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Land Use Land Cover Change Detection of Sululta Town Using GIS and Remote Sensing Techniques Sululta Town, Ethiopia

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Abstract

The Issues of land use and land cover have become increasingly important as problems of uncontrolled development, deteriorating environmental quality, loss of prime agricultural lands, destruction of important wetlands, and loss of fish and wildlife habitat continue to worsen. Using the Current technologies such as geographical information systems (GIS) with their software ArcGIS and remote sensing with their ERDAS software provide a cost efficient and precise to understanding land use land cover changes by using land sat images of 2010 and 2019 after digital image processing, subset area of interest, supervised image classification has been performed to classify the images in to different land use categories. The supervised classification produced good results with overall accuracies of 87.69 %, for Landsat 7 (2010), and 87.87 %, for Landsat 8 (2019).Individually the LULC change for Built up area is increased by 11.71%, for Agricultural land is decreased by 24.66%, for Bare land is increased by 6.3%, for Grass land is increased by 7.26%, for Forest land is decreased by 0.62% so from this positive growth from 2010 to 2019 have been found in Built up area (11.71%,), Bare land (6.3%,) and Grass land (7.26%,) and negatively (decreased area classified) in Agricultural land (24.66%,), and Forest land (0.62%). So in general knowing Timely and accurate land use and land cover change detection of Earth's surface features provides the foundation for a better understanding of the relationships and interactions between human and natural phenomena through any time.

Keywords: *Change detection, Land use, Land cover, remote sensing, Landsat satellite imager*

1. INTRODUCTION

1.1 Introduction

Land is the most critical normal assets on which all activities where based. The increasing of the population and human activities are expanding the interest on the constrained land and soil.

The earth's surface changes are divided into two categories (Barnsley, 2001). land use and land cover. Land cover initially describes the physical state of the land surface, which includes cropland, forests, and wetlands, human structures such as buildings, pavements and other the natural environment, including soil type, biodiversity, surface water and groundwater (Cheng, 2008) and (Jaiswal, 1999). Land use refers to the way in which human beings exploit the land and its resources including agriculture, urban development, grazing, logging and mining. However, land cover and land use often used interchangeably because the two terms are interdependent and closely related. Change detection is a process of identifying differences since it can help in monitoring and optimal planning of Earth's resources and also help to arrest undesired changes. Any change detection system should be able to define the changes area and change rate, distribution of change areas, change trajectories and the accuracy assessment of the change detection method (Lu, 2004).

Timely and accurate change detection of Earth's surface features provides the foundation for a better understanding of the relationships and interactions between human and natural phenomena for better management of decision making. (Lu D. M., 2004) and also in order to better manage and use resources or land use/land cover change (LULCC) is defined as the transformation of the land or replacement of one land-cover type on the earths. People migrate to the capital in search of job from different corners of Ethiopia. Housing is a basic requirement for any social class especially in Addis Ababa (Finfinne) the capital city of Ethiopia and Oromia regional state. There were lack of proper Monitoring of urban expansion and uncontrolled population growth and migration i.e. migration from Rural to capital city housing condition is inadequate in quantity and cost to meet the needs of the residents.

1.2 objective of the study

The main objective of this study was to produce a land use land cover map of Sululta town at different periods (2010, & 2019) in order to detect the changes that have taken place in land use land cover using geospatial techniques and subsequently to map the expansion and shrinkage of LULC over the same time period and Specific Objectives includes: To map the land use land cover of 2010, 2019,to determine the nature, rate, location and magnitude of land use land cover change, to assess the overall accuracy and cross check it with post classification data, to analyze the driving forces of land use and land cover change and urban expansion.

2. Literature review

In order to analyzed land use land cover change detection it is important to review the history and background basic concepts and related works done in past way. The highlights review of these study focusing on remote sensing, GIS and the Landsat program. Existing Classifications of change detection techniques in the past different classifications of the change detection methods have been proposed. The some proposed classification such as (Singh, 1989). In this paper on review of the digital change detection methods in 1989 categorized the change detection research on the basis of 1. The data transformation used and 2. The analysis technique used to detect the change. He classified the research work done till that time into various categories. A brief overview of all the prevalent techniques as image differencing, image rationing, image regression, vegetation index differencing, principal component analysis was offered. While evaluating these techniques on the basis of literature reviewed, it was concluded that different change detection methods produced different change maps. It was observed that most of the results were not compared with the ground truth and thus the capability of these methods was poorly evaluated. The paper provided the best results for each technique of change detection. (Jianyaa, 2008) in 2008 proposed two broad groups for classifying the change detection methods, namely, bi-temporal and temporal trajectory analysis. Bi-temporal methods measures the change between two date images while temporal trajectory analysis analyses the change based on continuous timescale measuring not only the change between two dates but also the progress of change over the period. Further he gave seven categories for change detection methods, namely, direct comparison, classification, object-oriented method, model method, time-series analysis, visual analysis and hybrid method.

(Hussain, 2013) in a recent paper (2013) have reviewed and categorized the change detection methods based on the unit of analysis, i.e pixel based object based approaches. In the pixel based methods the analysis is done on the basis of variation in pixel intensities while object based approaches, first extract objects from the image and then try to perform change detection based upon the objects extracted. The object based methods are more suitable for Very High Resolution images. The subclasses with each category are defined and the change methods are categorized based upon these classes.

3. Methodology

3.1 Description of study area

Sululta Town is found in the central part of Ethiopia, Oromiya Special Zone surrounding Addis Ababa. Astronomically, the study area extends from 9° 30'00"N to 9° 12'15"N latitude and 38° 42'0"E to 38°46'45"E longitude. In relative terms, it is located at a distance of 23km along Addis Ababa- Bahir Dar road and in south direction by Addis Ababa and in the left three directions.

