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Geospatial Analysis of Reversal of Desertification in Cholistan desert of Bahawalpur City

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Abstract

The expeditious increase in urbanization leaves a salient outcome on changing land use land cover (LULC) by replacing the areas of desert and water with architecture, vegetation, thereby changing the ecosystem. The objective of this study is to calculate and analyze geospatial changes caused by land use land cover classes over a time span of 20 years from 2000 to 2020 in Cholistan desert of Bahawalpur city in the context of population livestock and on the basis of data, to predict the land use land cover changes. To compute these land use land cover changes during the time span of 20 years from 2000 to 2020, the supervised maximum likelihood method, to classify the satellite imagery from the Enhanced Thematic Mapper Plus (ETM+) and Land operational imager (OLI) is used. Supervised change detection is performed to get the numerical number of changes in land use land cover classes to detect the interconversion of classes. Moreover, for a better understanding of geospatial changes with livestock and population, various indices are derived from Landsat imagery. These indices are the Normalized vegetative index and the Normalized built-up index (NDVI and NDBI). The findings show that there has been an 18% rise in the built-up area, ≈ 100% decrease in the desert, a 15% drop in water bodies, 35% increase in population, 12.7% decrease in livestock, and a 6% increase in vegetation, with variable patterns of agriculture in these classes. This research finding will assist the policymakers for the sustainable development and to conserve the natural resources of the study area.

Keywords: Geospatial, LULC, Cholistan Desert, Remote sensing, GIS

INTRODUCTION

Cholistan is derived from the term Cholna, which means "moving" (El-Ghani et al., 2017). Rohi (Cholistan) is an enormous desert measuring 26300 square kilometers, during 4000 B.C., Cholistan was considered the genesis of civilization, known as the Hakra valley civilization (Nawaz and Kumar, 2016). Bahawalpur city is located on the southerly bank and inundation by the Sutlej River, also with the legendary Cholistan desert on its eastern border. (Mohsin et al., 2013). The city is the divisional headquarters and represents a distinctive place in the district due to its geographical, historic, climatic, physiographic, cultural, and demographic aspects (Mohsin et al., 2016). Prodigious difficulties are being faced by the globe in relation to population growth, urbanization, poverty environmental degradation, energy supplies, global climate change, material consumption, and waste creation (Matthew and Hammill, 2009; Fragaszy et al., 2011). It is important to have solutions to problems for sustainable development that contains ensuring long-term ecological sustainability, providing for fundamental necessities, and fostering fairness among generations (Holden et al.,2014). A multidisciplinary study will be necessary to find answers to these problems. The solution to many sustainability and energy-related concerns depends on geotechnology competence (Fragaszy et al., 2011). Geotechnical characteristics differ geographically (Kim and Santamarina, 2008). Land use and land cover change are two distinct categories. Land use refers to the human use of land and land cover represents the physical and biological aspects of the land (Meyer and Turner, 1992). Land cover analyses and land-use transformations, primarily related to population expansion, are regarded as critical components for evaluating the relationship between population growth, land use conversions, and environmental changes. It is common knowledge that as the population grows, urban areas expand. However, the pace of growth is affected by several numbers of different factors. It is understood, and various research indicates that increased human inhabitancy and resource consumption cause the urban land area to expand and change in land use and land cover (Khan et al.,2014). Land use refers to the many actions carried out by humans to divide the terrain into various patterns with corresponding modifications. (Carole and Barbara, 1993). It may be utilized to produce food, provide housing, provide entertainment, process materials, and so forth (Halder, 2013). Human actions are causing enormous changes in the terrestrial environment at breakneck speed, magnitudes, and spatial scales. Human-caused land-cover change is a significant source and component of global environmental change. The most geographically and/or commercially significant human uses of land worldwide include different types of cultivation, cattle grazing, habitation and building, reserves and protected areas, and timber extraction. These and other land uses have together changed the global land cover (Turner et al., 1994). Along with its repeating nature, satellite remote sensing data have shown to be immensely valuable in mapping land use/land cover patterns and changes over time. GIS technologies can quantify such changes even if the resulting geographical datasets have varied scales/resolutions (Ghaffar and Hira, 2016). Since the introduction of Landsat 1 in the early 1970s, several attempts have been undertaken to map changes in land use and land cover. Such research has aided in the understanding of the dynamics of human actions in space and time (Sarma et al., 2001). It is critical to investigate the link between urban expansion and land-use changes. Small and large metropolis urban growth is heavily reliant on land conversion and transformation. The effects of land-use changes on urban growth are also determined by population expansion and redistribution. Human exertions such as deforestation, intensive agriculture, and urbanization have significantly affected the earth's surface during the last 50 years, resulting in an imbalance in ecosystem services and changing the pattern of cities (Arshad et al., 2017). Urbanization is a spatiotemporal way of transforming urban components. Within the urban territorial system, these components include land use, industry, population, and a number of other natural and social considerations (Yang et al., 2021). Modifications and transformations caused by such human activities on the terrestrial surface have given rise to the idea of urban expansion and land-use change, both of which have serious ecological consequences. The expansion of metropolitan areas is having a considerable impact on local utilization. Population explosion is a key phenomenon that causes urban growth and city expansion in any direction. Aside from population increase, economic and technological progress can lead to fast urban growth in the form of suburban sprawl and many changes in the city center (Arshad et al., 2017).

The fast expansion and changing patterns of urban areas have awoken planners to the significant issue of agriculture land conversion, which has been observed on the outskirts of cities where unplanned urban growth results in the conversion of fertile agricultural land (Mohsin et al., 2016). In recent decades, agriculture land conversion in Pakistan has joined other agricultural issues such as water logging, soil salinity, and low per-acre yield (Israr-ud, 2005). Furthermore, changes in people's socioeconomic features (financial problems, monthly income, and preferences) are to blame for the conversion of agricultural land to residential colonies (Mohsin et al., 2016). One of the key elements pushing agricultural interconversion in the form of housing colonies is the displacement from rural to urban regions by individuals seeking a higher standard of living (Ghaffar, 2006). Agriculture land conversion is becoming a severe issue in Bahawalpur, as it is increasing in other regions. Bahawalpur is Pakistan's 12th biggest city. According to 2009 estimates, the city has a population of 507,228 people, with a population growth rate of roughly 3% per year, up from 40,000 people in 1941. Because of its prominent position and importance in the region, the city is now seeing a considerable increase in urban population and a surge in socioeconomic activity. Farmland conversion to non-arable uses has also increased in Bahawalpur City in recent years (Mohsin et al., 2016). The length of the cultivation season continuously expands as a result of the major changes made to natural desert soils by irrigated agriculture farming (Su et al., 2010). Through sand dune fixing and stability by mechanical and vegetative techniques, the Pakistan Council of Research in Water Resources (PCRWR) has transformed the severely deserted soil into fertile land on more than 100 acres at Dingarh Cholistan (Akram et al., 2008).

