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Spatio-Temporal Analysis of Land Use Change and its Driving Factors in Layyah, Punjab, Pakistan

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ABSTRACT

Specific objective of this study was to find out the distribution of various land use changes in District Layyah from 2000 to 2020 using geographic information system (GIS) and remote sensing (RS) techniques, and the forces or factors that lead to land use change. District Layyah has experienced remarkable land use and land cover (LULC) changes for the past three decades. Three Landsat satellite images i.e. thematic mapper (TM), Landsat enhanced thematic mapper plus (ETM+) and operational land imager (OLI)/ TIRS for the years 2000, 2010 and 2020 were acquired from USGS website in order to detect the land use changes. By using ERDAS Imagine software, the maximum likelihood classification was employed in order to classify the images. The spatial and spectral distribution of five land use types was made including i.e. Water, Built-up, Vegetation, Desert, Bare and Sparse land. Ground Truth points were noted and these points were used for the validation and classification of the images. This accuracy showed an overall accuracy rate of 85% with a Kappa coefficient of 0.9 which demonstrated the basic classification method because the images used in the research were highly good. Results showed that the rise was revealed in Vegetation, Built-up and Water land uses from the year 2000 to 2020. On the other side, the decrease in Bare and Sparse land and Desert land use was calculated. The main driving factors behind these LULC changes were found the growth in population, agro-technological advancement and various physical factors (e.g. availability of water and so on), resulting an increase in built-up area. Present research will be beneficial in understanding the most important land use changes to estimate the future change trends in various land use classes for policy making and land use management.

Keywords: *Land Use Change, Driving Factors, RS, GIS, Layyah*

1. Introduction

Land use is can be defined as the manner in which biophysical resources of land are being used for various purposes like built-up, industrial and vegetation use and so on [1]. Land use changes perform an important role at the local and global levels [2]. Increased and unchecked population growth besides the industrial and economic growth particularly in the emerging countries in the late 21st century, have accelerated the pace of land use change. Therefore, the Land use changes have been witnessing greatly throughout the world during the few past years especially in the developing countries with growing population growth and the increasing urbanization [3, 4]. Land use change is one of the main environmental issues globally, which is responsible for climbing of the land values and conversion of the farmlands to numerous urban and miscellaneous uses and degradation of land beside fall in ecosystem services [5-7]. Principal driving forces responsible for land use change are political and socioeconomic decisions which are regarded as the key factors in this sense [8]. Moreover, any changes in the land use and land cover (LULC) can be the result of alteration in the intensity of the present LULC types because of man-made activities and the natural factors [9]. It has been noticed from the previous researches that the land use change is possess the potential to have an important ecological impacts [10]. Various researches have also been confirmed the impacts of land use changes on agricultural production and on environment [11-13]. Despite the impacts of the human actions on land use changes, changing in the climate, environmental factors, conditions of soil and landscape features have also been regarded as land use changes. Besides the human variables for example, the environment and government decisions [14]. LULC has a direct link with the change in climates of the cities as well [15]. Therefore, recently, the LULC changes and their environmental impacts have attained a prompt attention globally [16, 17].

Satellite remote sensing spatial data is considered tremendously useful to map out the discrete land use classes [18]. It concentrated the world wide change significant problems on the global, local and at the regional levels [19]. Furthermore, in year 2000, Council of the Europe implemented the Convention on European landscape because of increased changes in land use which adversely influenced the surface of the earth [20]. The Landsat images were initially administered in the ERDAS Imagine Software according to the need of the study area and selected land use classes i.e. agricultural land use and barren land classes were mapped to know the potential impact on the land use [21, 22]. Change detection techniques have been distributed into three stages mainly based on the pixels [23].

The land use change researches provide us very much useful information towards improved information of the past practices, present land use change patterns and the future land use trends as crucial for policy makers and land use management [24-26]. Many studies have been conducted in various areas of Pakistan to determine the land use and it's causing factors and impacts. Like a study conducted in Quetta, Balochistan using satellite imageries found increase in built-up area and decrease in open spaces [27]. Similarly, another

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study conducted in Quetta to monitor the urban sprawl and urban land use change found the substantial increase in built-up area (52.33%) and a great loss of vegetation up to 60% [28]. Similarly, the extensive urban sprawl and resultant land use changes are monitored in different parts of the Karachi, the biggest city of Pakistan by using the remote sensing and geographic information systems [29]. Therefore, the present research aimed at accomplishing the comparative analysis of LULC of District Layyah, Punjab, Pakistan by using tools of Remote Sensing data and Geographic Information System. The district has high agricultural potential but facing notable changes in its land use over the past years which are needed to highlight for better planning and management of land use. Therefore, the objectives of the present study were; First, to identify and detect various categories of LULC and the changing pattern in land use in District Layyah from 2000 to 2020 by using the Remote Sensing data and Geographic Information System to disseminate the various changes in study area and second, to evaluate the main driving factors or forces keeping in view the extent and role of the LULC change.