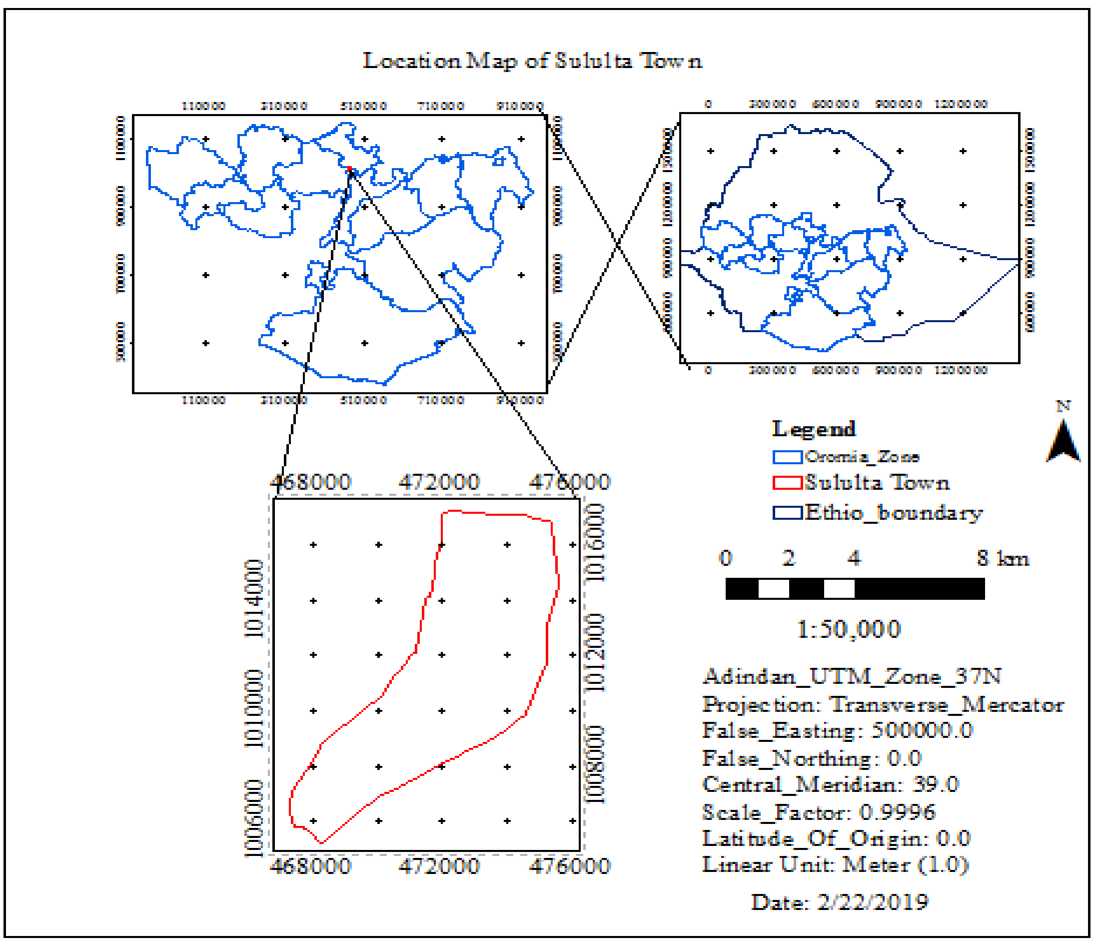

Figure 1 study area Map

3.2 Topography

The topography of the area varies from chains of mountains around Entoto ridge in the south to plain lands in the East, North-west, and north. Slope is also another topographical aspect that influences the land use planning and management. The steepest slope in the area is situated in the elevation range of 2640m to 2800m almost around the southern ridge of Entoto and north-eastern fringes. By implication high run off and lateral erosion is high in these areas compared to the gentle slope locations. The gentle slope lies mostly in the central part of the study area within 2580m to 2700m altitude where the existing built up area lies. The flat area of the Town is found in the altitude of less than 2580m in the east and north-west of the study area. This area is one of the likely water logging area during the rainy season and potential grazing land in dry season.

3.3 Materials and methods of the study

The procedures, materials and methods performed in the project work forms deriving static land scape and subsequently change in Sululta Town over different period of time. Land scape change in Sululta Town was carried out in four satellite imageries over different period of time (2010, & 2019). In addition to this Google earth images are carried out for various lands. Pre-processing activities were carried out in order to enhance the quality of the image and readability of the features. The Landsat satellite images of 2010, & 2019were geometrically corrected.

3.3.1 Materials

No.	Software/Material	Purpose	Remark
1	ERDAS Imagine	Digital image processing like image enhancement, Classification…	Version 2014
2	ARCGIS	Integration of spatial and non-spatial data and also for map layout preparation	Version 10.2.1
3	Google Earth	Ancillary data	
4	Microsoft office word and excel	Writing, chart preparing and statistical analysis	2013

3.4 Data source and used

Data used in this study comes from different sources. For example boundary of sululta town digitized from Structural plan (master plan) of Sululta land administration town and all land sat of 2010 and 2019 downloaded from USGS earth resource observation system data center. (https://earthexplorer.usgs.gov). All the images are downloaded at level 1 geotiff format and all the images are from Landsat ETM+ and LC (OLI-TIRS) and all have a 30m spatial resolution.

Year (G.C)	Satellite	Sensor	Acquisition Date	Band No
2010	Landsat 7	ETM"	Dec 05, 2010	9= (1, 2, 3, 4, 5, 61, 62, 7, 8)
2019	Landsat 8	LC	January 2, 2019	11= (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11)

Boundary of sululta town digitized from Structural plan (master plan) of sululta municipality office 2006 and land sat downloaded from USGS earth resource observation system data center. (https://earthexplorer.usgs.gov)

3.4 Digital Image Processing

In today's world of advanced technology where most remote sensing data are recorded in digital format, virtually all image interpretation and analysis involves some element of digital processing. When remote sensing data are available in digital format, digital image processing and analysis may be performed using a computer.

The most of the common digital image processing functions available in image analysis systems can be categorized into the following four categories. Frist, Preprocessing functions involve data analysis and extraction of information, and are generally grouped as radiometric or geometric corrections. Radiometric corrections include correcting the data for sensor irregularities and unwanted sensor or atmospheric noise. Geometric corrections include correcting for geometric distortions due to sensor-Earth geometry variations. Secondly, Image enhancement is to improve the appearance of the imagery to assist in visual interpretation and analysis. Thirdly, Image transformations are operations similar in concept to those for image enhancement. Fourthly, Image classification and analysis operations are used to digitally identify and classify pixels in the data.

3.5 Digitizing

Using existing shape files saves time and generally results in more accurate map layers. But if a line or polygon files that doesn't exist such as a boundary for your study area you will need to create digitized shape files. Digitizing is the process of drawing or tracing map features to create a new geographic file. The shape files of sululta town boundary digitized in polygon shape files from structural plan that exist in AutoCAD form.

3.6 Subset / extract by mask

The image download from USGS using path 168 and row 54 covers a very wide area. But the study area Sululta town is within this image and subseted using the boundry shape files as AOI.

Masks are shape files that allow you to cover up areas that you don't want to show without clipping them. Clipping data only works with shape files, not with grids/raster data, so masks are especially useful when you are working with raster data. The Sululta Town boundary is in vector data shape files but lands sat are in raster data so in order to subset shape files of this Sululta Town from landsat using extract by mask is as below.

3.7 Image Classification

In supervised classification, the user develops statistical description for various known land cover types that is called ***signature*** extraction. The procedure is used to identify the similar pixels/signature for different land cover types for the whole image. The steps that are followed for this supervised classification are as follows: Frist Training sites are the areas defined for each land cover type within the image, second Signature Development is the stage of creating the spectral signature for each type of land cover, third after developing signature files for all land cover classes the next step is to classify the images based on these signature files.