In Pakistan's agricultural industry, livestock is important; it represents around 56.3% of the value added to agriculture. This industry employs more than 35 million people and accounts for close to 11% of the GDP (Rehman et al.,2017). Meat, milk, eggs, manure, fiber, skins, and horns are all products of livestock. Meat is a significant animal product that has a high level of nutrients and is regarded as a necessary component of the human diet. Livestock is a key component of the value-added services offered by agriculture and occupies a prominent place in the industry; in fact, it is one of the subsectors with the greatest growth rates in the majority of developing nations (Delgado, 2005; Meadowcroft, 2009). As the employment of impoverished and landless individuals in small farming families, livestock production makes a positive economic contribution to the country (Ahmad et al., 1996).

Observing the Earth's surface from space via satellites is significant for verifying man's human influence on the natural environment (Khan and Qasim, 2017). Remote sensing systems generate a vast volume of spatial data, and the Geographic Information System is the primary instrument for effectively utilizing such data. (Mishra et al., 1994; Fareed et al., 2016). Satellite remote sensing may be used to monitor desertification due to its temporal and synoptic view. It is the most advanced tool for investigating, and monitoring environmental destruction (Chen and Duan, 2008; Ladisa et al.,2012). As the global ecosystem has been badly altered by an increasing number of human activities at various scales, remote sensing technology has been widely adopted as an effective quantitative indicator of environmental quality (Jiang et al., 2021). Remote sensing has been widely utilized to evaluate and map ecosystem features and functions, as well as infer ecological processes, using a combo of current instruments and data (Chopra et al., 2001). The capacity to undertake synoptic, geographically continuous, and frequent observations, resulting in massive data volumes and various datasets with varied spatial and temporal resolutions, is a significant benefit of remote sensing (Atzberger and Rembold, 2013). Remote sensing measures reflected radiation, and it is feasible to inversely estimate features of the Earth's surface such as land cover type, biomass, and leaf area index for each picture pixel using such observations and a forward model of light interaction with the Earth's surface. Other features of importance (e.g., land usage; land function) may only be inferred and mapped inversely and indirectly through contextual interactions across space (de-Araujo et al., 2015).

Therefore, the analysis of earlier years in Bahawalpur city revealed LULC alterations, a major increase in the urban population, and urban development. In the last several decades, the conversion of desert and agricultural land to residential structures has gained the most importance due to the rising need for commercial spaces and housing amenities. For a review of the trend of rapid population growth with urban area expansion, and reversal of desert the greatest objectives of the study were;

To look into LULC classes and their trends in Bahawalpur city during last the twenty years

To work out the increasing urban expansion percentages with respect to built-up changes.

To identify the classes that is more contributing in the reversal of desertification.

To evaluate agriculture trends with livestock census data given from available study years.

To evaluate the relationships between NDVI and NDBI by regression analysis.

To create graphs and maps to evaluate the parameters to validate the findings.

Overall, the main goal of this study is to highlight the interactions of LULC with the population and livestock of the city. The individual aspects of the above-mentioned factors have been studied but the combined impact for the comprehensive results for researchers, and policy members were missing and this study addresses that missing link.

MATERIALS AND METHODS

Study Area

The focus area of research is Bahawalpur city (Fig 1). It is situated in Pakistan's Punjab province, on the northernmost tip of the Bahawalpur District. Latitude 29° 22′ N and longitude 71° 37′ E are about where Bahawalpur city is located in absolute terms. The city is 152 meters above sea level. One of Pakistan's most populated and urbanized cities is Bahawalpur. The immense Cholistan desert, which acts as a physical border between Pakistan and India, gives Bahawalpur a very significant geographic position. The average annual temperature of Cholistan desert and Bahawalpur is 27.5°C. The average lowest winter temperature is 7 degrees Celsius, while the average maximum summer temperature is 46°C. The map of Bahawalpur city is formed from google maps. Google maps is a consumer application offered by Google. It offers a boundary line of the Bahawalpur city in the Bahawalpur district. This raster dataset is processed in ArcGIS by Georeferencing and digitization. The outcome of digitizing gives the shapefile of Bahawalpur. A suitable small map of my study area is