2. Materials and Methods

2.1 Description of Study Area

District Layyah lies in southern Punjab and it is bounded by district Jhang on its East, Dera Ghazi Khan on its West, Bakkar on its North and district Muzaffargarh on its South. Layyah has three tehsils (sub-divisions) namely Layyah, Chaubara and Karor Lal Esan. The population of the district was about 1.82 million according to the 2017 National Census of Pakistan as compared to the 1.12 million in 1998 with a growth rate of 2.59 [30, 31]. District Layyah is located at 30° 45′ to 31° 24′ North latitudes and 70° 30′ to 71° 47′ East longitudes (Fig. 1).

Its height is 500 feet from sea level. The area eastern part of the district comprised sandy desert. So, the area under study region is famous for its sand storms due to extraordinary temperatures throughout the summer season. A very little annual rainfall pours in Layyah in two seasons of the year. Relief features of the study area include rich and fertile fields, citrus gardens, grams and historical places. The area possesses rich agricultural lands and access to an extensive canal system, harvests many crops and being most popular for the production of grams [32].

2.2 Data Acquisition and Collection

In order to meet the objective of the study, the satellite images for the years 2000, 2010 and 2020 were acquired from the website of USGS to examine the spatio-temporal land use changes of the District Layyah, study area. The characteristics of these downloaded satellites images have been shown in the table 1. The field work was performed to collect the Ground Control Points (GCPs). Maps and preprocessed images were validated.

2.3 Image Pre-processing

Radiometric, geometric correction and layer stacking correction techniques are regarded as preprocessing methods prior to the extraction of information from the images. Landsat TM of years 2000, 2010 and 2020 were acquired. The various bands of the tiff image were converted in the image format via layer stacking technique in the ERDAS IMAGINE 8.0 software to generate the False Color Composite (FCC) image. Then all the images were geometrically exported to the ArcGIS software and then to the Universal Transverse Mercator (UTM). The district Boundary of the study area was extracted via Software ArcGIS 10.2 through masking tool. Images of the various acquired years were independently classified using supervised classification. The spectral signature for all land use classes were created through pixel analysis of the image. The study area images were broadly classified into five major land use classes such as Barren, Vegetation, Desert, Water and Built-up land use class.

