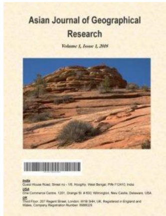

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Application of GIS and Remote Sensing to Analyse Land Use Land Cover Change Detection and Vegetation Dynamics Using Multi-temporal Satellite Images; The Case of Mariamdehan Kebele, Tigray Region, Northern Ethiopia

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Authors' contributions

This work was carried out in collaboration between both authors. Author EM proposed, data collected, analysed, writing, designed the study and wrote the first draft of the manuscript. Author YG managed the analyses of the study, reviewing and managed the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

Detecting Land use and land cover change and vegetation condition has become a central component in current strategies for managing and monitoring of environmental changes caused by anthropogenic activities. To come up with such decisions, geoinformatics technology is providing new tools to conduct vegetation and land use land cover change detection analysis for managing and wise utilisation of natural resources as well as to provide information for policymakers in a given study area. This study examines the use of geoinformatics technology to analyse land use land cover (LULC) change and vegetation dynamics using multi-temporal satellite images for the

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maryamdehan kebele in the years 1984, 2005 and 2015. Both primary and secondary data were used from different sources. Satellite images of the year 1984, 2005 and 2015 were downloaded from the govis.usgs.gov website and ground control points (GCP) data were collected by handheld GPS for supervised image classification in Erdas imagine and ArcGIS environment. The findings show that six main land use land cover classes were detected and vegetation values were also computed in each period. As a result, the total area of the kebele was 3646.49 hectare, from which in 1984 forest area (40.691%), grassland (26.15%) and farmland (10.81%) were dominant classes and in 2005 settlement (52.41%), forest area (25.04%) & farmland (11.71%) and in 2015, 35.14% was covered by forest land, 30.04% by Settlement, and 14.74% by farmland. Water resource decreases from 9.3% to 0.64% in 2015 and the bare land also changes from 3.18% to 0.903% because of urban expansion and agricultural activities in the kebele. In addition, the vegetation condition looks like a sinusoidal trend from the year 1984 up to 2015 because of climate change and human interventions in the kebele. To conclude that detecting LULC change and analysis of vegetation dynamics plays a great role in land use management and wise utilisation of natural resources by applying Geoinformatics tools in the kebele and it provides information for the policymakers to prepared future plan and for sustainable development.

Keywords: Geoinformatics technology; RS; GIS; change detection; NDVI; vegetation dynamics.

1. INTRODUCTION

The land is one of the most important natural resources, as life and various developmental activities are based on it. Land use land cover change has been identified as one of the most important drivers of changes in ecosystems and its services [1]. These changes result from population growth, urbanisation, and migration of poor rural people to urban areas for economic opportunities. However, information on the consequences of land use land cover change for ecosystem services and human well-being at local scales is largely absent. The sprawling process of expansion is disordered, unplanned, leading often to inefficient and unsustainable urban expansion patterns. The fundamental objectives of studying land use land cover changes are to investigate the social, economic, and spatial causes of changes so that proposals can be made on the suitable use of land and patterns of development. Land use land cover change detection studies coupled with spatial analysis serves as an effective tool for scientists and policymakers for efficient land management plans. Remote sensing and GIS plays an important role by offering an advantage of rapid data acquisition, storage, manipulation and analysis for land use land cover mapping [2] and Vegetation cover (VC) change detection is essential for a better understanding of the interactions and interrelationships between humans and their ecosystem. Remote sensing (RS) technology is one of the most beneficial tools to study spatial and temporal changes in vegetation cover using satellite images [3].

Vegetation plays a vital role in the global hydrological cycle, water supply, and aquatic functions. How vegetation responds to future environmental change poses one of the largest uncertainties in climate model predictions. Disturbance, both natural (e.g., wildfire, insect outbreaks, disease, windstorms, drought) and anthropogenic (e.g., timber harvesting, land conversion), can have a profound effect on hydrological processes through the impacts on vegetation dynamics. With climate change, natural disturbances are becoming more frequent and catastrophic. This, together with growing human disturbance, will undoubtedly affect water resources and consequently, have significant implications for land managers and policy makers [4]. Assessing and monitoring the state of the earth surface is a key requirement for global change research [5,6]. Classifying and mapping vegetation is an important technical task for managing natural resources as vegetation provides a base for all living beings and plays an essential role in affecting global climate change, such as influencing terrestrial CO_2 [7]. Vegetation mapping also presents valuable information for understanding the natural and man-made environmental effects through quantifying vegetation cover from local to global scales at a given time point or over a continuous period. It is critical to obtain current states of vegetation cover in order to initiate vegetation protection and restoration programs [8,9].