Supervised classification requires the manual identification of Point of Interest areas as reference (Ground truth) within the images, to determine the spectral signature of identified features. It is one of the most common types of classification techniques in which all pixels with similar spectral value are automatically categorized into land cover classes or themes. land and range land taken us Grass land and since the reflectance of water body is not seen on Landsat image it is left. So in general land use land cover of the study area classified in 5.

1. **Agricultural Land** may be defined broadly as land used primarily for production of food and fiber.
2. **Urban or Built-up Land** is comprised of areas of intensive use with much of the land covered by structures such as: cities, towns, villages, strip developments along highways, transportation, power, and communications facilities, and areas such as those occupied by mills, shopping centers, industrial and commercial complexes, and institutions that may, in some instances, be isolated from urban areas.
3. **Grass land** defined as land where the potential natural vegetation is predominantly grasses, grass like plants, forbs, or shrubs and where natural herbivores was an important influence in its pre-civilization state.
4. **Forest Lands** have a tree-crown areal density (crown closure percentage) of 10 percent or more, are stocked with trees capable of producing timber or other wood products, and exert an influence on the climate or water regime.

5. **Barren Land** is land of limited ability to support life and in which less than one-third of the area has vegetation or other cover. In general, it is an area of thin soil, sand, or rocks. Vegetation, if present, is more widely spaced and scrubby than that in the Shrub and Brush category of Rangeland.

3.8 Accuracy Assessment

Land use Land cover maps derived from classification of images usually contain some sort of errors due to several factors that range from classification techniques to methods of satellite data capture. Accuracy assessment determines the quality of the map created from remotely sensed data. Accuracy assessment can be qualitative or quantitative, expensive or inexpensive, quick or time consuming, well designed and efficient or haphazard. The goal of *quantitative* accuracy assessment is the identification and measurement of map errors.

An error matrix is a square assortment of numbers defined in rows and columns that represent the number of sample units assigned to a particular category relative to the actual category as confirmed on the ground. The rows in the matrix represent the remote sensing derived land use map, while the columns represent the reference data that were collected from field work. These values are based on a sample of error checking pixels of known land cover that are compared to classification on the map. Error of commission and omission can be expressed in terms of user's accuracy and producer's accuracy. User's accuracy represents the probability that a given pixel will appear on the ground as it is classed, while producer's accuracy represents the percentage of a given class that is correctly identified on the map. On the other hand, Kappa coefficient is a measure of the interpreter agreement. The Kappa statistics incorporates the off-diagonal elements of the error matrices (i.e., classification errors) and represents agreement obtained after removing the proportion of agreement that could be expected to occur by chance. **Reference data labels:** The class label or value of • the accuracy assessment site, which is derived from data collected that is assumed to be correct; and

Classified data or map labels: The class label or value of the accuracy assessment site derived from the map.

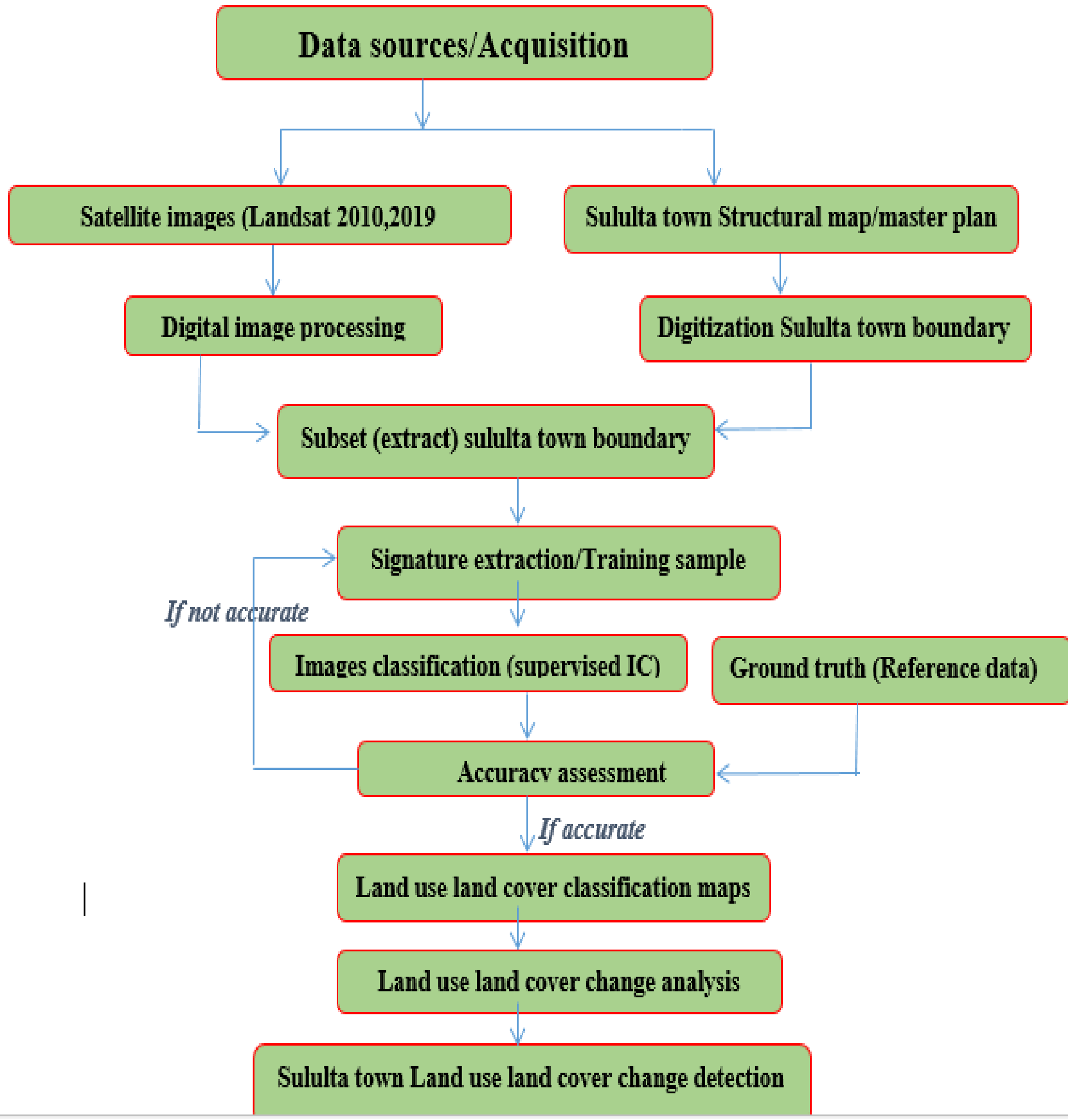

Figure 1 The General work flow diagram

4. RESULTS AND DISCUSSION

Today's land use and land cover become the main problems such as uncontrolled development, deteriorating environmental quality, loss of prime agricultural lands, destruction of important wetlands, and loss of fish and wildlife habitat continue to worsen So accurate and timely information of land use and land cover change is highly necessary starting from individual to many groups such as urban planners, policy makers ,land administration office and environmental protection office for better land use management and environmental development in land use and land cover changes and modeling of it for future time is, important for monitoring and resolving the negative consequences and increases the benefits . Sululta Town is in the Oromia regional state has witnessed land use land cover change. For the past decades, the Sululta Town has been known to be relatively small in population. But today, it is one of the fastest growing towns in population size and now day total area (45.1098km2)