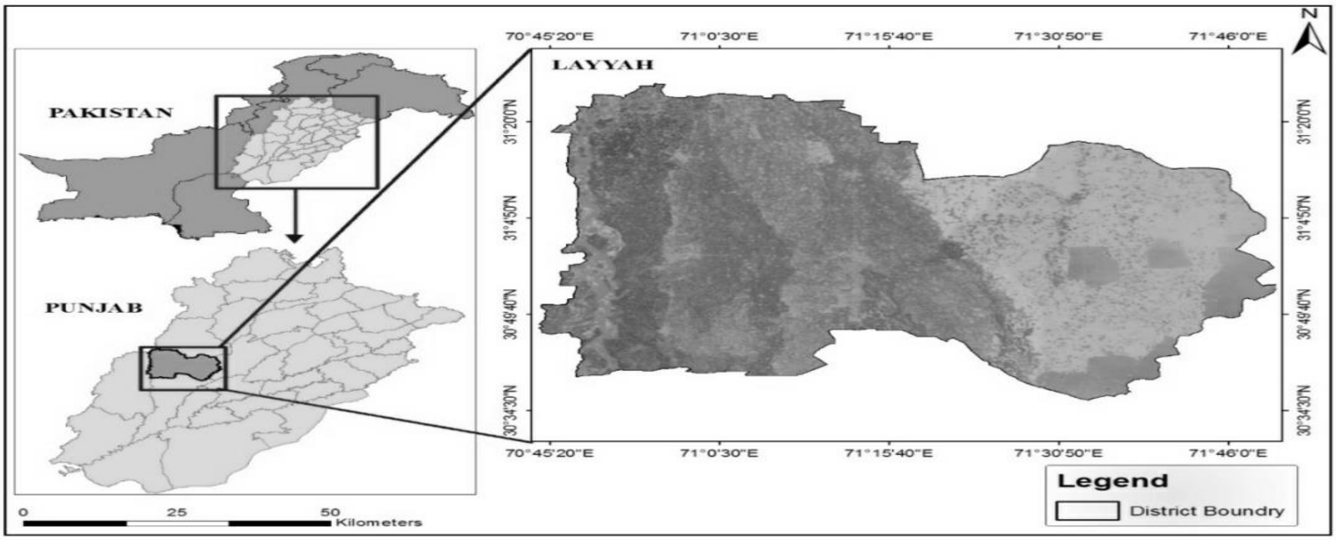

Fig. 1: Map of the Study Area

Table 1. Features of the Acquired Remote Sensing Images

Year	Satellite	Sensor	Band	Pixel	Season	Source
2000	Landsat 5	Thematic Mapper(TM)	7	30m	Dry	http://glovis.usgs.gov/
2010	Landsat 7	ETM+	7	30m	Dry	http://glovis.usgs.gov/
2020	Landsat 8	Operational Land Imager (OLI/TIRS)	9	30m	Dry	http://glovis.usgs.gov/

The images which were classified revealed the common ground features of the District Layyah, study area and gave the required information to understand the changes in land use patterns of the study area. After, the images were processed and the land use classes were extracted. These images data were acquired from the Landsat 5 Thematic Mapper (TM) for 2000, Landsat 7 Enhanced Thematic Mapper Plus (ETM+) for 2010 and Landsat 8 Operational Land Imager (OLI)/ TIRS for 2020 respectively of study area, District Layyah. These satellite images were downloaded from the website of the United States Geological Survey (USGS) (Earth Explorer). These satellite images were acquired in the form of geo-tiff with various spatio-spectral bands in the distinct files. The ancillary spatial data comprised on the earth reference data (most occasionally it is regarded as the data on ground truth) acquired through the real surveys of the ground which was obtained individually. The Global Positioning System (GPS) was utilized to validate the data related to the ground truth while accomplishing field work. Water, Built-up, Vegetation, Desert, Bare and Sparse land classes were included in the present study and the images acquisition dates were July 21, 2000, July 22, 2010 and July 23, 2020 respectively.

2.4 Image Classification and Accuracy Assessment

Supervised classification technique was used for classifying the images. Sample's training was created by using the training sample manager, visual explanation of the acquired satellite images in Google Earth Software and in the ground truth data. Each land use category's training samples were merged then. Training sample's signature file was generated. Maximum likelihood classification was used in order to classify the images. Image accuracy had been performed from ground truth data by producing the random points and then comparing these points to the map which has been classified by creating the confusion matrix. Producer accuracy, User accuracy and Overall accuracy were also performed by using the following Equation. Overall accuracy ¼ number of the sampling classes was classified correctly with number of the reference sampling classes (1).

Equation 1: Image Accuracy Assessment Types

$$User\ Accuracy = \frac{Number\ of\ Correctly\ Classified\ Pixels\ in\ a\ class}{Total\ Number\ of\ Pixels\ in\ a\ Class}$$

$$Producer\ Accuracy = \frac{Number\ of\ Correctly\ Classified\ Pixels\ in\ a\ class}{Total\ Number\ of\ Pixels\ in\ all\ Classes}$$

$$Overall\ Accuracy = \frac{Total\ Number\ of\ All\ Correctly\ Classified\ Pixels}{Total\ Number\ of\ Pixels\ in\ all\ Classes}$$

The values of Kappa (K) measures show how well the Remote Sensing classification approves or are correct with reference data [33]. The Overall accuracy was 87.81%, 93.3% and 95.4% for the images classified for the year 2000, 2010 and 2020 respectively which is indicative that classification is good and acceptable.

Table 2. Land-use Classification System and Type Description.

Land Use/Cover Types	National Land Cover Description
Built Up Area	Land that includes a settlement
Vegetation	Land exclusively utilized for growing the agricultural crops
Desert	Land which receives annual rainfall less than 10 inches
Bare and Sparse Land	Land which includes, bare land, rock and sand
Water	Comprises the water of inland and the River Water

Source: [34]

2.5 Land use Change Analysis

The internal trading for the land use classes were assessed using the vector datasets for the 20 years. These image datasets were intersected with the help of the intersect tool available in the ArcMap 10.2. These datasets were acquired in this manner and were then transferred to MS Excel. Land use change matrix was also created with the help of the pivot table. The resulting datasets were then noted in stable or in the converted land areas.

2.6 Image Enhancement

Image enhancement is basically a process of presenting an image more interpretable for a specific application. The basic purpose of image enhancement is to make the raw image or the remote sensing data more un-testable for the human eye. Enhancement procedures are most commonly used instead of the classification techniques in order to extract the features, locating and studying various areas, some objects on ground and to derive the meaningful information from these images. Usually, the enhanced images are used only for visual analysis, besides the actual images are used for specific automated analysis [35]. Geographic Information System and Remote Sensing define the changes in the land use types [36, 37]. LULC based on the visual understanding and satellite images was verified from the inspection of the field also.