Even though most of the highland parts of Ethiopia are very suitable places for living and agriculture activities but know the natural resources are degraded because of population density increment [10]. However, the country faces different problems in relation to natural resource management and land cover change is one of the most serious environmental problems. According to [11] he conducted a large number of case studies and finds that land-use change drivers are land use resource limitation, policy interventions, population pressure and expansion of urbanisation. In Ethiopian context, serious environmental problems are related with the unbalanced proportion of the population lives in rural areas (85%) and about 90% lives in the highlands are directly depend on subsistence agriculture which is entirely dependent on natural resources [10]. Therefore, in the country Land use and cover changes had been particularly dynamic in the 20th century which is due to increasing population, expansion of the agricultural sector and climatic change. Moreover, [11] explain that rapid population growth and low economic living standard have brought to numerous consequences to land cover and land use changes, change in climate and hydrological status in the country. Besides, land tenure policy has been changed since 1975 that also leads/contributed for the dynamic change of land use land cover utilisation and distribution in the country.

Studying land use land cover change pattern is providing information for managing dynamics of land use and meeting the demands of an increasing human population. Additionally, Information on land and land cover change detection analysis and vegetation status in the form of digital maps and in descriptive data are very crucial for planning, management and wise utilisation of land for different developmental activities [12]. Examining Earth surface remotely from space, is now crucial to understanding the influence of human's activities on his natural resource over a long time to understand its utilisation of the natural resources. Land use/cover pattern of an area is an outcome of natural and socio-economic factors and their utilisation by a human in time and space. The land is becoming a scarce resource due to immense agricultural and demographic pressure, so information on land use land cover and possibilities for their optimal use are essential for the selection, planning, and implementation of land use schemes to meet the increasing demands for basic human needs [13]. Therefore, this paper attempts to conduct land use land cover change detection and vegetation dynamics computation for Maryamdehan *kebele* between 1984, 2005 and 2015 years through the use of geoinformatics tools.

1.1 Objectives

1.1.1 General objective

To detect land use land cover change and vegetation dynamics using multi-temporal satellite images in Maryamdehan kebele using Geo-informatics tools.

1.1.2 Specific objectives

- ✓ To see land use land cover change dynamics on the kebele.
- ✓ To detect land use and land cover change between 1984, 2005 and 2015 using satellite images of the kebele.
- ✓ To assess soil and water conservation practices in the kebele
- ✓ To detect vegetation dynamics and trends in each year for the Mariamdehan kebele

2. MATERIALS AND METHODS

2.1 Description of Study Area

This research activity was done in kebele Maryamdehan, woreda Enderta, Tigray region. Maryamdehan was one of the kebeles within Enderta woreda; it is 7.6 Km far away from the capital of Tigray region, Mekelle city in western direction. Geographically it founds on 13.53^0 – 13.57^0 N latitudes and 39.44^0 – 39.47^0 E longitudes and the elevation varies from 1902 to 2259 meter above mean sea level with total area coverage of 3646.49 hectares and temperature varies between 18^0C and 19^0C.

2.2 Materials and Software are Used

The most used materials and software in this research work were mentioned as follows:

- Laptop computer for processing activities.
- GPS – Garmin 60: used for taking Ground Control Points data and boundary delineation.
- ArcGIS – 10.2 and Erdas Imagine 9.2: used for spatial data analysis, layer stacking, supervised image classification and mapping.
- Satellite Images of 1984, 2005 and 2015 downloaded from glovis.usgs.gov website.
- Ms-Office-2007: used for result report preparation and documentation purpose.

