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Research Article

A GIS-based technique analysis of land use and land cover change detection in taluka Mirpur Mathelo: A case study in district Ghotki, Pakistan

Shoukat Ali Shah [a,*] ***and Madeeha Kiran*** [b]

[a]*Institute of Water Resources Engineering and Management, Mehran University of Engineering and Technology, Jamshoro, Sindh, Pakistan*

[b]*School of Environmental Science, Northeast Normal University, China*

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ABSTRACT

Land use and land cover changes at the regional scale are necessary for a wide range of uses, including land planning, global warming, erosion, and landslide, etc. In this study, Land use and land cover change detection were studied by using remote sensing and GIS in taluka Mirpur Mathelo, Ghotki. For this purpose, ArcGIS 10.3 software was used. Firstly, supervised classification performance was applied to Landsat imageries which were acquired in 2013-2020. Image classification of six bands of Landsat imageries was carried out via a maximum likelihood classification process with the help of ground trothing data and signature file for both images 2013-2020 year. The second part focused on the land use and land cover change detection was evaluated with overlapping of the images. The results of the study indicated that severe land use and land cover change detection has occurred in the area during 2013-2020. The total relative change in the settlement is 2439.45 ha (1.94%) during the years. 592.38 ha (0.47%) changed in the vegetation cover. A total change of 3.16 ha (3.16 %) in the sand area. While barren land/plain -5094.63 ha (-4.06%) changed during the years. -1906.2 ha (-1.52%) shortage in the water body. It has been seen that decrease in barren land/plain and waterbody which has been converted into more in the sand and some portion in agriculture.

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1. Introduction

Human activity on the earths surface and its adaptation around the sphere is commonly known as land use and land cover (LULC). Human activity and increasing population impact on finite resources of cultivated area, forest field, urban area, and manufacturing industries. More area of agricultural land is required to be cultivated with growing human inhabitants which will also affect and shrinkage in quality and quantity of resources of the earth. [1] studied that the empirical examination by the investigators from diverse fields concluded that land use and land cover change has come to be important in agriculture, environment, ecology, geography, forestry, geology, and hydrology. Land cover change detection plays several essential characters in global environmental changes because the variance has certainly disturbed the sustainability, biodiversity, and relations between earth and the atmosphere. Proper planning, management, and utilization of natural resources are considered while studying land use and land cover changes [2]. Although, analysis of LULC from the past to present and it is simulating the future changes is significant for local and regional authorities. Unfortunately, traditional methods and techniques for land cover mapping especially in developing countries such as Pakistan are very poor, time-consuming and costly. Considering these difficulties, the attention of researchers has been directed towards GIS and remote sensing technology for monitoring LULC changes. This technology has been increasingly applied in the LULC mapping, analysis and urban development due to its cost-effectiveness and high efficiency [3, 4]. LULC changes have turned into a vital component in a present

* Corresponding author. Tel.: +92-303-249-9292, +92-333-366-5063
E-mail addresses: sarkar.sain151@gmail.com (S.A. Shah), madeehajanwery@yahoo.com (M. Kiran)
ORCID: *0000-0002-6723-9898 (S.A. Shah), 0000-0001-6061-642X (M. Kiran)*
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strategy for the management of natural resources as well as to check environmental changes [5]. The accurate and timely information on the spatial distribution of land cover changes over a wide area is more convenient with this powerful technique [6-8]. RS and GIS have a wide range of usage in the agricultural fields [9]. Many approaches have been created and applied for change detection to monitor land cover changes by remotely sensed information and data for image differencing, post-classification comparison, vegetation index variation [10]. These methods were found to be the most accurate reliable and time-saving by a variety of different studies that offered advantages of representation of nature and physio-graphical changes. To obtain accurate and timely spatial data as well as analyzing LULC changes in a study area RS imageries and GIS are very useful tools [11, 12]. Multi-temporal data acquisition from remote sensing are very effective in mapping and change detection of agricultural area, urban, waterbody, barren land, and landscape to planning and managing. Therefore, for valuable and sustainable improvement, the policymakers, land-use managers, executives and municipal authorities need these techniques and tools to monitor how the land is used and understand the development and directions of different kinds of land users, in particular, urban land use in the past, present and future. It was also suggested to the policymaker with scientific change assessment to understand the natural state of the study area and the complex relation between the physiographic and man-made features. Keeping in view, in the present research study geospatial technique was used to reveal the significance of land cover changes over the study area, which helped to assess the change directions and dynamics. Taking into account, the aim of the study to analyze the land use and land cover change detection by using GIS and remote sensing techniques that were applied in MPM taluka of district Ghotki.