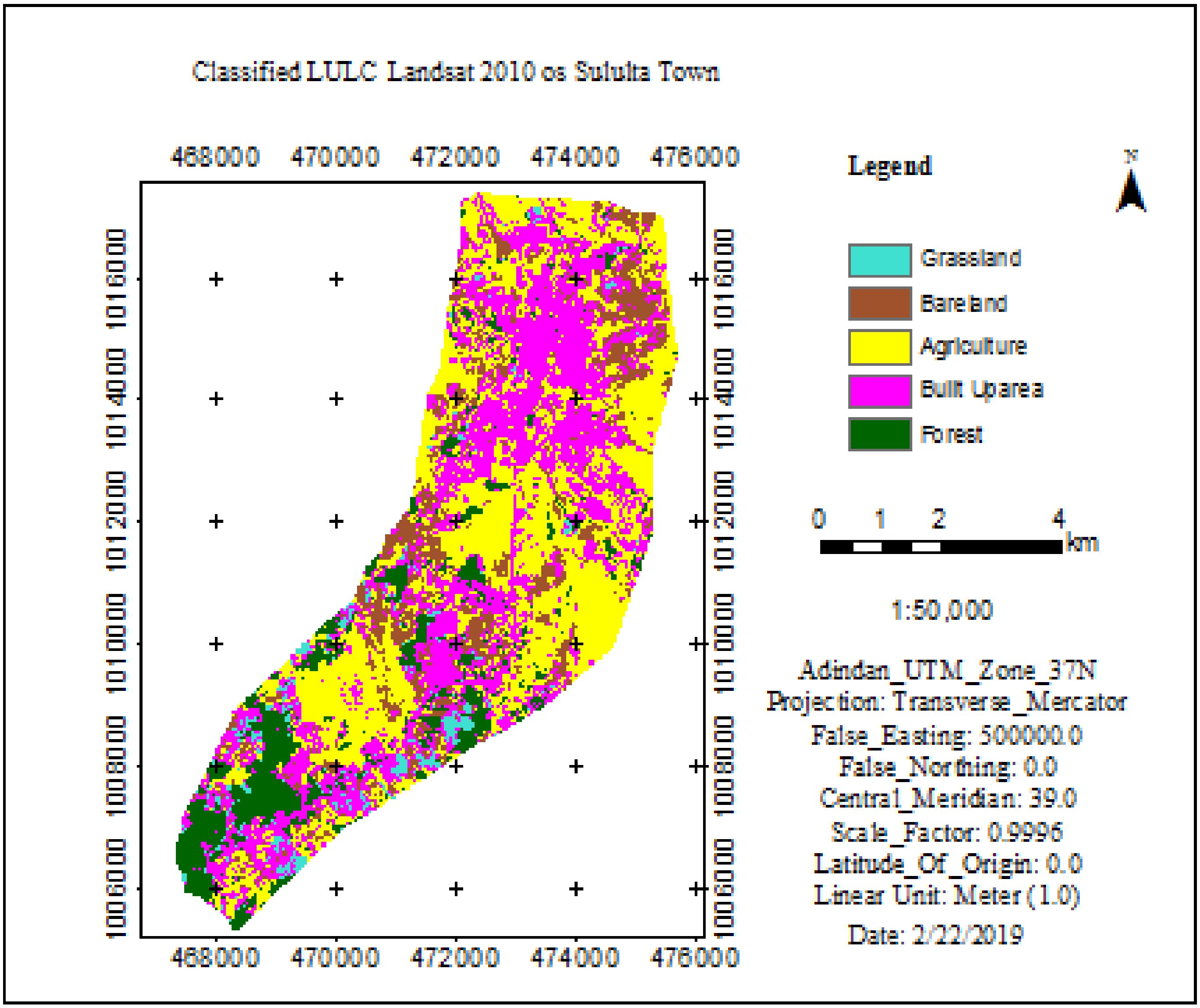

Figure 2 Land use land cover classification of Sululta Town status in2010

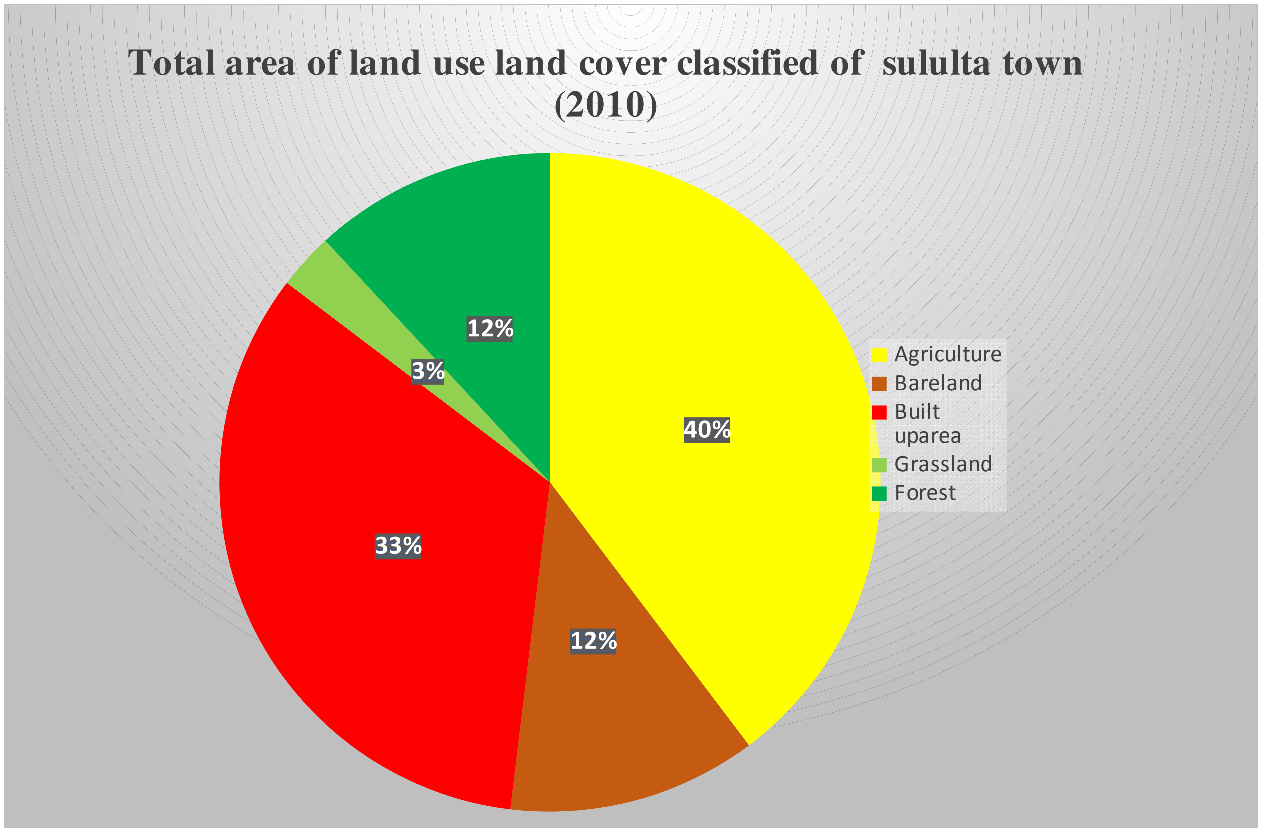

Figure 3 Total area of land use land cover classified of Sululta Town (2010)

Error matrix Land use land cover 2010 classification accuracy report

Classified data	Reference data						
		Agricultural land	Built up area land	Bare land	Forest land	Grass land	R.total
	Agricultural land	19	2	1	0	1	23
	Built up area land	2	21	0	1	0	24
	Bare land	1	0	5	0	0	6
	Forest land	0	0	0	9	0	9
	Grass land	0	0	0	0	3	3
	Col.total	22	23	6	10	4	65
	Number of LULC correctly classified=57						

Table 1 Error matrix Land use land cover 2010 classification accuracy report

Land use land cover types	producer's acurac y	user's acurac y
Agricultural land	19/22*100=86.36%	19/23*100=82.60%
Built up area land	21/23*100=91.30%	21/24*100=87.5%
Bare land	5/6*100=83.33%	5/6*100=83.33%
Forest land	9/10*100=90.00%	9/9*100=100.00%
Grass land	3/4*100=75.00%	3/3*100=100.00%
Overall classification accuracy =(19 + 21 + 55 +9+3)/65 =57/65= 87.69%		

Table 2 Land use land cover 2010 classification producer's accuracy & user's accuracy

Land use land cover types	Conditional kappa for each LULC class
Agricultural land	0.7371
Built up area land	0.8065
Bare land	0.8164
Forest land	1.000
Grass land	1.000
Overall kappa statistics =0.8283	