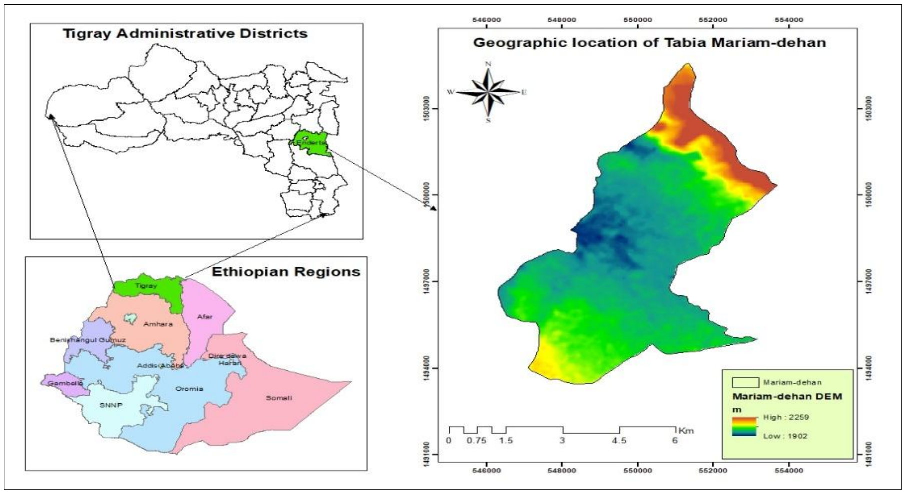

Fig. 1. Geographic location of Maryamdehan kebele
(Source: Autor generated map)

2.3 Research Methodology

The basic land use land cover change detection procedures were followed in this research work, to begin with, satellite images of 1984, 2005, and 2015 were downloaded from glovis.usgs.gov and GCP for land use land cover classes were collected using handheld GPS tool. Signatures were prepared using GCP points and supervised image classification was performed using Maximum likelihood classification algorithm to come up with the supervised image classification results and then it extracted by the kebele extent and areal tabulation method was applied to assess the changes using transitional matrix. In addition, the vegetation status was computed using near-infrared and red bands from the satellite images downloaded for image classification purpose. To compute vegetation status, the Normalised Difference Vegetation Index (NDVI) method was used, NDVI was first suggested by Tucker in 1979 as an index of vegetation health and density. The following formula was the basic concept in computing the vegetation status of a given area in which it ranges from -1 to 1. Whereas the values near to 1 represent health vegetation and wet areas, whereas the values approach to -1 represents the dry areas and unhealthy vegetation coverage.

$$NDVI = (NIR-RED) / (NIR+RED)$$

Where, NIR and RED are the reflectance in the near-infrared (NIR) and red bands, respectively. NDVI reflects vegetation vigor, percent green cover, Leaf Area Index (LAI) and biomass. The NDVI is the most commonly used vegetation index. It varies in the range of -1 to + 1. To detect the NDVI values trend in each year we create 30 random points and we extract NDVI values of the random points from each year to look the difference between them. Soil and water conservations practices were assessed using informal questioners from elderly farmers. Lastly not least result in interpretation, conclusion, and recommendations were derived.

2.3.1 Land use and land cover change analysis

2.3.1.1 Remote sensing data acquisition

The first step in land use land cover change analysis was to collect satellite images using the path/row information from free satellite image provider websites. In this study, three periods of (1984, 2005 and 2015) Landsat satellite images were acquired from free satellite provider that is glovis.usgs.gov and a brief description of them is given in Table 1. The downloaded satellite images were in tiff format and were stacked in Erdas Imagine 9.2 software and using the stack function to produce one single layer composing of all bands. Then from the stacked band, the study area was extracted using the kebele boundary.

2.3.1.2 Satellite image analysis procedures

1. Image Pre-processing: Preprocessing involves those operations that are normally required prior to the main data analysis and extraction of information. Selecting appropriate satellite imagery is the first task in image data processing.