3. Data Analysis

3.1 Overall Accuracy and Kappa Index

The Kappa statistics and overall classification accuracy (in percentages) was used to assess the classification accuracies [34]. To investigate the classification accuracy result of the images, the Kappa index or Kappa Coefficient (K) was calculated for all the maps classified. So, the overall classification accuracies for the year 2000, 2010 and 2020 were 87.6%, 85.65% and 89.2% respectively and the statistics of the Kappa for the images of 2000, 2010 and 2020 were 84.2%, 81.9% and 91.2% respectively.

Table 3. Land-use Classification and the Techniques used to Study.

Application	Techniques Used to Study
Land use/Land cover change	Differencing of Image, Image rationing, PCA, Chi-square, Post-classification, Detecting hybrid change and GIS
Vegetation	Differencing of Image and Post-classification
Urban change	Differencing of Image, Post-classification, Hybrid change detection, PCA & GIS
Landscape change	Post-classification and GIS
Deforestation	Post-classification, Differencing of Image and PCA

Source: [34]

3.2 Land Use Change Detection

Post classification change detection method in ArcGIS 10.2 was used in the present study. This classification technique is most commonly utilized by many researchers in the urban environments because of its accuracy and efficacy to detect the location, rate and nature of the change.

3.3 Principle Component Analysis (PCA)

Eigenvector transformation is also known as the Principal Component Analysis (PCA). During the process of change detection, two mechanisms/techniques can be applied for PCA. The very first technique can be applied by addition of the two images with different dates in one file. The other way is to subtract the second satellite image from the concerning image for first day or date after executing the Principal Component Analysis (PCA) distinctly. Thus, Standardized PCA, the first technique is considered most suitable than un-standardized PCA for change detection process while detecting land use change [38, 39].

3.4 Post-Classification Comparison

It is a very helpful method to extract the land use data. Supervised classification was basically the technique in which the analyst itself picks a number of the area of an image, then recognizes the kind of the task on the screen of the computer. According to this process as recognized by analyst, the system recognizes an attribute of the data which includes every kind. It classifies nearly all the similar image pixels remaining. Geographic Information System (GIS) and Remote Sensing (RS) are the vital tools for detection of the land use changes [40] important in investigating and assessing the land use changes [41, 42]. Spatial data and remote sensing possess the ability to identify the synoptic land use changes data over the particular time period with respect to location [43-45]. Land use change analysis was performed using co-relation analysis [46]. Kappa Coefficient (K) and Overall Accuracy (OA) were used for the evaluation of the accuracy from error matrix. The Producer's Accuracy (PA) 87.1% and User's Accuracy (UA) 88.3% were also assessed for the selected classes of land use.

4. Results and Discussion

4.1 Land Use Change Detection for the Year 2000

Table 4 and Fig. 2 and 6 showed the different land use classes in 2000. Water land use class was covered the land area of 200.2 km^2, Built-up land use covered just 88.7 km^2, Vegetation land use covered the biggest share of 2,330.3 km^2, Desert land use covered 1,602.3 km^2, while the Bare and sparse land use covered the land use of 2,159.3 km^2.

4.2 Land Use Change Detection for the Year 2010

Table 5 and Fig. 3 and 7 showed the different land use classes and their change detection in 2010. Water land use class was increased to 243.6 km^2, Built-up land use also enhanced the land area and reached 165.2 km^2, Vegetation land use also shown the increase and reached to 2,965.3 km^2, whereas the Desert land use shown a decrease and reduced to 1,194.4 km^2, while the Bare and sparse land use also declined to 1,811.7 km^2. These results demonstrated the notable variations in the land use of the district Layyah from 2000 to 2010.

4.3 Land Use Change Detection for the Year 2020

Table 6 and Fig. 4 and 8 showed the different land use classes and their change detection in 2020. Water land use class was again slightly increased to 251.9 km^2, Built-up land use also considerably augmented the land area and reached 237.2 km^2, Vegetation land use also exhibited the slight increase and reached to 3,054.0 km^2, whereas the Desert land use shown an unexpected increase in land area to 1,506.7 km^2, while the Bare and sparse land use again declined to 1,598.6 km^2. These results proved the important variations in the land use of the district Layyah from 2010 to 2020.