Table 3 kappa for each LULC class

LAND USE LAND COVER CLASSIFICATION OF SULULTA TOWN STATUS IN2019

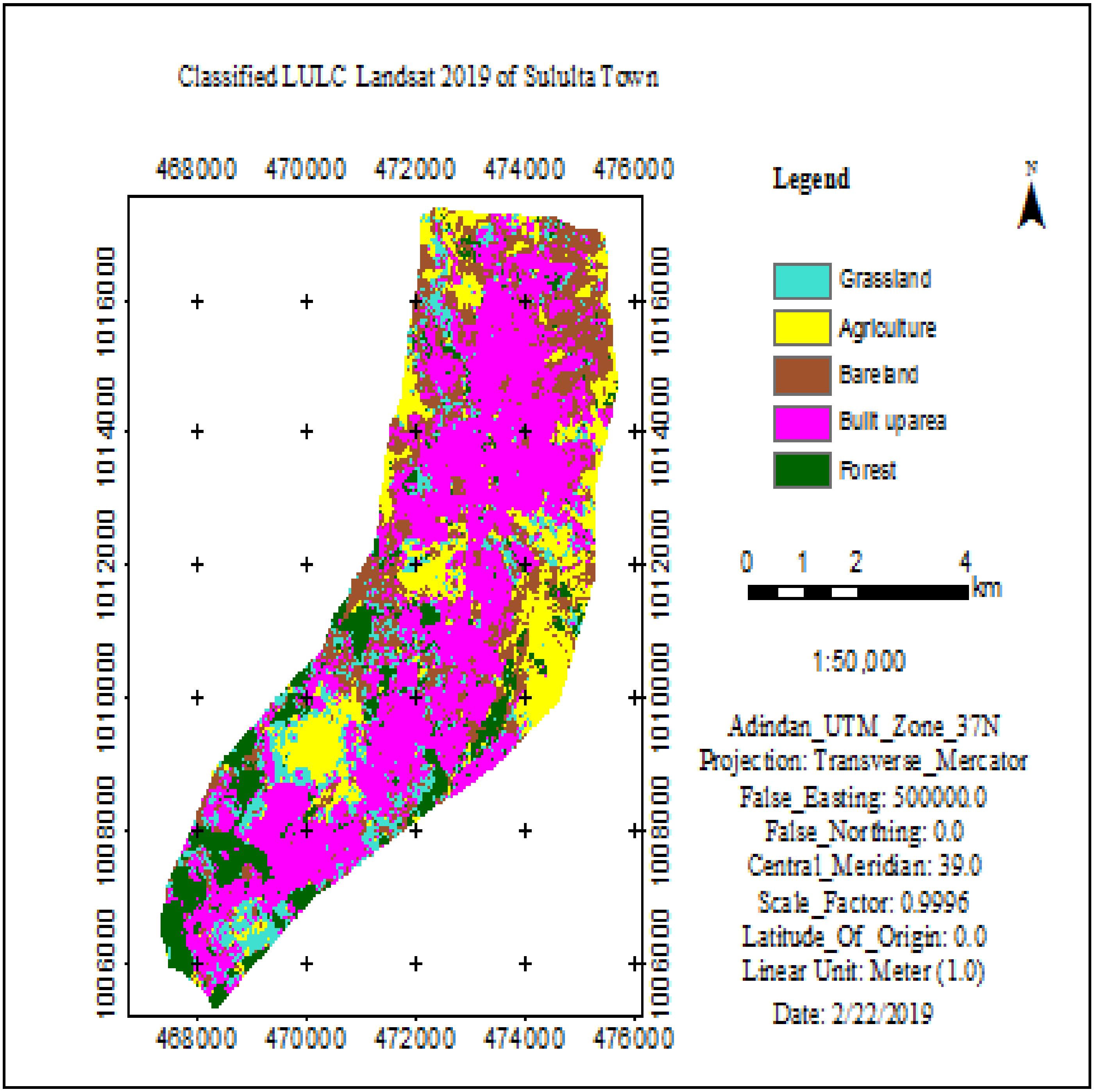

Figure 4 Land use land cover classification of Sululta Town status in 2019

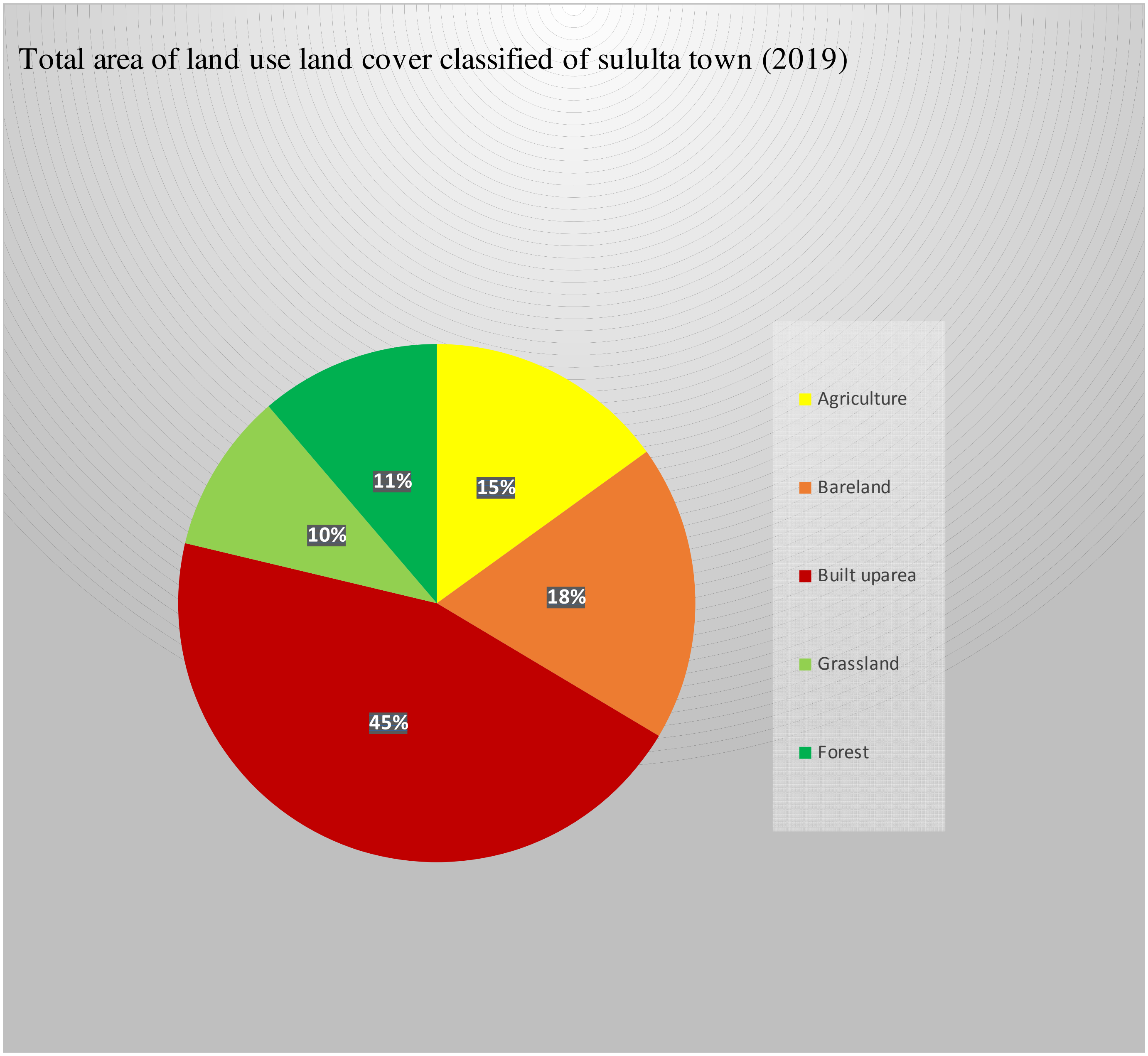

Figure 5 Total area of land use land cover classified of Sululta Town (2019)

Error matrix Land use land cover 2019 classification accuracy report

Classified data	Reference data						
		Agricultural land	Built up area land	Bare land	Forest land	Grass land	R.total
	Agricultural land	14	0	0	0	1	15
	Built up area land	1	21	1	1	1	25
	Bare land	0	0	12	0	1	13
	Forest land	0	1	0	6	0	7
	Grass land	1	0	0	0	5	6
	Col.total	16	22	13	7	8	66
	Number of LULC correctly classified=58						

Table 4 Error matrix Land use land cover 2019 classification accuracy report

Land use land cover types	producer's acurac y	user's acurac y
Agricultural land	14/16*100=87.50%	14/15*100=93.33%
Built up area land	21/22*100=95.45%	21/25*100=84.00%
Bare land	12/13*100=92.30%	12/13*100=92.30%
Forest land	6/7*100=85.71%	6/7*100=85.71%
Grass land	5/8*100=62.500%	5/6*100=83.33%
Overall classification accuracy (14 + 21 + 12 +6+5)/66 =58/66= 87.87%		

Table 5 Land use land cover 2019 classification producer's accuracy & user's accuracy

Land use land cover types	Conditional kappa for each LULC class
Agricultural land	0.9120
Built up area land	0.7600
Bare land	0.9042
Forest land	0.8402
Grass land	0.8103
Overall kappa statistics =0.8400	

Table 6 kappa for each LULC class (2019)

4.2 Change Detection Analysis

The Land use land cover change analysis presented in this project was based on the statistics extracted from the five land use and land cover maps of the Sululta Town. The changes in land cover during the study period land sat 2010 to land sat 2019 can be observed clearly from the after calculating the difference according to table below pie diagrams shown below.

	Landsat image 2010		Landsat image 2019	
Land use land cover type	Area (km^2)	Percent (%)	Area (km^2)	Percent (%)
Agriculture	17.919	39.7230757	6.7941	15.06125055
Bare land	5.4999	12.19225091	8.3448	18.49886277
Built up area	15.0858	33.44240054	20.3679	45.15182954
Grassland	1.2483	2.767247915	4.5243	10.02952795
Forest	5.3568	11.87502494	5.0787	11.25852919
Total Area	45.1098	100	45.1098	100