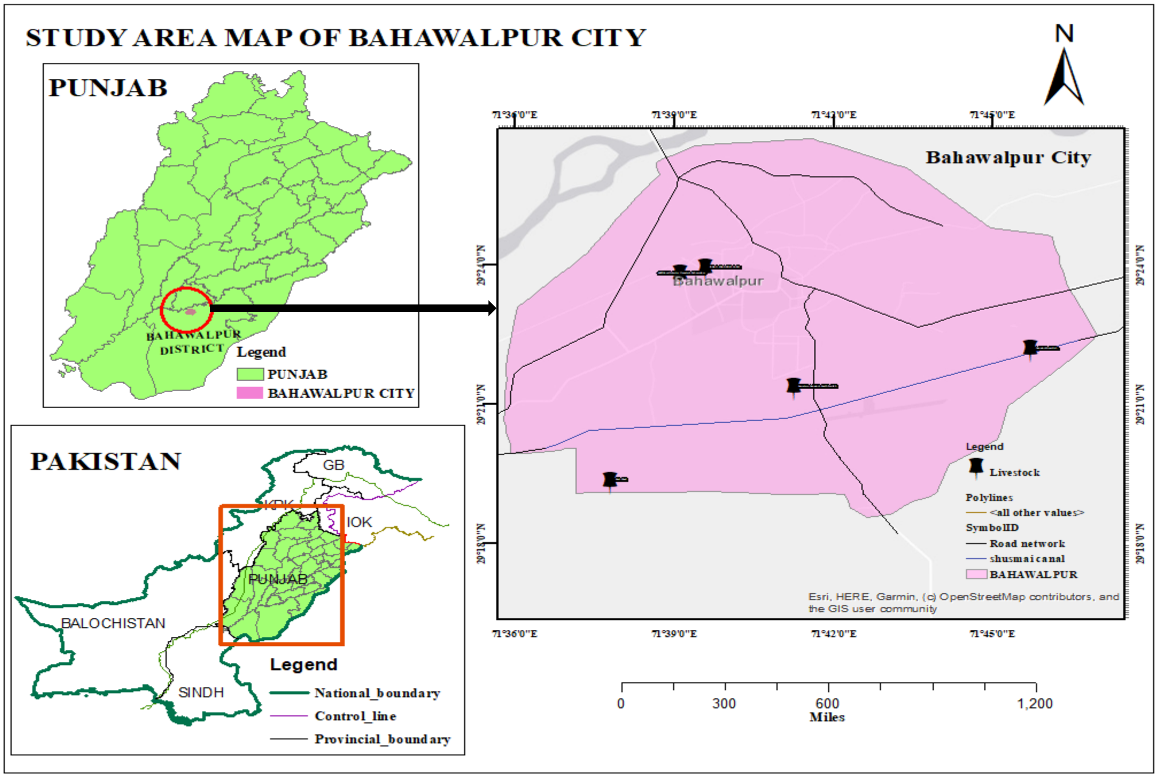

Figure 1. Location Map of Bahawalpur City and major livestock distribution in city.

generated from a shapefile of a digitized raster dataset. It is giving location map of Bahawalpur city in the Bahawalpur district covering an area of 19,110.87 hectares.

Data Sources and Acquisition

Data collection are sorted into satellite data and census data. USGS Earth Explorer supplied multi-spectral data created from Landsat satellite mission data for the years 2000 and 2020. The USGS Earth Explorer website offered free downloads of all satellite data (https://earthexplorer.usgs.gov). Using several satellite imageries, including Landsat 7 (ETM) and Landsat 8 (OLI), this study forecasts the LULC for future periods between 2000 and 2020. The specifications of Enhanced Thematic Mapper Plus (ETM+) and Operational Land Imager (OLI) images are given in table 1. The census data includes the census of the population of Bahawalpur city and the census of livestock. These two censuses included showing the relations between growing population with increasing settlements and variation of agriculture with livestock. Human population data is collected from the Pakistan Bureau of Statistics for the years 1998, 2008, and 2017 shown in figure 12. To know the variation with time livestock data for the years 2002 and 2019 are included in this study. This data is obtained from the Institute of Continuing Education and Extension given in figure 3.

LULC Supervised Image Classification

To estimate the LULC classification, ArcMap version 10.5 is applied. Using the supervised classification method, the satellite images are classified. It is a sort of image classification where the analyst controls the majority of the process by choosing the pixels that best reflect the targeted classes. Each image is divided into five groups, including built-up, vegetation, agriculture, desert, and waterbody using a supervised machine learning algorithm (SMLA) based on Maximum Likelihood Classification. These five classes are attributed to specific color schemes.

Built-up is shown in poinsettia red, vegetation in solar yellow, agriculture in leaf green, desert in topaz sand, and water in ultra-blue. Detail of land use land cover classes is given in table 2. Training samples is chosen for each of the specified land cover and land use types by drawing polygons around representative sites. The pixels contained by these polygons are used to capture the spectral signatures for the various land cover categories that are obtained from the satellite data. A good spectral signature will ensure that there is "minimum uncertainty" among the land cover types that need to be mapped. The 30, random sample signatures are selected on each satellite imagery for one class, giving a total of 600 spectral signatures. Each pixel with the highest probability received a class. The classification is estimated by accuracy in percentage by comparing the classified pixels to the source data. Extreme care is used in this process, and only pixels with similar spectral characteristics are chosen based on the one's knowledge of the study region and distinguishable features in the imagery. For more keen and accurate observation KML files are uploaded in Google Earth Pro to observe ground facts of the study area to get the accurate 30 signatures in supervised image classification for the respective years of 2000 and 2020. Following that, the images are subjected to supervised classification using a maximum likelihood approach, the area of the five classes is calculated by a field calculator in hectare.

Table 1: Details of satellite data.

Sr. No.	Reference years	Satellite sensor	Spatial resolution (m)	spectral resolution	path / row	Band used	date acquired	Source
1	March 2000	Landsat-7 ETM	30	Multispectral (9 bands)	150/40	1-7,8	Mar 26, 2000	U.S Geological Survey
2	Sep 2000	Landsat-7 ETM	30	Multispectral (9 bands)	150/40	1-5, 7,8	Sep 02, 2000	U.S. Geological Survey
3	March2020	Landsat-8 "OLI-TIRS"	30	Multispectral (11)	150/40	1-7, 10	Mar 09, 2020	U.S. Geological Survey
4	Sep 2020	Landsat-8 "OLI-TIRS"	30	Multispectral (11)	150/40	1-7, 10	Sep 17, 2020	U.S. Geological Survey

Accuracy assessment

Accuracy evaluation is the process of comparing specific pixels in a raster layer to known pixels for the class. The process for calculating the reliability of classified imagery is called classification accuracy assessment. Accuracy assessment of image classification March 2000, September 2000, March 2020, and September 2020 images are carried out to determine the quality of information obtained from the data. In order to evaluate the user's, producers, and overall categorization accuracy, error matrices are created for this study. By adding together, the entire number of pixels that were correctly classified and dividing it by the overall number of pixels, the overall accuracy is determined (Equation 1)

$$Overall\ Accuracy = \frac{\text{Total Number of correctly classified Pixels(diagonal)}}{\text{Total number of Reference Pixels}} \times 100 \quad (1)$$

$$\text{Kappa Coefficient (T)} = \frac{(TS)\times TCS)\_\Sigma\,(\text{Column Total} \times \text{Row Total})}{TS^2\,\_\Sigma(Column\ Total - Row\ Total)} \times 100 \quad (2)$$

For the year March 2000 overall accuracy is 90 percent with a 0.85 kappa coefficient calculated by equation 2. Each class gives different accuracy of users' and producers' values. Vegetation and desert give complete accuracy in both values. It is given that all