4.4 Accuracy Assessment of Classified Map of Past 20 Years (2000-2020)

The analysis results of the remote sensing imageries from 2000-2020 showed that District Layyah has undergone many changes in the land use patterns (Table 7 and Fig. 5 and 11). Firstly, the area of Vegetation land use class, which is the biggest portion of the land use class, encompassing miscellaneous crops and vegetation. During the last 20 years, Vegetation land has been considerably increased from 2,330 km^2 in 2000 to 3,054 km^2 in 2020. Secondly, the area of Water considerably increased from 200.2 km^2 in 2000 to 251.9 km^2 in 2020. Thirdly, the Bare and sparse land area was decreased from 2,159 km^2 in 2000 to 1,598 km^2 in 2020. Besides, the area of Built-up land was considerably increased from 88.7 km^2 in 2000 to 237.2 km^2 in 2020 was also classified, as study area is covered with the settlements mixed with the farm areas having low density. These results verified in various researches as a recent study conducted in Bahawalpur city by employing satellite remote sensing, machine learning and geographic information modelling found the massive increase in urban built-up area 4,768 acres

(90.08%) from 1990 to 2020 and in contrast, the decrease in vegetation and barren classes at the rates of 2,116.55 acres (6.61%) and 2,785.47 acres (32.11%) [47]. Another study undertaken in Tehsil Shorkot, District Jhang to assess the impact of changing land use on agricultural production from 2010 to 2020 using RS and GIS data revealed the noteworthy increase in built-up land class (16.6 km^2 in 2010 to 26.8 km^2 in 2020) and decrease in forest land class (90.8 km^2 in 2010 to 61.84 km^2 in 2020) and barren land class (528.54 km^2 in 2010 to 333.1 km^2 in 2020) [48]. Similarly, a study conducted in Dong Trieu district, Vietnam with utilizing Remote Sensing data from 2000 to 2019 to assess land use and its driving forces concludes a net decreasing tendency in major land use classes i.e. Cropland (1,852 acres), Forest (882.6 acres), Water body (2,836 acres) and Barren land (8,837.7 acres) [49].

4.5 The Land Use Transition Matrix from 2000 to 2020

The land use change detection matrix for the period among 2000, 2010 and 2020 was created with the help of pixel-by-pixel process to examine the land use change detection in District Layyah. It was examined the variable pattern of the land use types. Over the past 20 years it was revealed a substantive rise in the vegetation land use class at the place of other land use types. This land use increased greatly. Bare soil demonstrated a decreasing tendency during the year of 2000 to 2020. While the change in the built-up area slightly increased, and this revealed a prompt increase in the population. Desert land use area decreased and water land use class also increased progressively.

Table 4. Land-use Change detection for the year 2000

Name of land use class	Area (km^2)
Water	200.2
Built-up	88.7
Vegetation	2,330.3
Desert	1,602.2
Bare and Sparse land	2,159.3

Table 5. Land-use Change detection for the year 2010

Name of land use class	Area (km^2)
Water	243.6
Built-up	165.2
Vegetation	2,965.9
Desert	1,194.4
Bare and Sparse land	1,811.7

Table 6: Land-use Change detection for the year 2020

Name of land use class	Area (km^2)
Water	251.9
Built-up	237.2
Vegetation	3,054.0
Desert	1,506.7
Bare and Sparse land	1,598.6

Table 7. Land use Change matrix (2000-2020)

Class	Year 2000	Year 2010	Year 2020
Water	200.2 km^2	243.6 km^2	251.9 km^2
Built-up	88.7 km^2	165.2 km^2	237.2 km^2
Vegetation	2,330.3 km^2	2,965.9 km^2	3,054.0 km^2
Desert	1,602.2 km^2	1,194.4 km^2	1,506.7 km^2
Bare and Sparse land	2,159.3 km^2	1,811.7 km^2	1,598.6 km^2