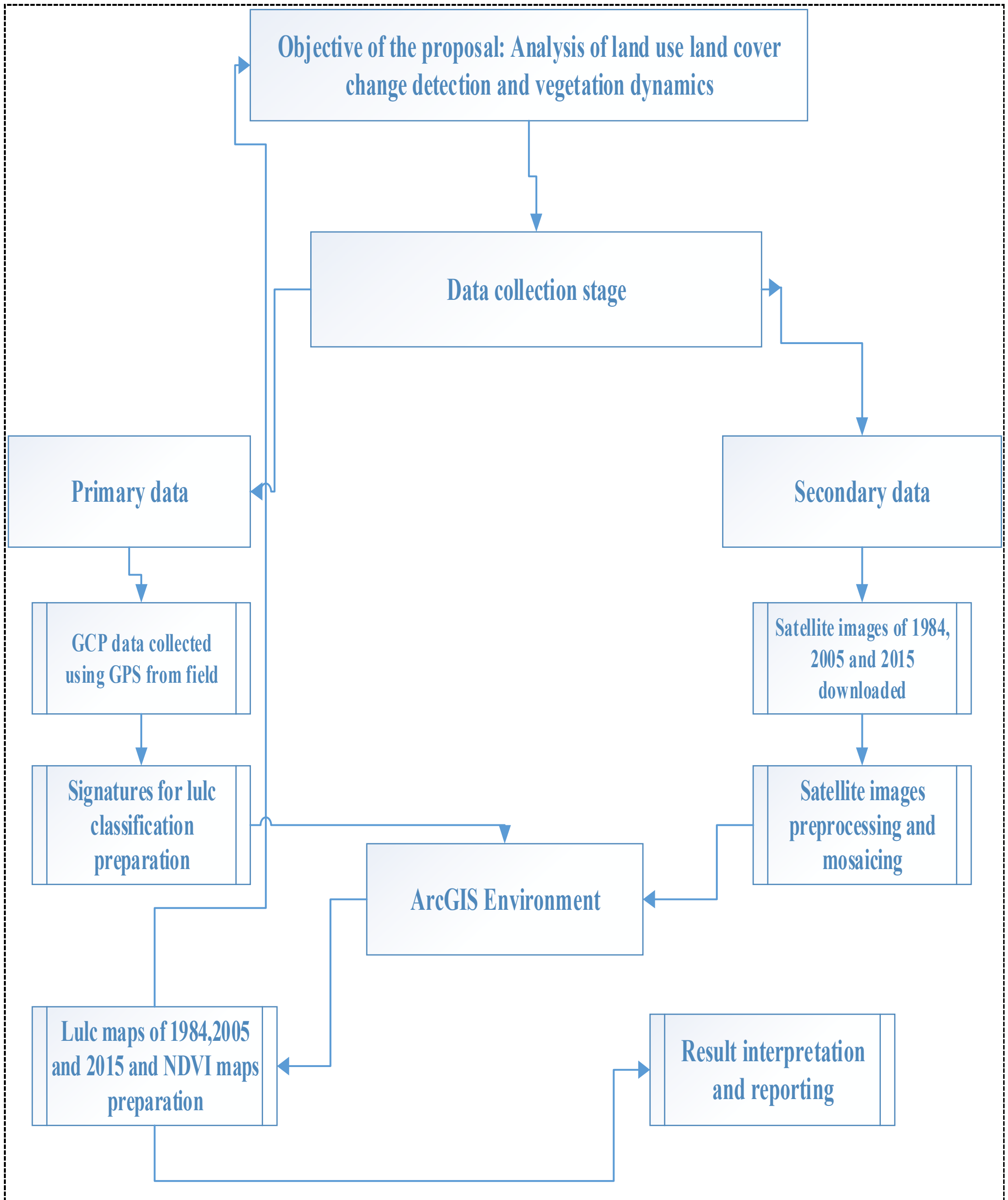

Fig. 2. General research framework of the research work

Table 1. Landsat data downloaded for land use and land cover classification

Sensors	Study area	Path and row	Bands	Pixel size / ground resolution (M)	Observation date
Landsat ETM	Maryamdehan	169/51	7	30 * 30	1984
Landsat ETM	Maryamdehan	169/51	7	30 * 30	2005
Landsat ETM	Maryamdehan	169/51	7	30 * 30	2015

a) Geometric Correction: In this work, the processing of these images has been geometrically corrected by the provider and they have been clipped with the boundary of the study area for further processing.

b) Image Enhancement: The goal of image enhancement is to improve the visual interpretability of an image by increasing the apparent distinction between features in the scene [14]. If the image is enhanced the distinct of features are clearer so that image analysis, classification, and interpretation are better. In addition, Image enhancement is used to increase the details of the image by assigning the image maximum and minimum brightness values to maximum and minimum display values, it is done on pixel values, and this makes visual interpretation easier and assists the human analyst. The original low dynamic range of the image is stretched to full dynamic range which is from 0 to 256 by using histogram equalisation. Moreover, spatial enhancement of convolution of Kernel 5 by 5 of high pass filtering has been done on the images of the respective years.

2. Image Processing (Satellite Image Classification Analysis): In this study, unsupervised and supervised classification methods were used. Supervised image classification was a method in which the analyst defines small training sites on the image, which were representative of each desired land cover category. The delineation of training areas representative of a cover type was most effective when an image analyst has knowledge of the geography of a region and experience with the spectral properties of the cover classes. However, the unsupervised classification technique is performed when there was little or no knowledge to the geography of the region where classification is undertaken. Therefore, first, the satellite image was classified in the unsupervised classification for identification of the features in a pixel form. Then by observing and recording identifiable coordinate points of features in the Google Earth were perform the supervised classification using the training points.