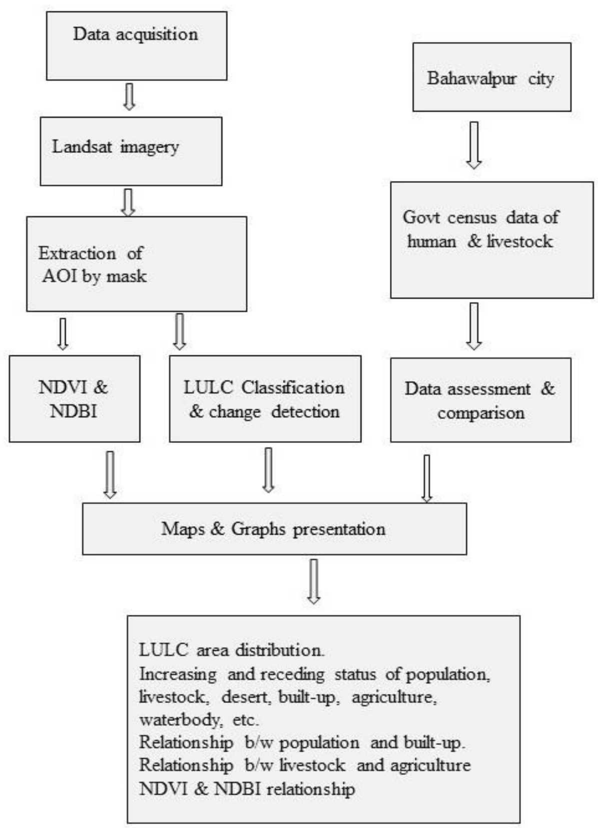

Figure 2. Flow diagram showing methodological and analytical steps

the classified pixels are hundred percent correctly classified. September 2000 classification is 94 percent and gives more accuracy than the previous classification. This class is giving the kappa coefficient of 0.91. The classification of 2020 for the month of March and September gives kappa 0.95 and 0.81 respectively. The overall accuracy for these respective months is 96 and 86 percent. These values show the accuracy of the classification of imagery. Table 3 gives strong values for the accuracy of the classified images of the year 2000 (March and September), and 2020 (March and September).

Table 2: Land use Land Cover Classes.

LULC Classes	Description
Built-up	Settlements, roads, constructions, industries, commercial areas
Vegetation	Trees, All kinds of green plants, grasses
Agriculture	Croplands, fields, cultivated lands, marginal crops, irrigated crops
Desert	Bare areas with sparse vegetation, sandy areas
Waterbody	Canal, waterways, wet areas, watercourses

Supervised Image Change Detection

The study uses the post-classification change detection approach, carried out in ArcGIS 10.5, for LULC change detection. In this study, various LULC classes with the lowest and maximum modifications are chosen to identify any potential changes during the past 20 years in the Pakistani city of Bahawalpur. The comparison of categorized Landsat images from March 2000 to March 2020 and September 2000 to September 2020 yielded the LULC variations shown in figure 4. Intersect geoprocessing tool is used to intersect two images of interested years. Results give the area change of resultant classes. The "from-to" class change is shown on the resulting change map. Information regarding "from-to" class changes is provided in a change map. It displays the locations of the modified and unmodified regions, highlighted in various colors (Fig 4). Cross-tabulation analysis on a pixel-by-pixel basis is used in this study to quantify the amount of conversion from one land cover category to another and their related area throughout the assessed period. So, between March 2000 and March 2020, and September 2000 and September 2020, statistics on the total LULC change as well as gains and losses in each class are then collated.

The NDVI and NDBI

The NDVI is a measurement of surface reflectance that provides a numerical estimate of biomass and the growth of plants. Therefore, NDVI values reflect the quantity of chlorophyll that is present in vegetation; a higher NDVI value indicates healthy, dense vegetation, whereas a lower NDVI value indicates sparse vegetation. NDVI is used to calculate the vegetation's density. By using equation 3 the NDVI is calculated for March 2000, September 2000, March 2020, and September 2020. These values are calculated in ArcMap on composite images for the respective year. Landsat 7 ETM is provided with different bands where band 3 is red and band 4 is near-infrared. Landsat 8 OLI is supported with the different bands but two bands are used in NDVI calculation. In Landsat 8 band 4 act for the red band and band 5 shows Near-infrared.

$$NDVI = (NIR - R) / (NIR + R) \quad (3)$$

Analyzing built-up regions in cities is helpful to study specific features of that area. Because it can offer timely and comprehensive views of urban land cover, it is important to monitor the geographical distribution and expansion of urban built-up areas. For the years 2000 and 2020, built-up characteristics in Bahawalpur city are extracted using the normalized difference built-up index (NDBI). Normalized Difference Built-up Index (NDBI), which has indices from -1 to 1, is used to extract built-up attributes given in equation 4. Vegetation has a lower NDBI value than an urban location, and bare soil reflects more light in SWIR than

Table 3: Accuracy assessment of supervised LULC classification

Year	Accuracy (%)				Accuracy (%)			
	March 2000		**Sep 2000**		**March 2020**		**Sep 2020**	
LULC class	**Producer's**	**User's**	**Producer's**	**User's**	**Producer's**	**User's**	**Producer's**	**User's**
Built-up	91	91	100	87	100	88	76	90
Vegetation	100	100	100	100	100	100	100	100
Agriculture	81	90	81	100	100	100	88	80
Desert	100	100	100	100	66	100	100	66
Water Body	100	66	100	75	100	100	100	100
Total	90		94		96		86	
Kappa Coe.	0.85		0.91		0.95		0.81	