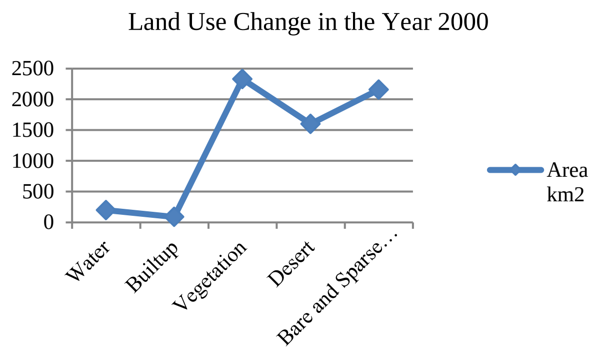

Fig. 3: Land-use Change Detection in 2000 in District Layyah

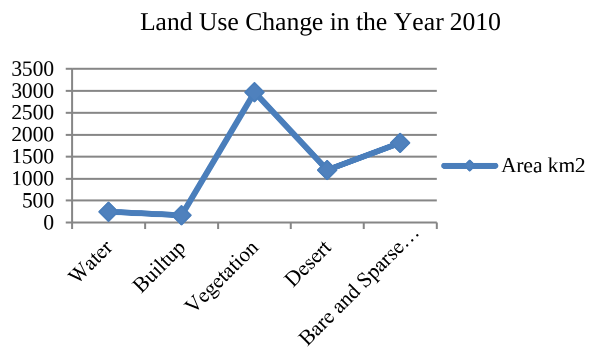

Fig. 3: Land-use Change Detection in 2010 in District Layyah

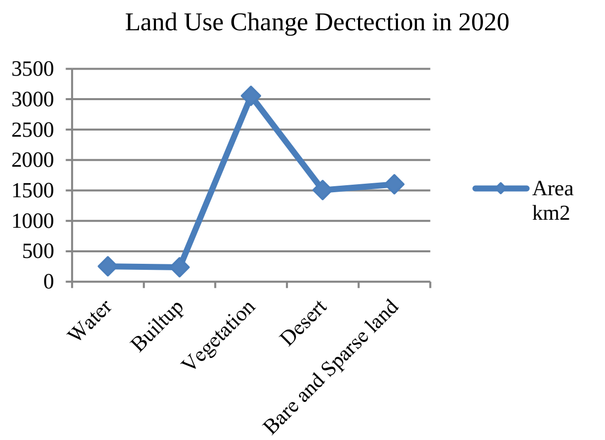

Fig. 4: Land-use Change Detection in 2020 in District Layyah

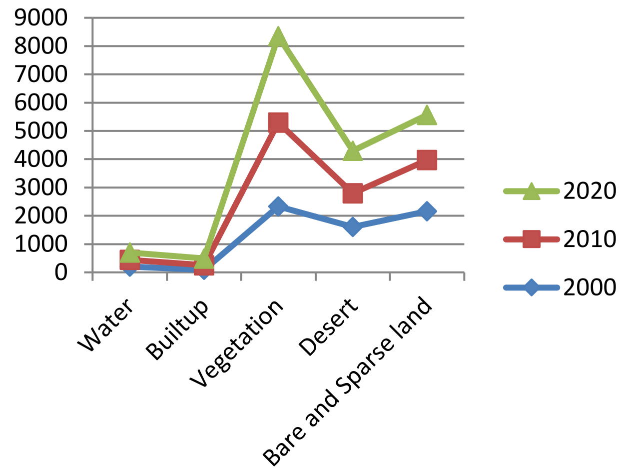

Fig. 5: Land use Changes in different classes from 2000-2020 in District Layyah

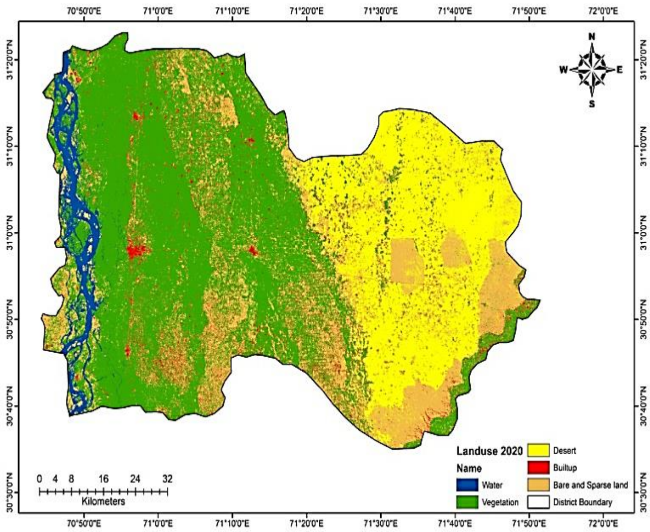

Fig. 8: Land-use Change for the year 2020 in District Layyah

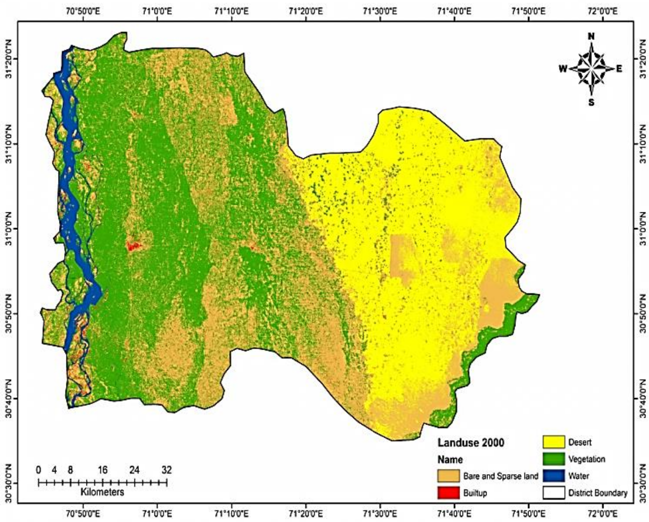

Fig. 6: Land-use Change for the year 2000 in District Layyah

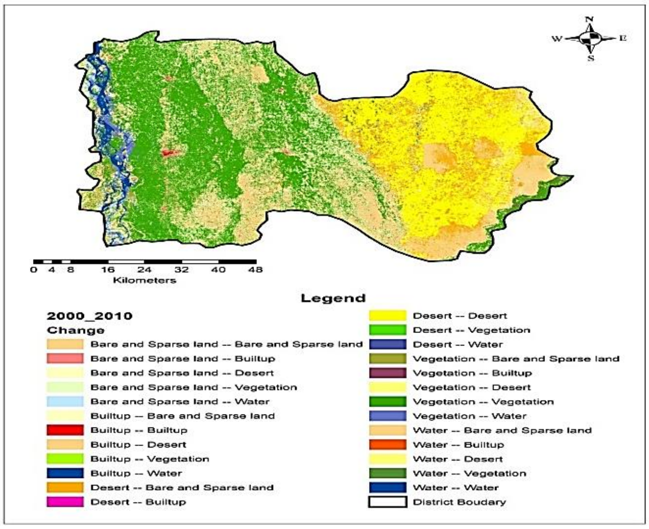

Fig. 9: Land-use Change from 2000-2010 in District Layyah

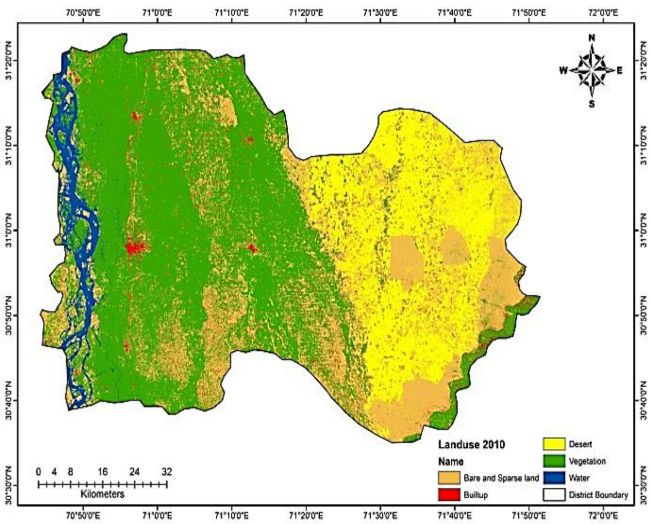

Fig. 7: Land-use Change for the year 2010 in District Layyah

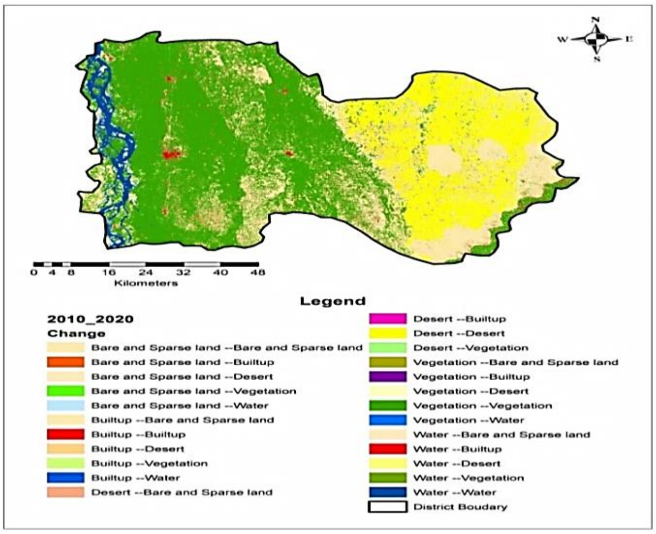

Fig. 10: Land use Change from 2010-2020 in District Layyah

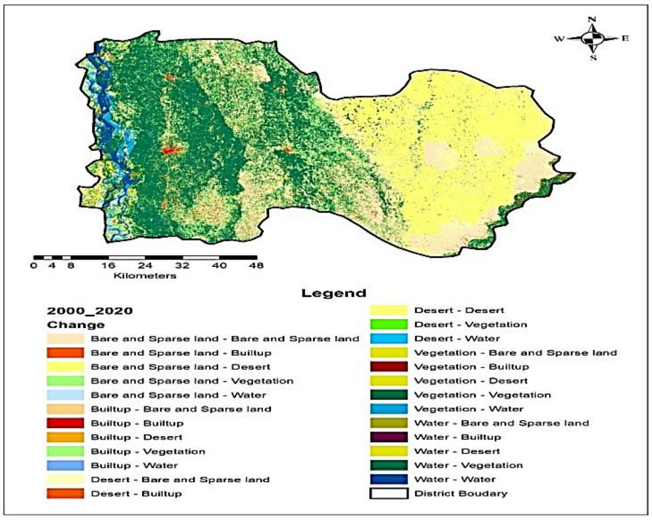

Fig. 11: Land-use Change from 2000 to 2020 in District Layyah

4.3 Proximate Drivers of Land Use Change

The amalgamation of the human activities which aims at seeking to certify the supply of the food and to make better the incomes of growing families or population were the main driving factors or force behind the land use change. It was observed through the field observations that the human activities had an adverse effect which became a reason of the land use changes of the area under study.

4.4 Primary Land Use Change Drivers

It is found that the accelerated consumption patterns which are needed to fulfill the hiking food requirements were among the major causes of land use change. Furthermore, the information derived from the natives of the study area through the interviews that improved infrastructure and ameliorated roads had increased the expansion in agricultural activities when compared with the other land use activities.

4.4.1 Population Growth