For this study, a simple classification scheme comprising six land use and land cover types was developed for the purpose of mapping. A combination of information collected from the field and a satellite image were effectively used in the preparation of the legend. Identification of some of the land use and land cover classes were required a number of field visits and discussions with farmers, to have not only a clear understanding of the main land use and land cover types but also to establish what types of changes are expected over time. What stage and type of land use and land cover is to be expected in what season of the year should be properly established to enable interpretation of the satellite images. Categorisation of land use and land cover types were culminated in the production of the land use and land cover legend, establishment of its characteristics, and identification and mapping of the various land use and land cover types [15]. The maximum likelihood classification is of the most popular methods of satellite image classification in remote sensing, in which a pixel with the maximum likelihood is classified into the corresponding class or pixel. This method has an advantage from the viewpoint of probability theory, but care must be taken with respect to the following items. (1) Sufficient ground truth data should be sampled to allow estimation of the mean vector and the variance-covariance matrix of the population. (2) The inverse matrix of the variance-covariance matrix becomes unstable in the case where there exists a very high correlation between the two bands or the ground truth data are very homogeneous. In such cases, the number of bands should be reduced by a principal component analysis. (3) When the distribution of the population does not follow the normal distribution, the maximum likelihood method cannot be applied.

3. Image post-processing (Accuracy assessment and ground verification): Land use and land cover maps derived from remote sensing always contain some sort of errors due to several factors, which range from classification technique to method of satellite data capture. In order to wisely use the maps, the errors must be quantitatively evaluated in terms of classification accuracy and intended to produce information that describes reality. Therefore, an accuracy classification assessment was carried out to verify to what extent the produced classification is compatible with what actually exists on the ground [16]. It involves the production of references (samples) that evaluate the produced classification. These references were produced from Google Earth and GPS points during fieldwork, which was independent of the ground truths used in the classification. Using this process error matrix was produced for each image of the three districts. And additionally, Field observation was carried out to obtain Ground Control Points (GCPs) for georeferencing the images, to understand the features of the different land cover classes, support visual interpretation of the images and select reference areas. Ninety reference points were taken using GPS receiver for ground truth verifications. At every reference point, co-ordinates and the current human activity evidence on each land use\land cover were documented. The change matrixes were determined by overlaying two land use and land cover maps at a time in ERDAS imagine software. The areas which were converted from each of the classes to any of the other classes were computed [17].

The interpretation and analysis of remote sensing imagery involve the identification and measurement of various targets in images in order to extract information. In this study, unsupervised classifications were carried out first to identify the overall land use and land cover clusters without training data. Then supervised classification was carried out for the three images of 1984, 2005 and 2015 based on the training areas and the different false color composites of 4, 3, 2. Then the change detection analysis was carried out by visual comparison of features and detailed quantitative approaches. Using the application of supervised image classification methods, six major land use and land cover types were identified. These include shrub/bushland, grassland, agricultural land, bare land, and water body, based on the characteristics of Landsat images of the year 1984, 2005 and 2015.

3. RESULTS AND DISCUSSION

3.1 Supervised Based Land Use Land Cover Classification Maps of Maryamdehan Kebele (1984, 2005 & 2015)

After satellite image downloading and preprocessing procedures land use land cover classification was performed using maximum likelihood classification algorithm. The final output of land use land cover change detection was supervised classification maps of the study area on a temporal basis. Accordingly, land use land cover classes of the area under different periods were detected and mapped in spatial and temporal basis, as well as its areal coverage, was mentioned as in the Fig. 3.