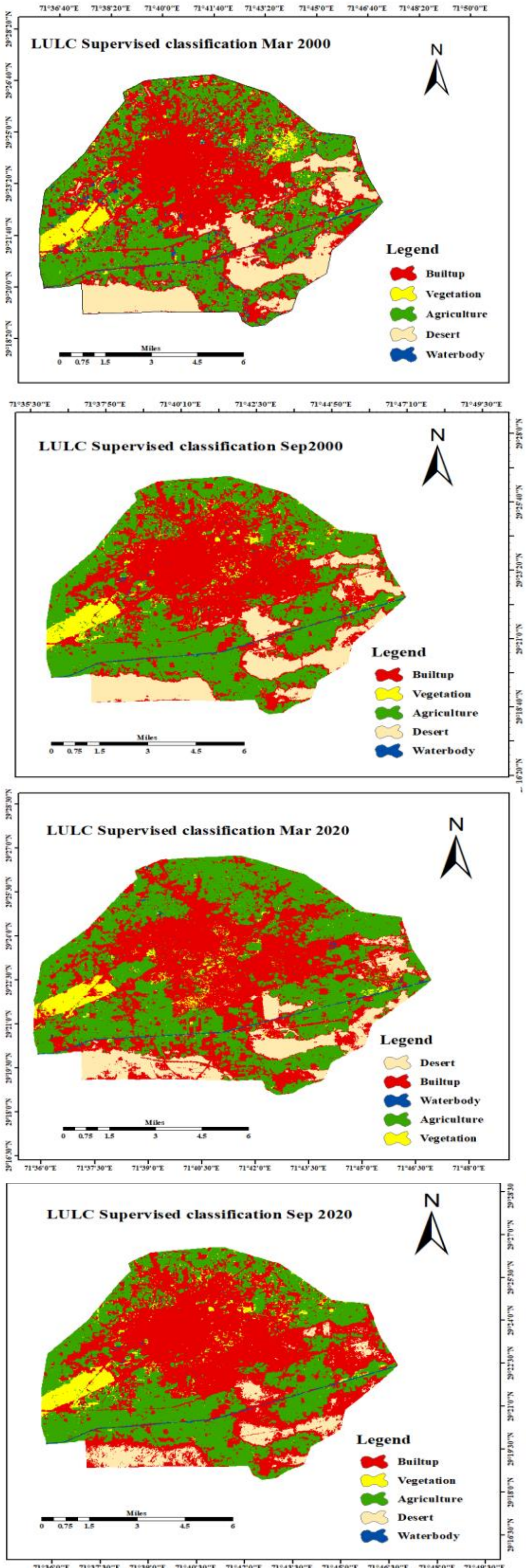

Figure 3. LULC supervised classification of March and September

NIR. Built-up regions and arid terrain may be distinguished from other landscape features by their distinct properties of spectral reflectance from the near-infrared (NIR) to the shortwave infrared (SWIR). Landsat ETM+ band 5 is shortwave infrared with a wavelength of 2.09- 2.35µm and band 4 is Near Infrared with a wavelength of 0.77-0.90µm. Landsat OLI uses 6 and 5 bands; Band 6 is SWIR with a wavelength of 1.57-1.65µm and band 5 is NIR with 0.85-0.88µm.

$$NDBI = (SWIR - NIR) / (SWIR + NIR) \quad (4)$$

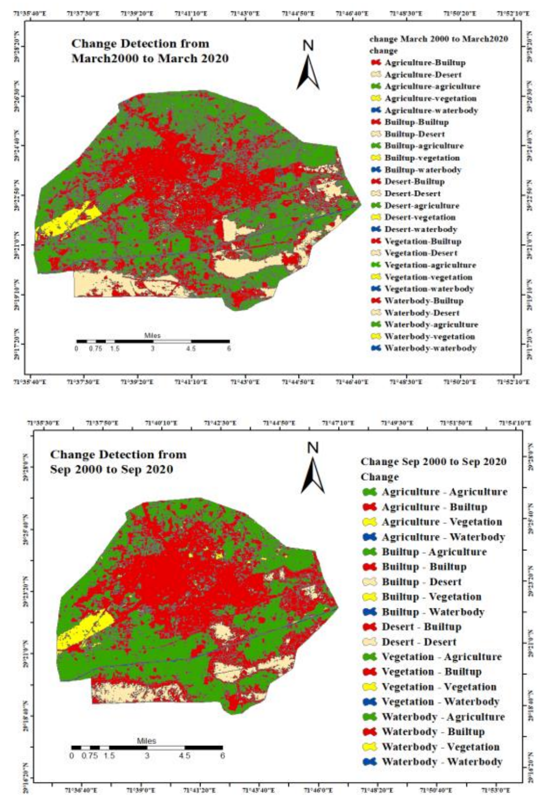

Figure 4. LULC Supervised Image Change detection of Sep (2000 to 2020), and March (2000 to 2020).

RESULTS

Supervised image Classification

In this study land use, LULC-supervised classification is done to evaluate the area occupied within the boundary of Bahawalpur city (Fig 1). The total area engaged within Bahawalpur city is 19,110.87 hectares (Fig 7). Bahawalpur is the agricultural area of Punjab. Major LULC classes that occupied this region are agricultural land that meets the need of livestock, desert areas that mainly represent the parts of the marvelous Cholistan desert, built-up areas that contain inhabitant areas of the city full of settlements, vegetative areas, and waterbody which mainly consist of Shushmai canal (Table 2). This canal enters the boundary of

Bahawalpur city near IUB solar park Bahawalpur and ends at Model Avenue near Cholistan university of veterinary and animal sciences Bahawalpur.