The purpose of this research study is to map the land use and land cover of MPM taluka to detect the changes from the last eight years that have been taken place. The following particular objectives of the research study are pursued to achieve the targets.

- To map land use and land cover classification scheme.
- To determine land use land cover change detection from 2013 to the 2020 year.
- To check the NDVI and vegetation index from 2013 to the 2020 year.

2. Materials and Methods

2.1 Location of Study Area

The research study was carried out in MPM taluka of district Ghotki, Sindh. MPM located on Latitude N: 28 02' 00' and Longitude E: 69 33' 00' Figure 1. The altitude of taluka 71 m above sea level. It covers an area of 125568 ha (1255.68 km^2). The taluka is also headquarters of district Ghotki and administratively subdivided into 11 Union Councils i.e. Mirpur I, Mirpur II, Dhangro, Jahan Khan Unar, Islam Khan Lashari, Gari Chakar, Sono Pitafi, Jarwar, Yaro Lund, Wahi Ghoto, Dino Mako. The topography of MPM taluka is divided into two main clear physical parts i.e. Cultivated area and Desert area. Desert area covers nearly half of the area of taluka and consists of windblown dunes known as Acharo Thar (White desert) that starts from Sanghar district to Cholistan (Punjab) along with Indian border state of Rajhastan. It goes along southern belt of the district Ghotki. The taluka is bounded by Rahimyar Khan district of Punjab province in the northeast, Kashmore district in the west and north-west, Sukkur district in south and southwest and Rajasthan, India in the east.

2.2 The Population of Taluka MPM

The total population of taluka MPM has been reported in the census [13] as (327,944) in which Rural 227,184 and Urban 100,760.

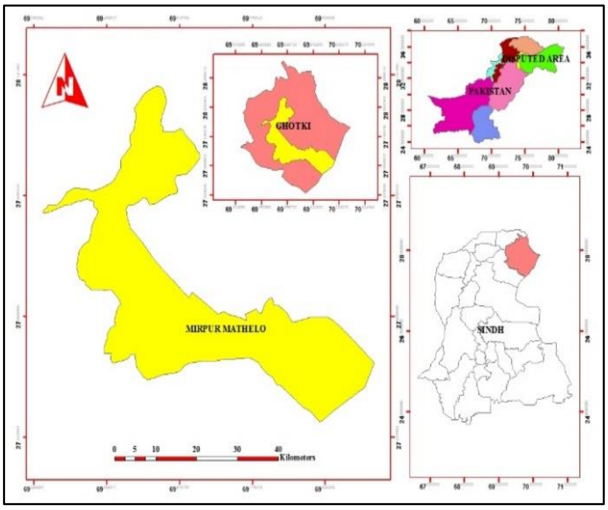

Figure 1. Location of MPM taluka, District Ghotki, Sindh, Pakistan

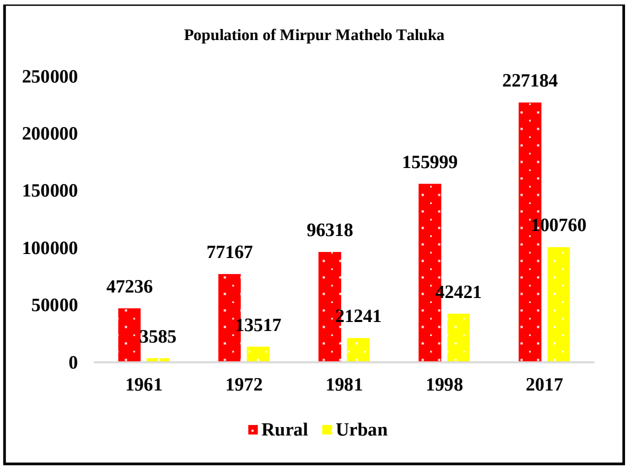

Figure 2. The population of MPM according to Census 1961 to 2017

2.3 Climate and Irrigation

MPM taluka is warm and has very little annual rainfall. The minimum temperature falls to 7°C in January is the coldest month. The maximum temperature is 45°C in May and June are the hottest months. Precipitation is highly erratic with an annual average of approximately 130 mm. Most of the inhabitants are engaged in agriculture. Wheat, cotton, vegetables, and fruits are the major crops in the study area. The climate is appropriate for growing vegetable crops and fruits such as dates, banana, mangoes, carrot, lemon, reddish, cabbage, onion, spinach, green chillies, etc [14]. The agricultural land has been irrigated by Masu wah which off-takes from Ghotki feeder canal which originates from Guddu barrage and some other network of distributaries, minors and also irrigated by Government and private tubewells.

