrease by 31%, 71% ,and 65.8% respectively (Table 3).

The growth of degraded and built up land will come largely at the expense of agricultural land, forest and grazing land respectively. This is because as it is seen in the probability matrix Table 4, the probability of these LU/LC categories to change to degraded land and settlement is high i.e. 40%, 5% and 28% respectively. As it is indicated in the probability matrix Table 4 in 2049, we expect 40% of forest to persist and 88% of shrub land and 76% of forest to change to other LU/LC. However, these built up and degraded LU/LC categories are expected to gain 54% and 74% from other LU/LC categories. This implies that shrub land and forest will have a net loss of 34% and 2% respectively. Thus, the prediction of decreasing of cultivated land and forest land while built up and degraded land increases might be expected to the increase in socio-economic boom, which represents the period after siege. It also reflected in the intensifying of ecological problems including the soil erosion and loss of key natural resources socio-economic development.

IV. Conclusion

Multi-temporal Landsat imagery of 1989, 1999 and 2019 were used to derive LULC maps which were further used in the CA-Markov process to successfully predict the future spatial and temporal changes of LULC. First, the findings revealed to witness expansion urban and degraded land in 2049, which should be taken into consideration by the city planners in their future plans for Gesuba in terms of road networks, infrastructure, and allocating some locations for future services such as schools, health centers, governmental buildings, public parks. Second, controlling the population growth and its associated impacts on the natural environment requires the right policy packages by national and regional governments to degraded area restoration in addition to provision of family planning services, increasing productivity, working on the pushing factors of migration and controlling illegal settlements. The overall analysis showed that most of future urban and degraded land expansion replaced agricultural areas and forest land which could be avoided through future policies or strategies. Finally, it is highly recommended that urban planners and decision makers utilize remote sensing and GIS techniques for effective monitoring of urbanization trends. Further study is suggested to investigate detailed drivers and consequences of changes.

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