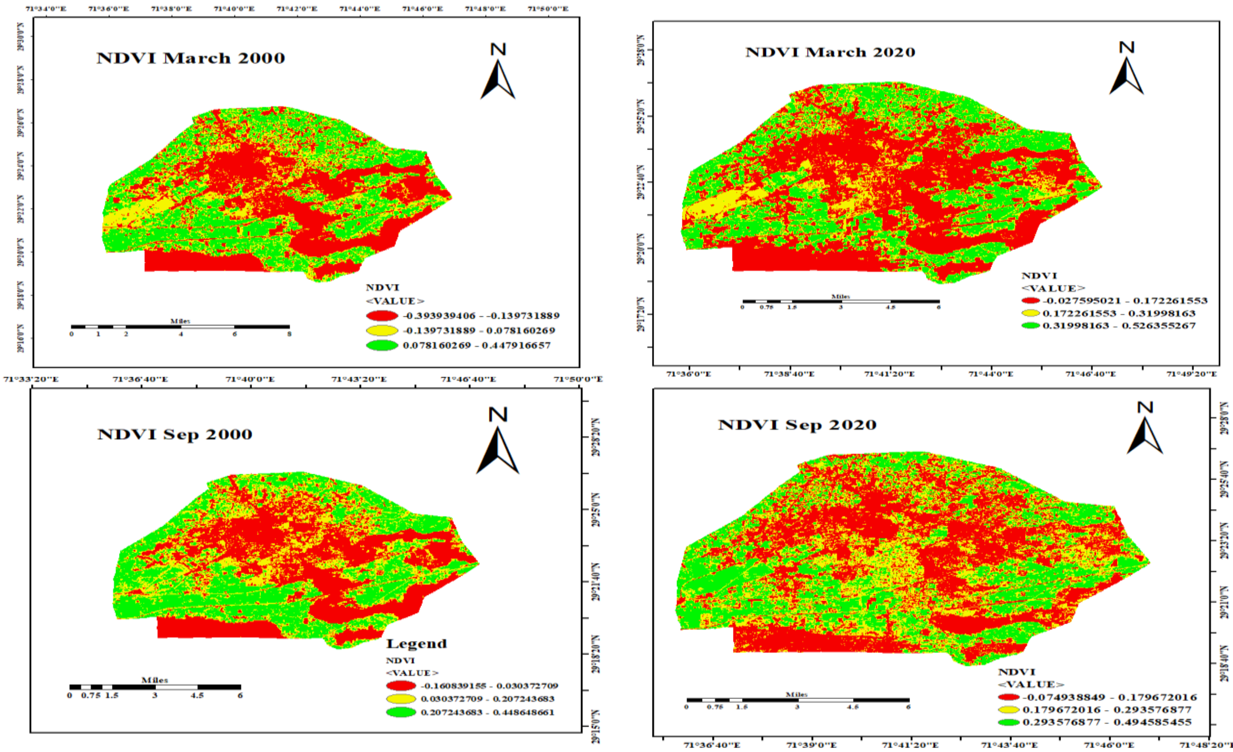

Figure 5. Normalized difference vegetation index maps of the Bahawalpur city.

The total occupied area under the Supervised classification is 19,110.87 hectares which is not equally divided between the classes of this area (Fig 3). In the month of March 2000, the major area is held by settlements, construction sites, roads network, and commercial areas which is 7703.55ha. The second most area occupied is the agricultural area which consists of 6953.13ha. Desert grasps an area of 2761.38ha. Minimum areas are held by vegetation and waterbody. Vegetation consists of trees that are found in parks, on the sides of roads, canals, outside houses, etc. Vegetation contains 946.89ha and the canal and its water courses contain a 745.92 ha area (Fig 7). The calculation in the month of September 2000 varies from that of march 2000 (Fig 7). All the classes are showing little variation in the interested area. The maximum area is kept by the built-up category which is 7824.69 ha. The second class is agriculture which 45 contains a 7850.7 ha area. Desert has 2474.73ha. The minimum areas are locked by vegetation and waterbody which are 784.62 ha and 176.13 ha respectively. The changes in the months of March and September are described here. The Built-up area increased by 121.14 ha from March to September 2000. The increase in agriculture area is 897.57 ha and the desert decreased by 286.65 ha. In percentage, this difference is given as. The built-up increased from 40.30% to 40.94%, agriculture increase from 36.4% to 41.07%, desert fall from 14.5% to 12.9%, vegetation change from 4.9% to 4.2%, and waterbody changes from 3.9% to 0.92 % in 2000.The vegetation and water decreased by 162.27 ha and 569.79 ha within 2000.

March 2020 makes the built-up area of 8083.62ha. It is the major area of all the classes in March 2020. The second class that contains a larger area is agriculture. It lockup the area of 8392.41 ha. Desert has 1839.87ha are occupied in march 2020 in Bahawalpur city. Vegetative area and waterbody confined the area of 642.15ha and 152.82ha respectively. The largest class in September 2020 is also built-up, settlement, construction, and commercial areas. The area occupied is 9515.79ha. The second most class that occupy is agriculture with 7364.43 ha. Desert confined the area of 1237.32 ha. The area is enclosed in September 2020 by vegetation and the waterbody is 840.96ha and 152.37 ha respectively (Fig 7).

The variation within the year 2020 can be seen. The built-up shows positive change and an increase from March to September of 1432.17ha. it increases from 42.3% to 49.7%. This increase is due to the increasing population burden on the city. Urban growth reveals an increase in the burden and demands of resources in

Bahawalpur city. The changes in agricultural class also occur.

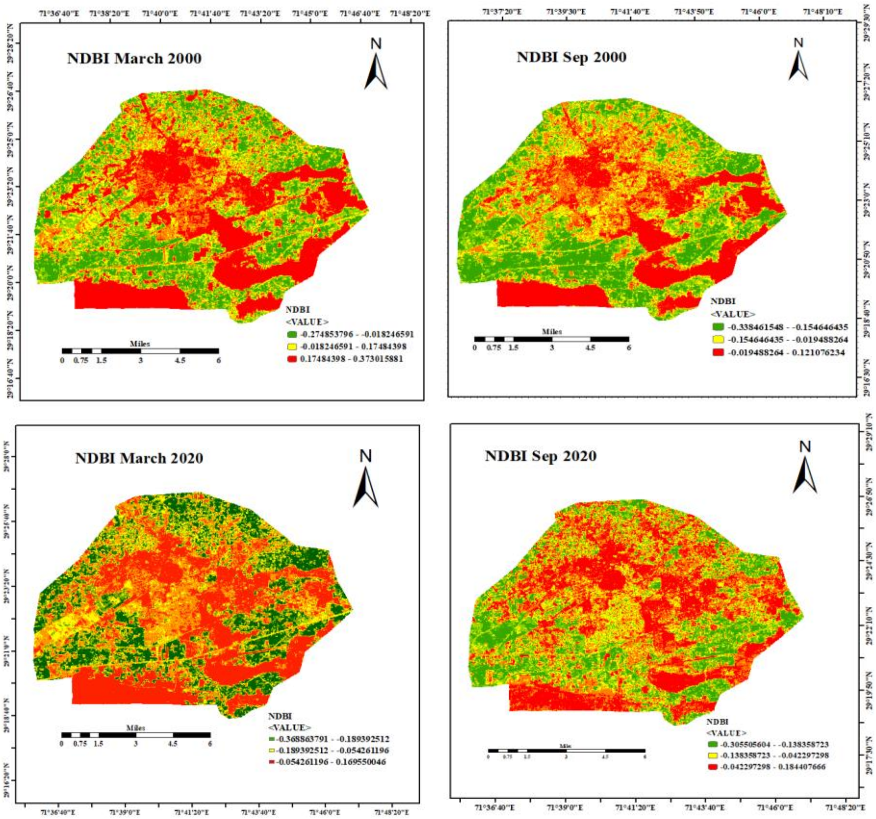

Figure 6. Normalized difference built-up index maps of the Bahawalpur city.