2.4 Data Used

To identify changes over a period 2013-2020 required temporal Landsat satellite imageries. For mapping, the land use and land cover and change detection. Two images 2013 and 2020 that were cloud-free were acquired from remote sensing satellite Landsat 8 OLI/TIRS. The study area lies on the Path 151 Row 41. The Landsat 8 OLI/TIRS images were downloaded from USGS (GloVis) (http://glovis.usgs.gov) earth resource observation system data centre. All visible and infrared bands except the thermal infrared were included in the analysis of the imageries of the 2013-2020 year. The Topographic map was used and digitized to create a spatial database. This process was carried out using geospatial tools ArcGIS 10.3. software.

2.5 Ground Trothing Data

Ground trothing data/sampling points were collected from taluka MPM. The union councils were considered easily and timely to conduct field surveys for the collection of coordinates for different land use in the area of study (Figure 3). The geographical map of MPM taluka was followed and randomly sampling points (Longitude and Latitude) were taken with the Garmin 62s GPSMAP device. It is a handheld navigator by Garmin. The main function of the device is to navigate through even the most remote regions and terrain. By using this device settlements, vegetation, barren land, orchards, waterbody, sandy area, etc. sampling points were taken. A total of 110 ground sampling points were collected for five categories (Table.1) including 25 samples of vegetation, 20 samples of barren land/plains, 31 samples of settlements, 19 samples of Waterbody, and 15 samples of Sand, respectively. After the collection of sampling points, the collected data were prepared into MS Excel format and added into Landsat imageries for analysis and accuracy assessment to get the required objectives.

Table 1. Description of LULC categories

S. No	Class / Categories	No. of Samples	Description
1	Settlements	31	Built-up, Commercial areas, Buildings, Cities, Roads, Villages, Industries, etc.
2	Vegetation	25	Crops land, Pastures, Trees, Orchards, Grass, Plantation etc.
3	Waterbody	19	Ponds, Streams, Reservoirs, Canals, Minors, etc.
4	Barren land	20	Un cultivated area, Exposed soils, Landfills, Saline, Silt, etc.
5	Sand	15	Sandy area Thar (Achro)

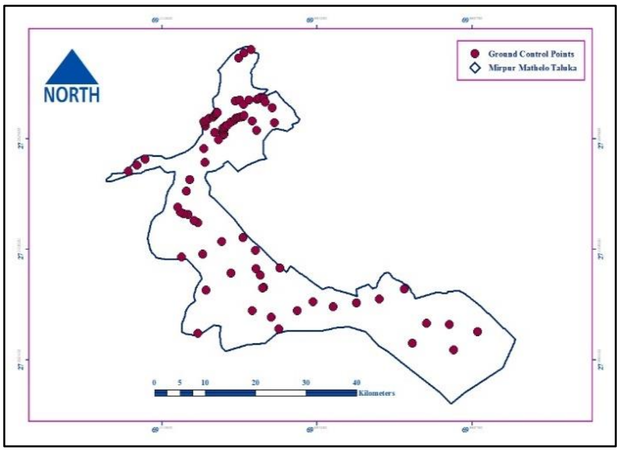

Figure 3. Ground Trothing Survey/sampling points of MPM taluka

2.6 Classification of RS Images

The boundary of the study area was digitized using ArcGIS 10.3 tool and overlapped onto satellite imageries. Two un-classified images 2013 and 2020 (Figure 4) were exported to ArcGIS 10.3 for map composition and cross-classification, tabulation, and land use and land cover changing modelling. The extraction of the Mask process was applied. During the process of image classification, a maximum likelihood classification algorithm was used for supervised classification to determine the classes. This practice has been used in various studies for RS image classification [15-19]. For supervised classification the signature file was made for each image, the pixels of the images were arranged into classes based on the signature by using classification decision. The cross-classification was done with re-classified maps. Before preprocessing and classification of satellite imageries, extensive randomly sampling points during field surveys and interviews were conducted in taluka. To find change detection with the help of image analysis, the post-classification comparison method is widely used in the world. In the present study, the quantitative method of change detection i.e. post-classification method was carefully chosen to find land use and land cover in the research study area.