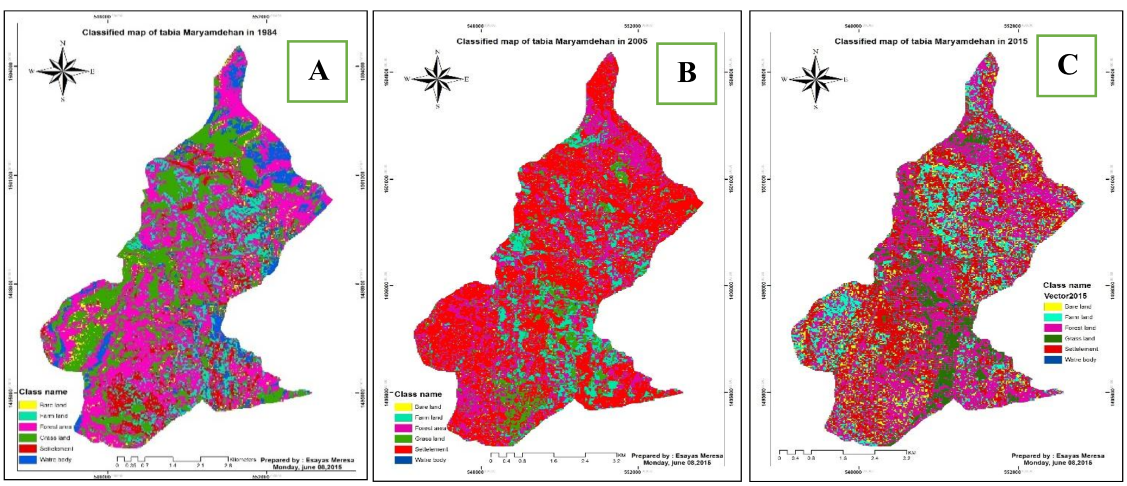

Fig. 3. Supervised based Land use land cover maps of 1984 (A), 2005 (B) and 2015 (C)

Table 2. Land use land cover classes areal distribution in Mariamdehan kebele (1984, 2005, and 2015)

LULC classes	1984		2005		2015	
	Area (Ha.)	Area (%)	Area (Ha.)	Area (%)	Area (Ha.)	Area (%)
Bare land	115.98	3.18	63.9	1.75	329.59	9.039
Farm land	394.25	10.81	427.34	11.71	537.83	14.74
Forest area	1483.8	40.69	913.15	25.04	1281.7	35.14
Grass land	953.6	26.15	318.57	8.73	378.2	10.37
Settlement	359.44	9.85	1911.3	52.41	1095.7	30.04
Water body	339.41	9.3	12.778	0.35	23.547	0.64
Total	3646.5	100	3646.5	100	3646.5	100

Table 3. Transitional change matrices from 1984 to 2005

ID	Class_Name	Waterbody	Forest land	Farmland	Grassland	Settlement	Bare land
1	Water body	1.22	87.17	41.93	29.40	174.69	4.78
2	Forest land	4.70	373.30	156.59	104.48	813.93	26.97
3	Farm land	1.74	98.91	87.26	57.59	136.41	6.09
4	Grass land	3.65	247.33	88.13	71.68	525.80	18.44
5	Settlement	1.83	75.69	45.93	54.20	176.69	6.44
6	Bare land	0.17	25.05	5.48	3.83	79.34	2.09

Table 4. Transitional change matrices from 2005 to 2015

ID	Class_Name	Waterbody	Forest land	Farmland	Grassland	Settlement	Bare land
1	Water body	0.35	4.52	2.52	1.30	4.18	0.43
2	Forest land	6.70	284.48	153.03	86.47	295.96	81.51
3	Farm land	5.92	151.98	49.33	95.00	106.57	16.44
4	Grass land	2.09	129.45	28.53	63.94	73.86	23.31
5	Settlement	8.44	683.87	295.52	121.62	594.79	202.70
6	Bare land	0.17	23.66	10.35	5.92	18.97	5.92

3.2 Land Use Land Covers Transitional Matrices/ Dynamics in 1984, 2005 and 2015

According the results mentioned above the trend of forest land was downward from 1984 to 2005 and upward from 2005 to 2015 the reason behind this was that the farmers were creating awareness on the use of plantation for domestic activities, like for fuelwood, for homestead gardening, source of economy by selling and built up of homes. This increasing of a plantation in the kebele has also played its own role in minimising the impact of climate change. Water resources were decreased from 1984 to 2015 due to the computation of the resources, climate change, urban pressure and agricultural expansion in the kebele. The transition matrices are shown us there is a high changing of land use land cover classes among each other due to different human activities and natural phenomena.

3.3 Spatial and Temporal Vegetation Dynamics of Mariamdehan Kebele in 1984, 2005 and 2015

Assessment and monitoring of vegetation condition of a given area is important information for preparing an action plan for using and managing the area for sustainable utilisation and future planning by policymakers. Based on the