Table 7 area difference of LULC Classified in 2010 & 2019

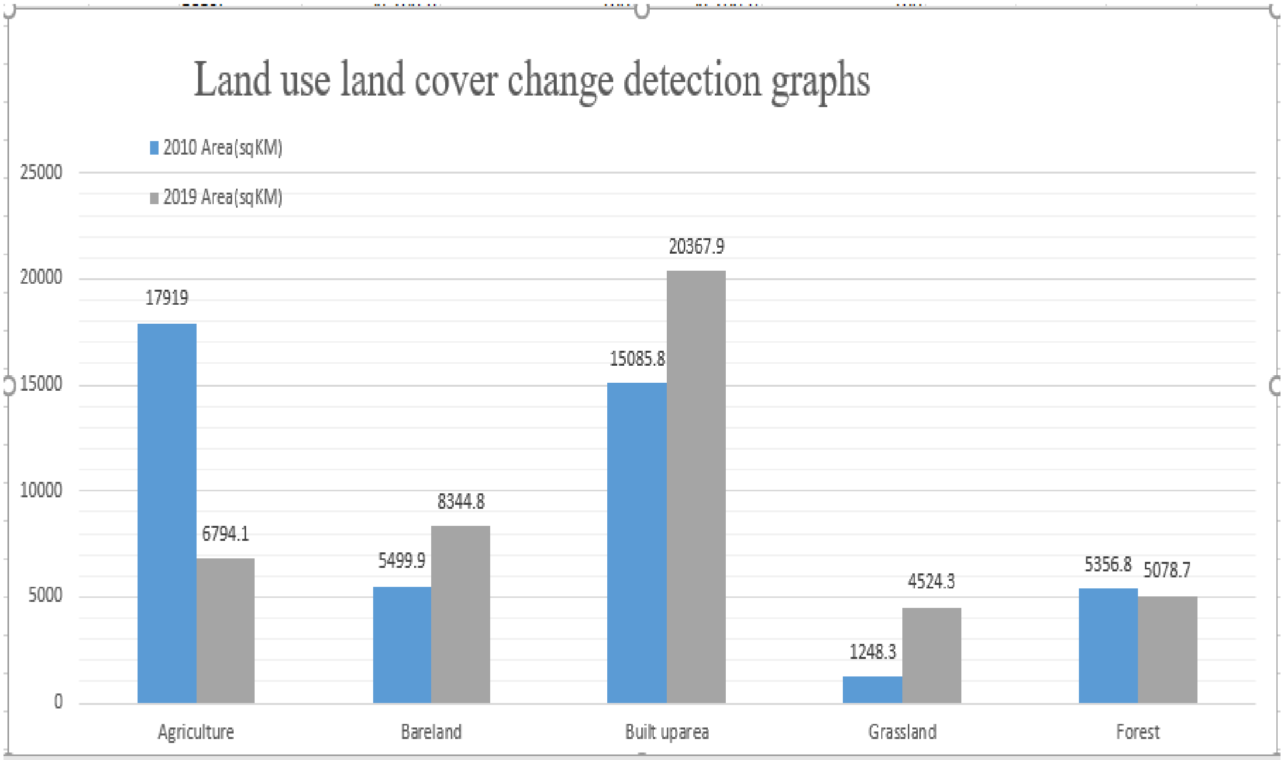

Figure 6 Land use land cover change detection of 2010 and 2019 in area

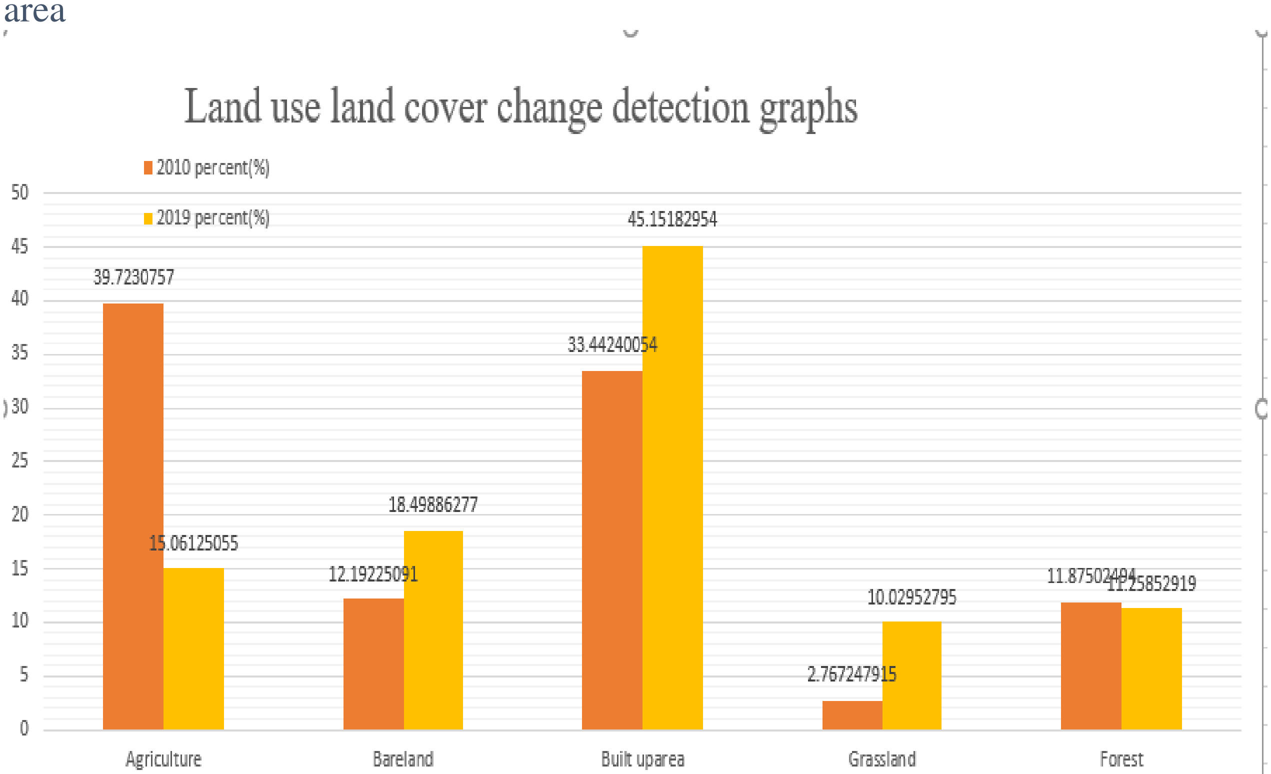

Figure 7 Land use land cover change detection of 2010 and 2019 in area in percent