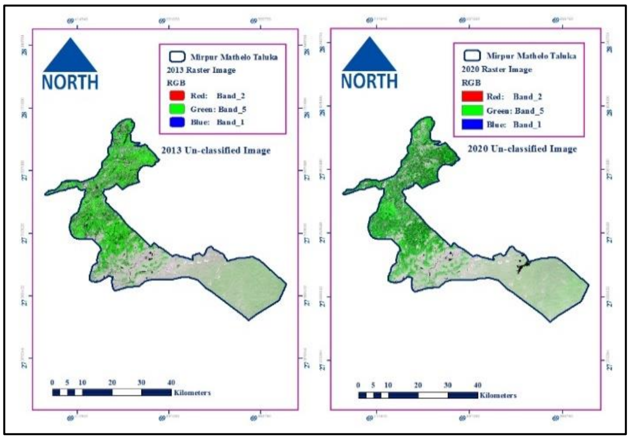

Figure 4. Un-Classified images (2013-2020) of MPM taluka

2.7 Change Detection Analysis 2013-2020 Years in MPM Taluka

Change detection is a process of recognizing the differences in the state of an object or phenomenon by observing it at different periods. The significance of change detection is to determine which land use and land cover is changing to the other. The researcher's widely used this technique for change detection is to overlay images, change vector analysis, image rationing, classification comparisons of land cover statistics, principal component analysis, and the differencing of NDVI [20]. The classification comparisons of land cover statistics were used in this study. The areas where covered by each land cover type for the various periods have been compared. Afterward, changes directions (positive and negative) in each land cover type have been determined.

2.8 NDVI of MPM Taluka

The normalized difference vegetation index (NDVI) is an identical index allowing to make an image showing greenness and biomass [21, 22]. It is a standard for comparing vegetation greenness between satellite images [23]. The index takes benefit of the contrast of characteristics between 2 bands from a multispectral raster dataset the chlorophy ll pigment absorption in the red band and the high reflectivity of plant material in the near infrared NIR band. Extremely low or negative values present areas with no vegetation at all, such as clouds, water, snow. Very low values present an area of little to no vegetation such as rocks, concrete or bare soil. Moderate values present areas of shrubs and grassland. High values present forest areas and lush green. NDVI specifies a measure of healthy vegetation and ranges in value from 1 to 1. Values closer to 1 present green vegetation. NDVI was considered from Landsat 8 data using band 4 (red) and band 5 (near infrared) using Equation (1).

$$\text{NDVI}=\frac{\text{Near Infrared (Band 5)} - \text{Red Band (Band 4)}}{\text{Near Infrared (Band 5)} + \text{Red Band (Band 4)}} \quad (1)$$

3 Results and Discussion

3.1 Classification of Satellite Imageries

To study, the application of GIS and RS tools, land use and land cover analysis, and change detection in MPM taluka were determined. Different illustrative samples were collected to generate a signature file. A supervised classification method was followed and then the maximum likelihood classification algorithm was applied for the 2013 and 2020 year imageries. The images were grouped into five classes i.e. settlement, vegetation, waterbody, barren land, and sand. The total classified area 125568 ha of taluka has been calculated, which was later divided into land use and land cover (Table 2). Classified images 2013 and 2020 year (Figures 5 and 6) were analyzed and determined the area with settlement 25264 ha (20.1%) and 27703.4 ha (22.1%). The vegetation during the years was calculated as 35978 ha (28.7%) and 3656.9 ha (29.1%). The sand-covered an area of 52870 ha (42.1%) and 56839.1 ha (45.3%). Barren Land covered an area of 7726.8 ha (6.2%) and 2632.14 ha (2.1%). The waterbody determined in an area during the years was 3729.8 ha (3%) and 1823.58 ha (1.5%).

Table 2. Area covered under categories 2013-2020 of MPM taluka

Classification category	2013		2020	
	Area ha	Area %	Area ha	Area %
Settlements	25264	20.1	27703.4	22.1
Vegetation	35978	28.7	36569.9	29.1
Sand	52870	42.1	56839.1	45.3
Barrenland	7726.8	6.2	2632.14	2.1
Waterbody	3729.8	3.0	1823.58	1.5
Total	125568	100	125568.2	100