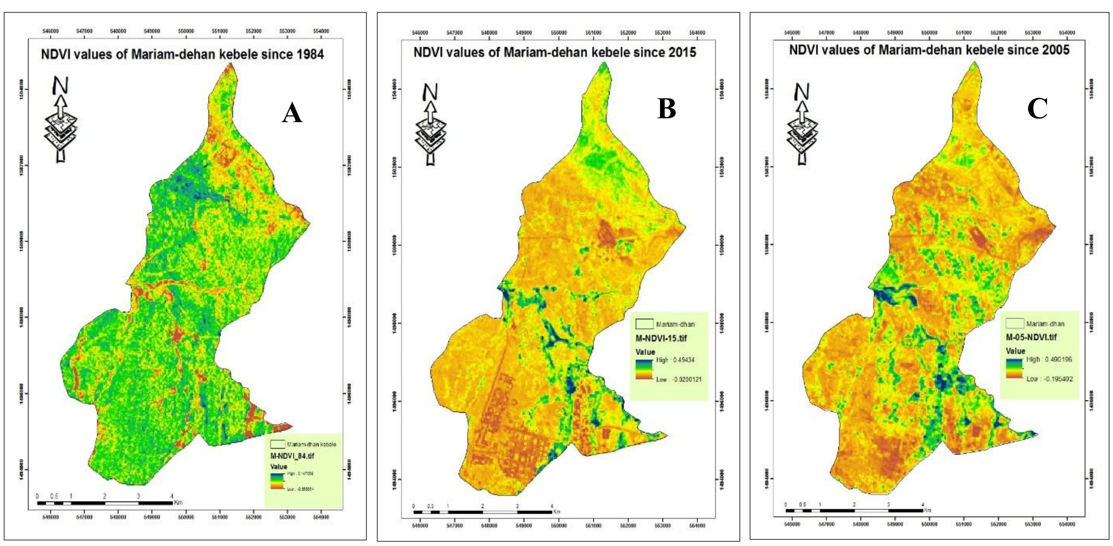

Fig. 4. NDVI based vegetation dynamics maps of the kebele in 1984 (A), 2005 (B) and 2015 (C)

NDVI computation algorism the following spatial maps which shows vegetation dynamics were developed using image analysis tool on the ArcGIS environment. Accordingly, there is good vegetation coverage in 1984 than the others and very low vegetation coverage was observed during 2015, this may be caused by urban expansion and agricultural activities in the kebele. But the point pattern based NDVI analysis shows that there is Good vegetation coverage both in the years 1984 and 2015 than the 2005 year (Fig. 4).