Growth in the population had been increasing gradually in the study area since 2000 to 2020 as it was 1.12 million in 1998 and climbed to 1.82 million in 2017 [31]. Moreover, Migration of the individuals from rural to urban places was very much common. It is believed that if the population density is high, there will be more built-up land use. The growth of population and urbanization also brought changes in land use i.e. as these are witnessed in case of many Pakistani cities (e.g. Quetta, Bahawalpur and others) [27, 50].

4.4.2 Agro-technological Advancement

Advancement in agriculture in the study area comprises excessive use of the spray, pesticides and fertilizers along with heavy machinery in order to prepare the land ready for the extensive agriculture. It means that the agricultural expansion takes place at the place of the other kinds of the land use of the study area. Though, urban land use planning has got due attention in many researches but agricultural land use planning turned little focus in many studies [51]. According to a study in the District Layyah, the study area, the rise in the use of pesticides and using the desert and barren land for agriculture and for residential purposes had influenced the land use changes in the area under study [32].

4.4.3 Physical Factors

Various physical factors are also responsible for the rapid changes in land use of many areas. For instance, the availability of water responsible for conversion of desert and barren land use class into vegetation land use class. Past studies focused on the land use changes especially centered at its various patterns [52]. During the 20th century, due to fast increase in the population, the available resources of land has been depleted rapidly, which has drawn the attention of various countries of the world more on the current status of the land use [53, 54], impacts on the land use and environment [55-57], vigorous simulation and forecast [58, 59] at various spatiotemporal epochs. It is widely believed that the chief driving forces analysis and spatiotemporal dynamics estimation for land use in future may assist ascertain the emerging trends and extent of the particular changes in land use. These changes are very serious for justifiable land use and reduction of the global environmental issues regarding land use. Many studies have also proved the impact of land use change impact on agricultural production around the globe [60, 61].