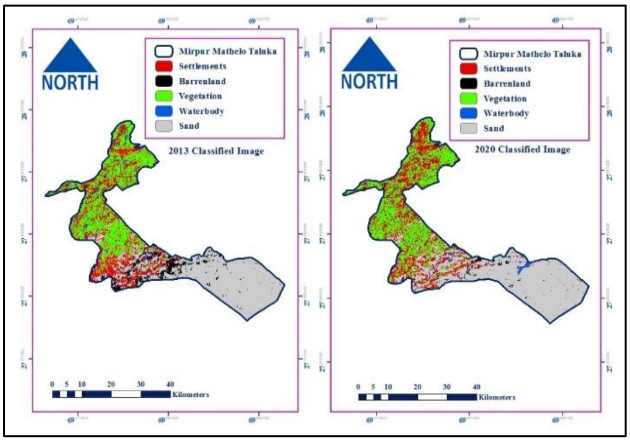

Figure 5. Classified images (2013-2020) of MPM taluka

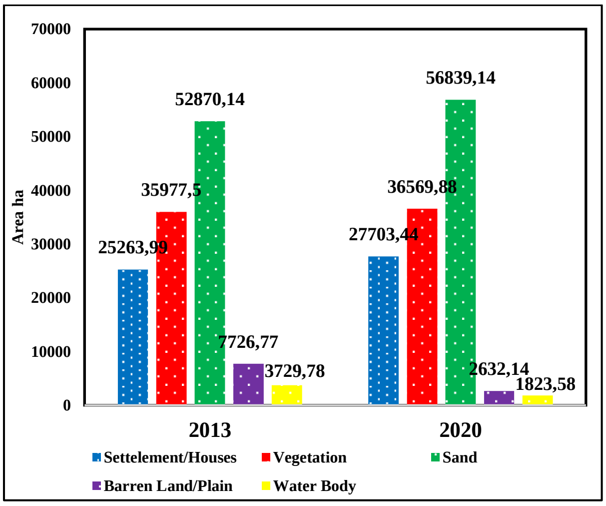

Figure 6. Clustered column chart for Area under LULC (2013-2020) of MPM

3.2 NDVI of 2013 and 2020 Imageries of MPM Taluka

Figure NDVI of MPM taluka calculated for both imageries shown in Figure 7. The peak NDVI for the image of 2013 and 2020 year was 0.508 and 0.533. It has been confirmed that the normalized difference vegetation index of an area increases with the height and maturity of vegetation and crops.

3.3 LULC change detection in MPM Taluka

Based on the analysis, the involvement of several facts and figures, the modern tools GIS, remote sensing imageries, ground trothing survey, and existing study area conditions, we have done LULC change detection and categorized the study area into five classes i.e. settlements, vegetation, sand, barren land, and waterbody. The land use and land cover change detection was calculated from the imageries with overlapping of 2013 and 2020 year (Figure 8).

Settlements:

LULC changes are relatively more pronounced in the MPM taluka, one of which is the massive increase in residential areas. Comprising mostly of residential and commercial establishments, the total area under the settlement was increased by 2439.45 ha (1.94%) in Taluka.

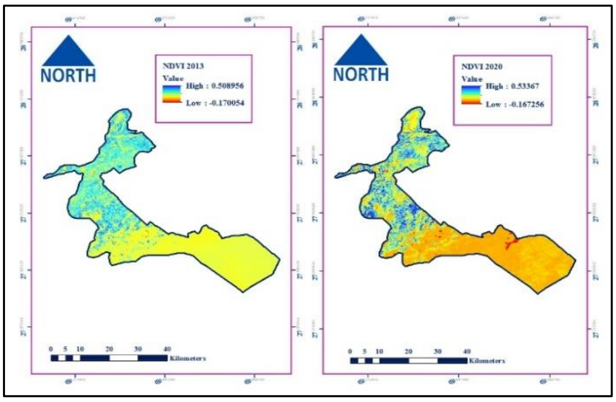

Figure 7. NDVI (2013-2020) images of MPM Taluka

The built-up expansion has been mostly encroaching the agricultural land and barren land near to cities. Particularly expanding along the roads and peripheral zones, the increasing urbanization adversely affects environmental quality in the taluka. Urbanization, population growth, market forces, and other activities of development are a principal factor of LULC change in the area.

Sand:

Sand is the first largest category of LULC. This class was considered the most change class during the 2013 to 2020 years. It has been increased by 3969 ha (3.16%). This is mainly due to climatic factors, especially wind. The movement of sand one place to another due to wind is a complex process that involves different types of grain movement that occurred less or more simultaneously. The environmental factors mostly wind and air factors which pulverize the sand to the agricultural and plain areas of the taluka. This change class only along with the sandy areas of the taluka.

Vegetation:

Vegetation is the second largest of all identified classes in this study. The agricultural land revealed a continuously raised throughout the study period. The total area under this class was increased to 592 ha (0.47%) from 2013 to the 2020 year. This increase is not a huge change in the study area considering the population. This is mainly because in the period from 2013 to 2020 there were no cropping patterns and advanced technology used to increase agricultural growth. The main reason peoples are only focusing on settlements and built-up houses and shifted from villages to cities. Other factors such as economic returns from the cash crops and climate change have also played a role in shifting land from one use to another.

Barren land:

The barren land category is among the small LULC categories of this classification. The barren land decreased from 2013 to the 2020 year -5094.63 ha (-4.06%) in the study area. It has been experiencing positive changes, this category was considerably reduced due to built-up and agricultural land increased in the study area.