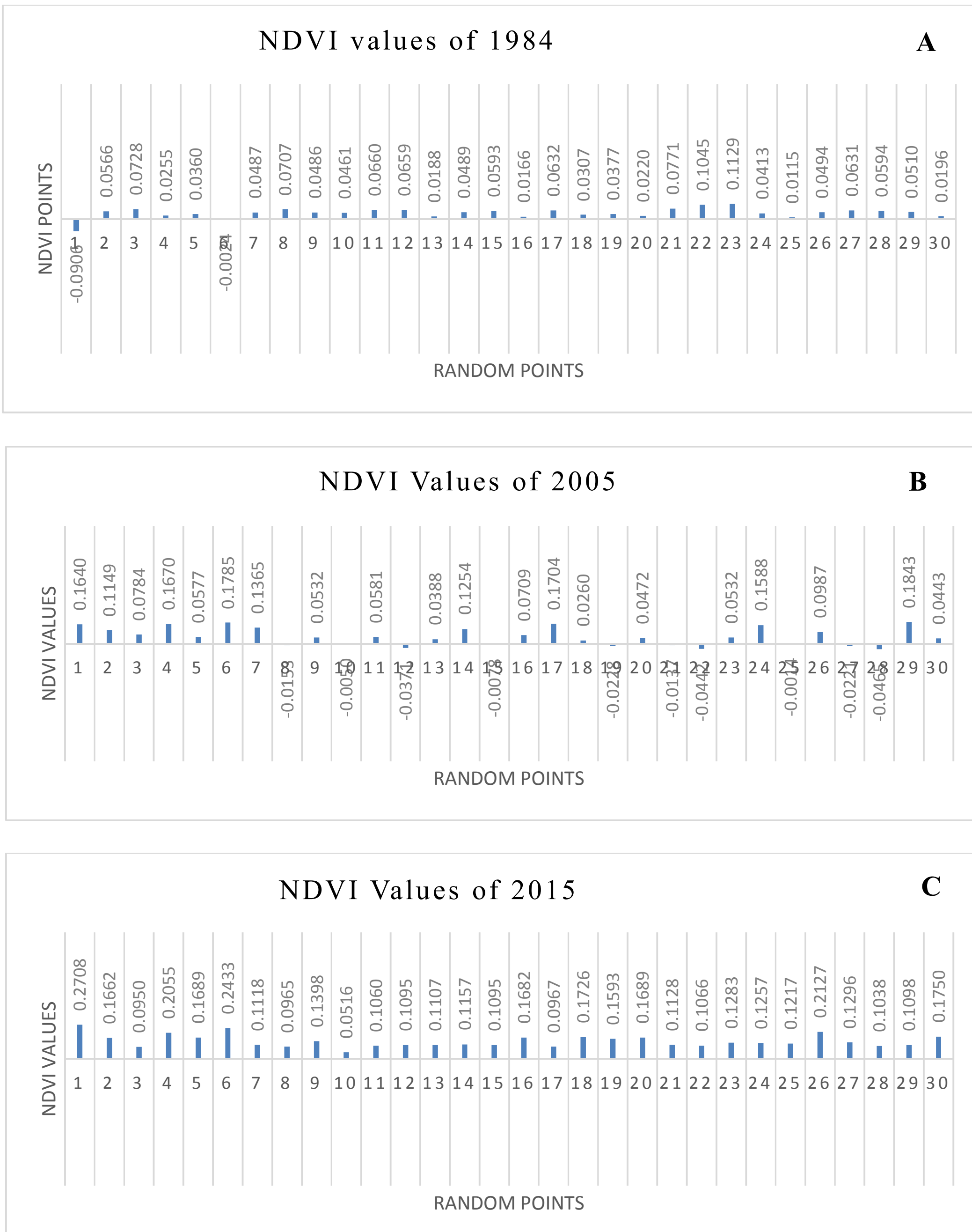

Fig. 5. Random points based NDVI change detection in 1984 (A), 2005 (B) and in 2015 (C)

Table 5. Transitional change matrices from 1984 to 2015

ID	Class_Name	Waterbody	Forest land	Farmland	Grassland	Settlement	Bare land
1	Water body	1.04	119.27	40.97	36.19	105.18	36.80
2	Forest land	10.00	501.01	214.88	133.71	487.35	132.93
3	Farm land	5.05	133.10	60.72	50.98	110.57	27.32
4	Grass land	5.39	354.42	139.89	114.66	258.55	82.38
5	Settlement	1.91	129.19	57.68	33.15	101.70	37.23
6	Bare land	0.26	40.71	25.14	5.39	31.32	13.48

3.4 Trends in Vegetation Values on the Selected Periods in the Maryamdehan Kebele

Based on the random points NDVI analysis in each year there is good vegetation coverage in the year 1984 and 2015 as shown in the below-mentioned graphs (Fig. 5) than the year 2005. This may cause due to climate conditions variation and other anthropogenic activities performed in the kebele.

4. CONCLUSION AND RECOMMENDATION

4.1 Conclusion

Analysis of vegetation dynamics and land use land cover change analysis using GIS and Remote sensing plays a great role to manage, wise utilisation and for future planning of natural resources as well as used for decision making by policy makers for sustainable management and development. Findings show that the kebele have high forest land coverage, which is 35 % of the total area, this plays its own role in conserving soil resource and uses as one option in minimising climate change impacts. And there is a decreasing trend of vegetation coverage in the kebele due to different human and natural activities in the kebele this can be improved by practising and introducing of improved soil and water conservation practices in the kebele for improving the vegetation condition and to use the resources for sustainable utilisation and development. As a conclusion, Geo-informatics tools plays a great role in performing vegetation dynamics and land use land cover change detection of a given area using multi-temporal satellite images for sustainable natural resource utilisation and planning, and it is the best tool for spatial decision-making issues as input for policymakers and other organs.

4.2 Recommendation

- Understanding the dynamics of vegetation status and land use land cover change in a given area is important for wise utilisation, proper management and future planning of resources.
- There is a scarcity of water resource in the kebele, so introducing water harvesting structure is important for improving the farmer’s livelihood through agricultural production.
- The kebele have high forest area coverage so awareness creation on the importance of plantation in minimising climate change impacts.
- Introducing improved soil and water conservation practices were important in the kebele for better utilisation of natural resources and to maximise Agricultural production and productivity in the community.
- Most of the farmers have some idea on how to conserve their natural resources, this should be strengthened and needs serious awareness creation on the community by researchers and natural resource management experts.
- Vegetation coverage is in good condition in the kebele, this should be important to minimise the impact of climate change risks in the community and to make the environment healthy.
- GIS and Remote sensing tools were important in mapping, exploring and management of natural resources for wise utilisation, proper management, and future planning purpose.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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