5. Conclusion

The present study aims at investigating the land use changes in District Layyah and its driving forces. For examining the land use changes dynamics, the explanation of the multi temporal satellite images has been concluded to be very useful technique. Results revealed that a constant reduction was recorded in Desert and Bare land use classes, whereas the Water, Built-up and vegetation land use class areas were increased drastically during the year 2000 to 2020. In present research, the assessment of land use and its changes detection was performed by using digital image processing methods. The findings revealed that the important reason for conversion of Barren and Desert land into agriculture land was to fulfill the requirements of the food and alteration in the land use. During this period, the human population increase led to increased desire in the vegetation production. The high-quality LULC maps can produce essential base for fruitful policies of planning and land management [34]. The land use change researches provide us very much useful information towards improved information of the past practices, present land use change patterns and the future land use trends as crucial for policy makers and land use management. Hence, this study could be assisting in future research on land use and land cover and their causing factors on local and regional levels. The study suggests that land use change detection is vital for land use management so that it should be deployed in policy formulation and decision making. The district Layyah has possessed good fertile agricultural land therefore the haphazard population growth dangerous for the agricultural land base and as well as for surrounding land uses transformations. Therefore, it should be regularly monitored and land use policies should be formulated according to the ground realities to make the land use efficient and sustainable.

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