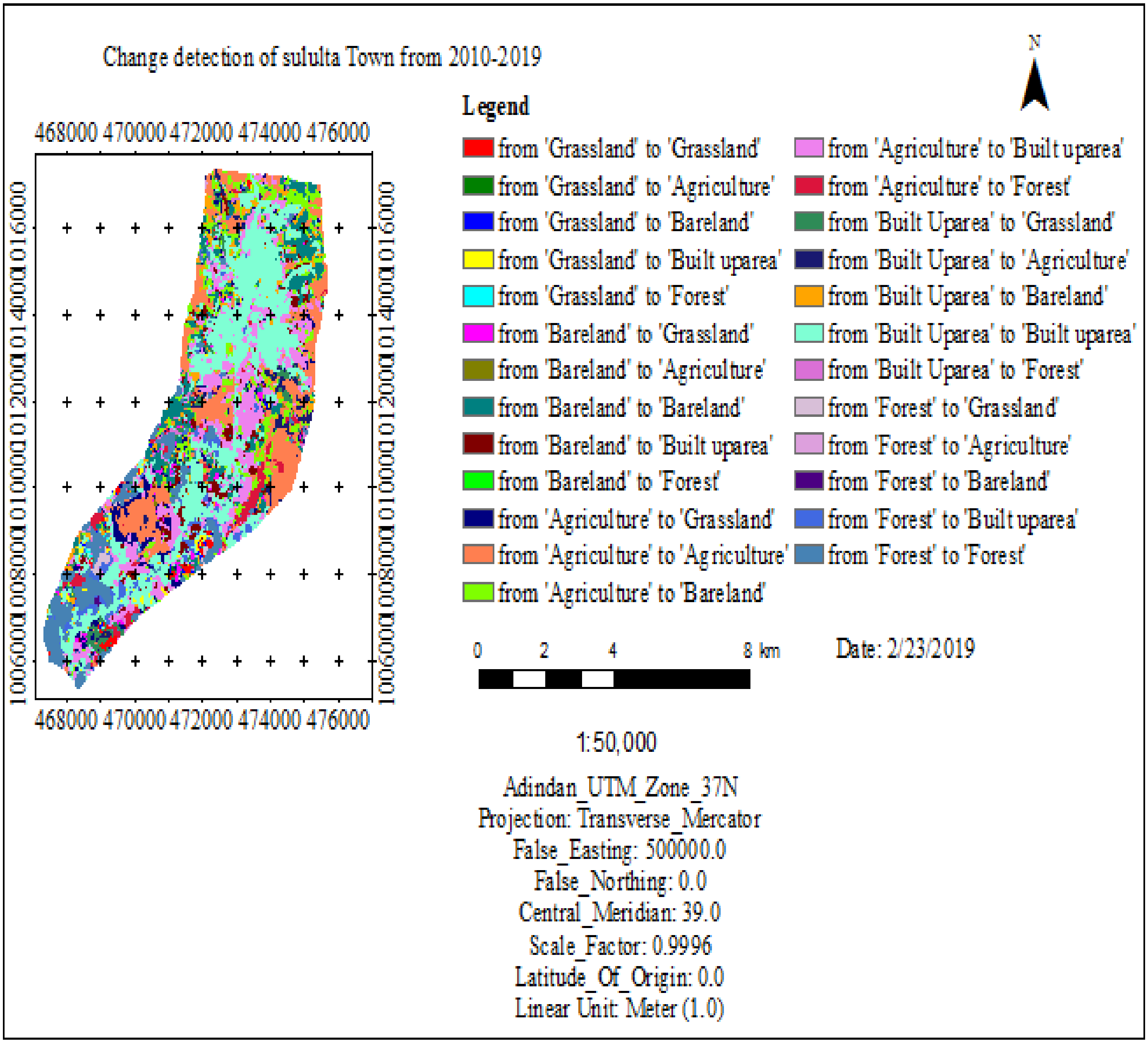

Figure 8 change detection of sululta town for each LULC types for 2010 and 2019

LULC 2010 (km^2)	LULC 2019 (km^2)					
	Agricultural land	Built-up area	Bare land	Forest land	Grass land	**LULC2010Total**
Agricultural land	**6.0966**	6.0318	3.3822	1.1286	1.503	18.1422
Built-up area	0.657	**11.9754**	1.3986	0.3159	1.2024	15.5493
Bare land	0.1098	1.6056	**3.1149**	0.0117	0.3699	5.2119
Forest land	0.0756	1.2582	0.1287	**3.5829**	0.2673	5.3127
Grass land	0.0072	0.3141	0.1341	0.0378	**0.396**	0.8892
LULC2019Total	**6.9462**	**21.1851**	**8.1585**	**5.0769**	**3.7386**	**45.1053**
Class change	0.8496	9.2097	5.0436	1.494	3.3426	
Image difference	-11.196	5.6358	2.9466	-0.2358	2.8494	

Table 8 class change and image difference of each LULC types for 2010 and2019

This evaluation classifies all of the pixels in the selected area of interest and compares the results to training sample (ERDAS Imagine 2014). The pixels of each training sample are not always so homogenous that every pixel in a sample is actually classified to corresponding class. Each sample pixel only weight the statics determine the class. However, if the signature statics for each sample are distinct from those of other sample, then a high percentage of each sample pixel is classified expected. Contingency matrix of 2010 and 2019 containing the number of pixels that are classified were found to be presented in table. For land use land cover 2010 among the 65 points that are random point assigned 57 point are correctly classified and 8 points are misclassified similarly for 2019 among the 66 points that are random point assigned 58 point are correctly classified and 8 points are misclassified. So the overall accuracies are 87.69% and 87.87% for the year 2010 and 2019, respectively according to the Anderson (1970) classification, accuracy values should be above 85 % and our results are shows the accuracy above it which is acceptable for international standards.

5. Conclusion

LULC change detection analysis is very important for planning, decision making and other land related activities. This study used an integrated approach to understand past and present condition of LULC. Generally, the five classes have been considered by using Grigg classification level for LULC mapping for the period of 2010 and 2019 in Sululta town which are Agricultural land, Built up area, Barren/open land, Forest land, and Grass (range) land. By fully utilizing remote sensing and GIS tools, and reviewing different literatures. The study has generated LULC map for 2010 and 2019 employing LANDSAT 7 ETM^+ and LANDSAT 8 LC data of different sensors.

As shown in table 9 the LULC change for Built up area in 2010 is 33.44% and in 2019 45.15% so Built up area is increased by 11.71%, for Agricultural land in 2010 is 39.72% and in 2019 15.06%, Agricultural land is decreased by 24.66%, for Bare land in 2010 is 12.19% and in 2019 18.49%, Bare land is increased by 6.3%, for Grass land in 2010 is 2.76% and in 2019 10.02%, Grass land is increased by 7.26%, for Forest land in 2010 is 11.87% and in 2019 11.25%, Forest land is decreased by 0.62% so from this positive growth from 2010 to 2019 have been found in Built up area (11.71%,), Bare land (6.3%,) and Grass land (7.26%,) and negatively (decreased area classified) in Agricultural land (24.66%,), and Forest land (0.62%)

The accuracy level is above 85% in all different 2010 and 2019-time period data which is acceptable by the international standard as per the literature of Anderson accuracy check and This study would be an asset for the environmentalists, ecologists, land development authority, climate change analysts and all other fields which are fully based on this one of the important parameters in different application areas.

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