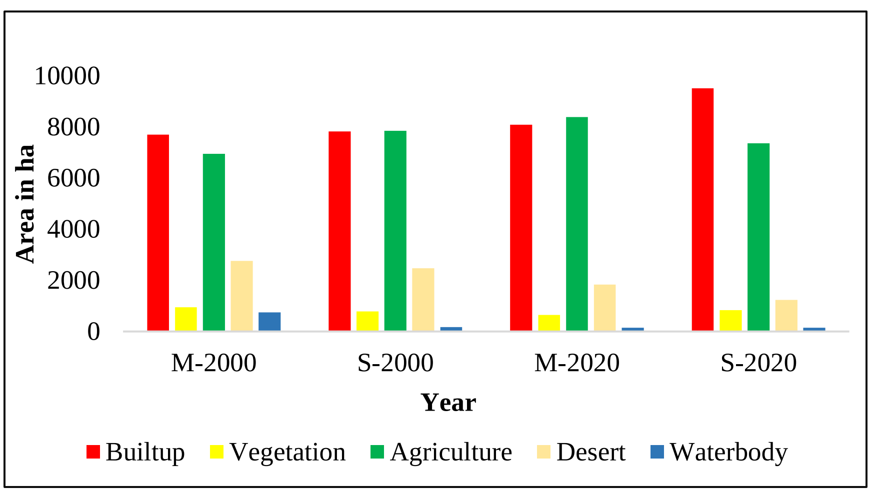

Figure 7. The variation in area from March and September (2000) to March and September (2020) in supervised LULC image classification.

Agriculture decreased by 1027.98ha. The percentage change of 43.9% to 38.5% occur. The desert area also changes with a percentage change from 9.6% to 6.5%. The difference in the area occurs at 602.55ha. The desert area also decreases due to the increase of settlements. The variation in vegetation occurs but at a minimum percentage from 3.3% to 4.4%. Bahawalpur city boundary does not contain river Satluj but some of its canals and waterways that irrigate agricultural areas of the city. These canals are the Shashmai canal (Fig 3) and the desert branch from the Bahawal canal. Shashmai canal is Non-Perennial Canal that irrigates sweet water areas. The Non-Perennial Channels start running from 15th April to 15th October of each year. So water was not available in March and the amount of water started decreasing at the ends of September and October. This is the reason that water changes occur minimum from March to September. The water percentage almost does not change and the area occupied by water land remains at a minimum of 0.45ha. These facts and figures can be seen in figure 7.

Change Detection Results

Change Detection (March)

Supervised change detection is achieved out from 2000 to 2020 (Fig 4). It is done to detect the change in classes of study area Bahawalpur city (Fig 1). Some of the classes show change and conversion to other classes. Two main change detection analyses are performed to detect this conversion. One from March 2000 to March 2020, and the other from September 2000 to September 2020. The interconversion of all five classes (Fig 4) took place that can be explained in detail. The changes in main classes from March 2000 to March 2020 given in map figure 4. When we discuss land conversion, the major conversion occurs into built-up areas from all classes. The conversion of vegetative land to built-up occurred with 244.77ha with a percentage increase of 1.28%. The large vegetative patch is present on the west of Bahawalpur city near old bypass and National highway N5. Some of its parts

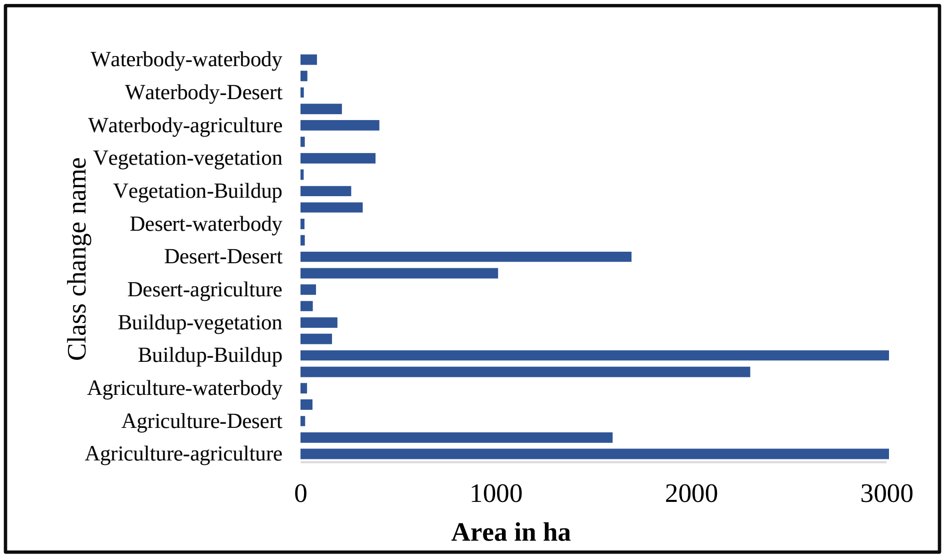

Figure 8. Supervised LULC change detection from March 2000 to March 2020 shows LULC class conversion.

were converted into built-up areas from 2000 to 2020. The agricultural area converted into the built-up area is 1583.55ha from 2000 to 2020 with a percentage increase of 8.28 from agriculture. The desert area that converts into built-up is 996.95ha with a percentage of 5.22. Desert is decreased by built-up. A minimum change of waterways occurs to built-up with 197.55ha. The built-up area increased from 2000 to 2020 is 5066.72ha. This is the total conversion of different land use classes into built-up class (Fig 4). All these interconversions of built-up, vegetation, agriculture, desert, and waterbody to built-up are graphically represented in figure 8. Agricultural areas are mostly concentrated near the Shashmai canal and in the area that is irrigated by the desert branch of the Bahawal canal. There is an increase in agriculture from 36.38% to 43.9%. The area conversion from built-up, vegetation, agriculture, desert, and waterbody to agriculture took place (Fig 8). The built-up area that is converted into agriculture is 2287.55ha with a percentage of 11.5. The vegetative area that is converted into agriculture is 303.64ha with a minimum percentage of 1.58. It is a very small area that is converted into agriculture from vegetation. The increase from already present agricultural land is 28% with 5355.11ha area. Too minimum conversion from desert to agriculture occurs with a percentage of 0.335 with the change of 64.044ha. The change from waterbody to agricultural land occurred with 389.68ha with a percentage of 2.03. It is a minimum change from waterways to agriculture. All these changes can be seen visually in figure 4.