Waterbody:

The area under open water has reduced to almost half Figure 8. There was a decline in the total share of this LULC -1906.2 ha (-1.52%) in Table 3. Climatic change and anthropogenic impacts on water bodies are the most stressed natural resources in the study area. On the other hand, morphological changing in irrigation canals and distributaries and loss of area owing to human intervention and fluctuations in the water budget. The lining of canals and distributaries and less rainfall in the area also impact on the shortage of water.

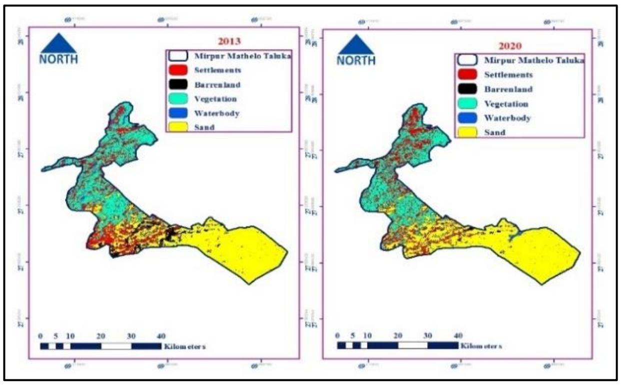

Figure 8. LULC change detection (2013-2020) of MPM taluka

Table 3. Land use and land class (2013-2020) images of MPM taluka

Class	Area (ha) 2013	Area (ha) 2020	Change Diff Area (ha) 2013-2020	Change Diff %
Settlements	25264	27703	2439.45	1.94
Vegetation	35978	36570	592.38	0.47
Sand	52870	56839	3969	3.16
Barren Land	7726.8	2632	-5094.63	-4.06
Water Body	3729.8	1824	-1906.2	-1.52
(-) indicates a decrease in Area				

Figure 9 shows the pictorial view of LULC change detection between 2013-2020. Table 4 presents change detection of MPM taluka that how much area of land cover has converted into another land cover area between 2013-2020. Figures 10 and 11 show column clusters chart and graph details of LULC change detection (2013-2020), respectively.

3.4 Vegetation mask of MPM taluka

The vegetation mask of MPM taluka is presented in Figure 12 which shows the overall vegetation in 2013 and 2020 year. It is cleared in the image that the green colour shows the area under flora and the white colour indicates the area under settlements, roads, barren land and cities, ponds, etc. The Landsat imageries of 2013 and 2020 (Table 5) year indicated that the total estimated area of vegetation mask was about 35978 ha (28.6%) and 36570 ha (29.12%) of the total geographical area while no vegetation mask area was 89590.7 ha (71.3%) and 88998.3 ha (70.8%) of the total geographical area. The overall difference in the 2013-2020 year vegetation mask was increased to 592 ha (0.47%).

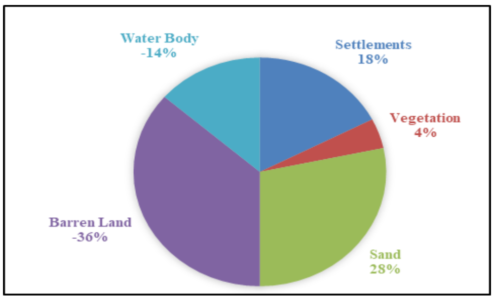

Figure 9. Pictorial view of LULC change detection between 2013-2020

Table 4. LULC (2013-2020) change detection of MPM taluka

Land use land class change 2013-2020	Area (ha)
Barren land – Barren land	1721.6099
Barren land - Sand	4544.4403
Barrenland - Settlements	1085.5777
Barrenland - Vegetation	45.81358
Barren land - Waterbody	166.41821
Sand – Barren land	228.00401
Sand - Sand	51456.838
Sand - Settlements	808.32976
Sand - Vegetation	8.6104422
Sand - Waterbody	471.4239
Settlements – Barren land	449.56551
Settlements - Sand	961.52241
Settlements - Settlements	16651.234
Settlements - Vegetation	6850.0159
Settlements - Waterbody	217.47599
Vegetation - Barrenland	17.000329
Vegetation - Sand	2.3412793
Vegetation - Settlements	7183.5386
Vegetation - Vegetation	28857.708
Vegetation - Waterbody	143.07478
Waterbody – Barren land	47.945613
Waterbody - Sand	3.2509999
Waterbody - Settlements	1833.547
Waterbody - Vegetation	971.45384
Waterbody - Waterbody	775.30934

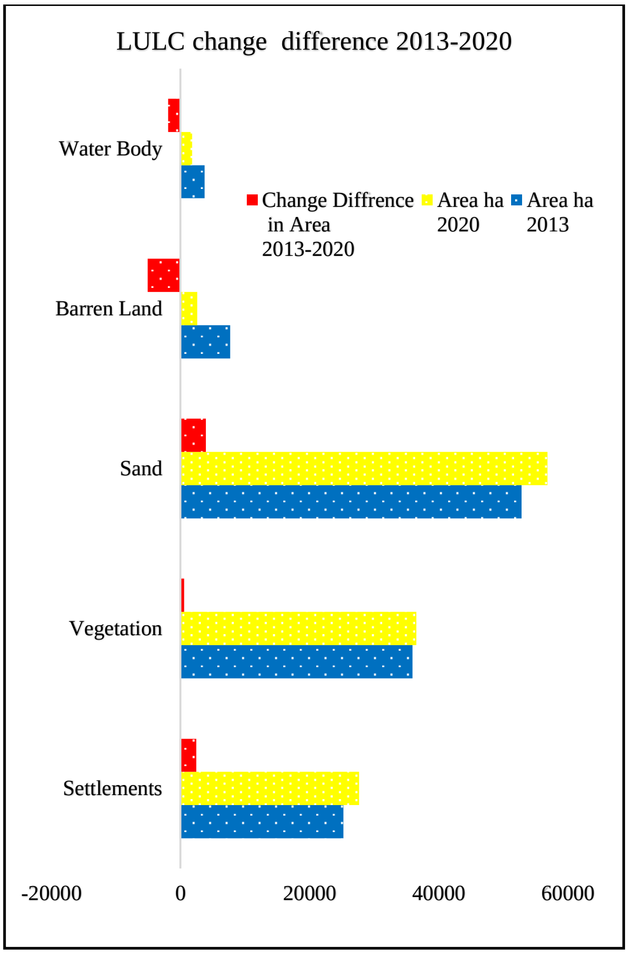

Figure 10. Column cluster chart of LULC (2013-2020) change detection of MPM taluka

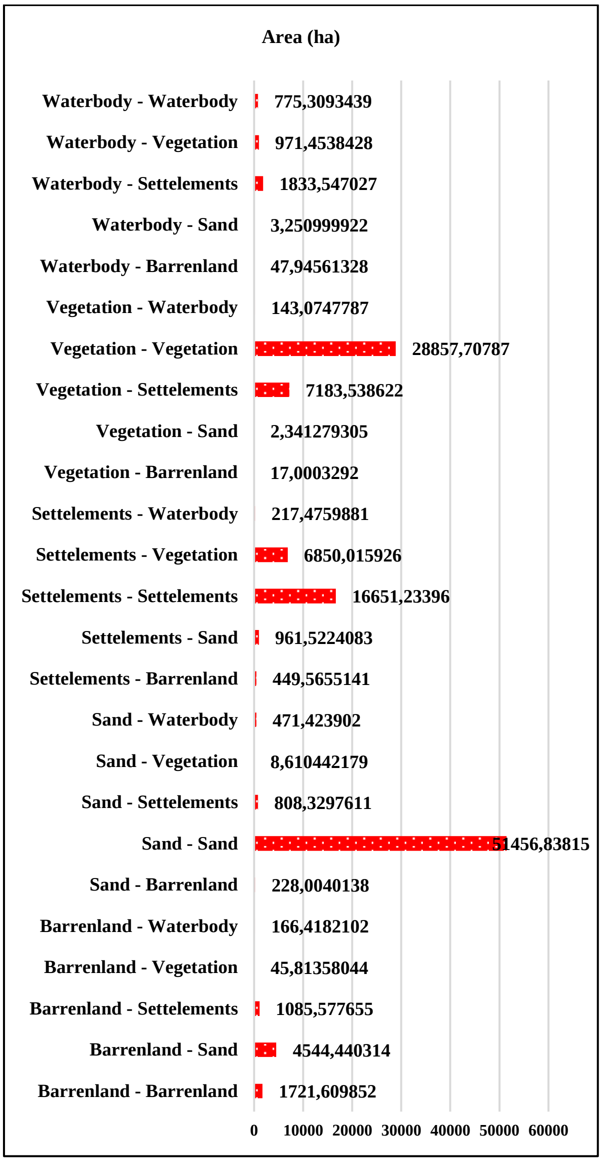

Figure 11. Column cluster graph of LULC (2013-2020) change detection of MPM taluka

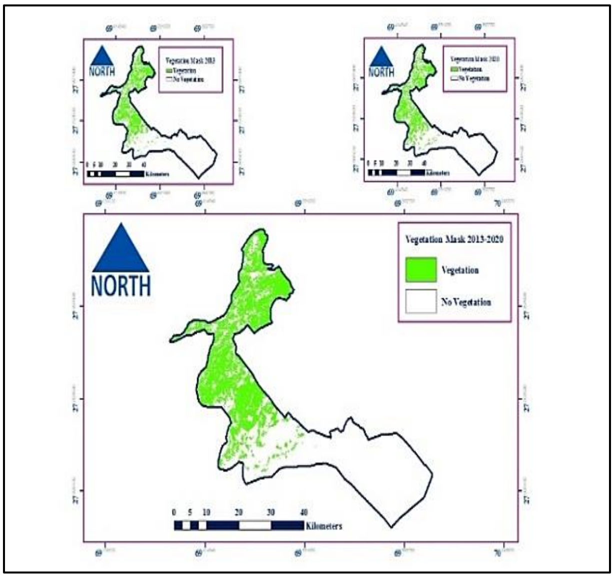

Figure 12. Vegetation Mask (2013-2020) of MPM taluka

Table 5. Vegetation Mask (2013-2020) of MPM taluka

Year	Vegetation Mask Area (ha) of MPM 2013-2020			
	Vegetation Area (ha)	Percentage of Geographical Area (ha)	No Vegetation Area (ha)	Percentage of Geographical Area (ha)
2013	35978	28.65	89590.7	71.35
2020	36570	29.12	88998.3	70.88
Diff 2013-2020	592.00	0.47	-592.40	-0.47
Total G Area (ha)	125568			

4. Conclusions

The objectives of this study were to deliver a recent outlook for land use and land cover change detection that took place from 2013 to 2020 years in MPM taluka. GIS and remote sensing technique provided significant information on the nature of land cover changes particularly the area and Spatio-temporal distribution of different land cover changes. During this period, the analyzed results give interesting observations.

The total relative change in a settlement is 2439.45 ha (1.94%). From 2013 to the 2020 year the settlements have been increased, peoples started migrating villages to cities for business and other work. It has indicated the impact of population and development activities over the study area. There was a total change in the sand area 3969 ha (3.16 %) was noted. A significant rise in the sand area from the barren land area due to no-cultivation of barren land or no management of land for purpose of agriculture or settlements. The main reason was also noted the climatic factors affecting this portion i.e wind which takes a grain of sand one place to another.

Barren land decreased to -5094.63 ha (-4.06%), Waterbody estimated as -1906.2 ha (-1.52%) according to facts and figures and confirmed from irrigation department that shortage of irrigation water for agricultural land during some previous years. While the waterbody ponds area converted into settlements and uses in agricultural land to fill the gap of food and cash crops with the growth of population.

Vegetation increased as 592.38 ha (0.47%). The vegetation area during 2013-2020 years increased on some portions. But there was also less use of advanced agricultural technology due to small owner of the land, they can not bear expenditure to prepare the land for different cropping patterns.

The results of classes proved that supervised classification is a more versatile method for land cover change detection and on the hand, this technique of classification is easy to use and benefits of vectors make this method is useful.

Remotely sensed imageries specified convenience to investigate the LULC changes in a given time interval. Updated information of LULC mapping gives the most important information and facts for sustainable, accurate planning and management. It provides prediction regarding the amount, state, composition and configuration of the changes which can be used as an early warning for proper planning for decision making. These facts and figures helped to land use manager and policymakers to set up sustainable development that was facing the rapid expansion of urbanization. Remote sensing and GIS are suitable tools for revising, renovating the land use maps and then manage land cover changes based on analyzed and up to date information. The above-mentioned problems, significant and necessity of LULC changes monitoring and analyzing regarding the facts future planning should be done. The updated information of land cover changes give help to policymakers to aware the past, current and future situation to establish the necessary decision and polices about incremental tend of urbanization/settlements and decrease the possible negative consequences in the future as well as help in complex adaptive measures. İn other words, this study provide input to policymakers to examine and understand the scenarios of LULC changes and formulating an effective and eco-friendly land use policy in the MPM taluka.

Declaration

The authors declare that there is no conflict of interest regarding the publication of this manuscript. Besides, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication or submission, and redundancy have been completely observed by the authors.

Author's Contribution

S.A. Shah and M. Kiran significantly contributed to this study.

Nomenclature

GIS	: Geographic Information System
GloVis	: Global Visualization
LULC	: Land Cover Land Classification
MPM	: Mirpur Mathelo
OLI	: Operational Land Imager
PBS	: Pakistan Bureau of Statistics
RS	: Remote Sensing
TIRS	: Thermal Infrared Sensor
UC	: Union Council
USGS	: United States Geological Survey

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