Of all the classes the desert is the class that shows the smallest positive conversion and increase in area, but it has a negative trend and it is high in the decrease of area (Fig 4 and Fig 8). The built-up that is converted into the desert is 146.63ha area with a percentage of 0.76. The vegetative area that is converted into the desert is 0.066ha with a percentage of 0.00035. This conversion is minimum because the major conversion occurred in the decrease of the desert (Fig 4). Agriculture converted into the desert with an area of 8.72ha with a minimum percentage of 0.045, which is too minimum. The number of waterbodies converted into the desert is 1.95ha with a percentage of 0.011 given in figure 8. Opposite to this minimum change desert decrease from March 2000 to March 2020 (Figure 4). The vegetation patches that occur in Bahawalpur city show some change. A few classes show minimum conversion into vegetation. These classes are built-up, agriculture, desert, and waterbody with 174.21ha, 47.03ha, 7.140ha, and 21.03ha area respectively. The percentage conversion is also minimum for these conversions. All the classes show minimum conversion into a waterbody. For example, these classes, built-up, agriculture, desert, and vegetation give the conversion of 48.82ha, 18.02ha, 6.465ha, and 6.69ha into water areas with a percentage of 0.25%, 0.095%, 0.033%, and 0.035% respectively. From the above facts and figures, it can be asses that the minimum positive conversion areas are desert and waterways, and vegetation. Bahawalpur city contains small vegetative sites and a minimum area occupied by waterways. The desert shows a decreasing trend and shows squeezing near major sites near Chak no 12, new Cantt Bahawalpur, and Cholistan University of Veterinary and Animal Science Bahawalpur, which once were the major desert sites in the city. The built-up class has a positive trend (Fig 4) and show maximum conversion of all the classes into built-up. The settlement and built-up area are concentrated in the center of the city in old Bahawalpur city. The area is spread outward by settlement and construction sites.

Change Detection September

The change detection is brought off from September 2000 to September 2020 shown in map figure 4. Different land use land cover classes convert into built-up (Fig 9 and Fig 4). The major change occurring from built-up-to-built-up means that increase in the original area by 7737.92ha with the highest percentage of 40.48%. It shows the increase in the built-up area by construction sites settlements and commercial sites. The vegetative area that is converted into the built-up area is 73.43ha with a percentage increase is 0.385%. This is the little area conversion. The area of 431.1004ha of agriculture is converted into the construction site with a percentage change of 2.255%. The major portion of the desert that is converted into built-up is 1252.53ha with 6.555%. It is the major of all classes that converted into the built-up. The minimum conversion of the waterbody to built-up occurs with an area of 30.43ha with a percentage of 0.159 (Fig 9). The reason for the conversion of waterways to built-up is that water dries in the waterways due to non-perennial flow and the area is occupied by small shops and temporary and rough constructions by vendors in the city. The agricultural area shows the minimum positive change. These little conversions occur from built-up, vegetation, and waterbody with an area of 58.40ha, 13.97ha, and 5.41ha with a percentage of 0.30%, 0.074%, and 0.028% respectively (Fig 9). These numbers are minimum and hence prove my study that there is a decrease in the agricultural area. A maximum shift occurs from the decrease in the agricultural areas in Bahawalpur city. Built-up converted into the desert with an area of 17.82ha with a percentage of 0.094%. Not any other class shows the conversion into the desert. This is the minimum increase in the desert to prove the statement that a major change or decrease in desert areas occurs in the desert region of Bahawalpur city. The large portion of desert regions lies near the boundary of Bahawalpur city towards the south. There is decrease in the desert from September 2000 to September 2020 (Fig 9).

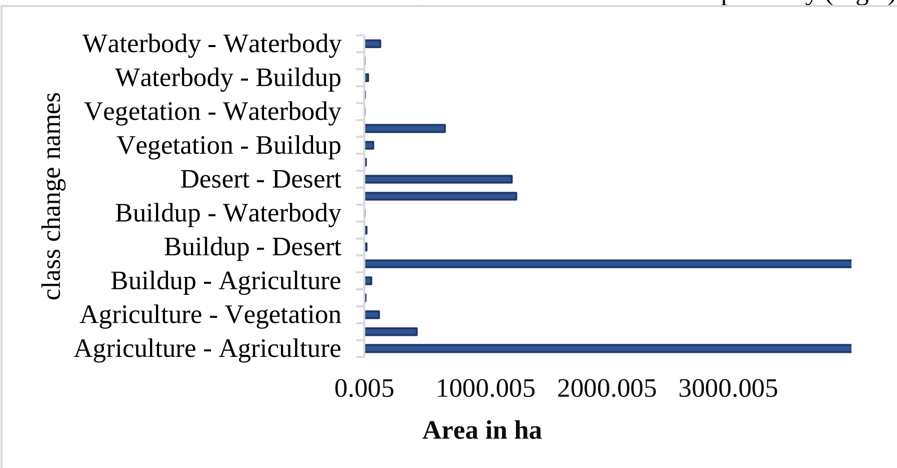

Figure 9. Supervised LULC change detection from September 2000 to September 2020 showing class conversions.

A very little increase in vegetation occurs from September 2000 to September 2020. It can be seen in figure 4 that the conversion of different classes to vegetation is very little. For example, built-up, agriculture, and waterbody show conversion of land with an area of 18.24ha, 120.43ha, and 0.704ha with percentages of 0.095%, 0.64%, and 0.0036% respectively (Fig 9). These numbers are very little show few changes in the vegetative flora of Bahawalpur city. A little conversion occurs from different classes to waterways. These conversions can be seen in figure 4. These classes are built-up, vegetation, and agriculture with areas of 2.890 ha, 2.644ha, and 9.95ha with percentages of 0.0152%, 0.0138%, and 0.053% respectively. These show the little variation in the waterways in the study area of Bahawalpur city.

NDBI and NDVI

Figure 6 maps show the NDBI values and maps of March 2000 and September 2000. The values in the map of March 2000 start from – 0.27 and ends with the highest positive value of 0.37. This positive value of 0.37 shows the built-up areas and construction sites in the urban areas of Bahawalpur city. The negative values in this map show non-urban areas like vegetative areas, agricultural areas, and waterways. In figure 6 the NDBI for September 2000 is also demonstrated. The values start from a negative value of -0.33 and end at the highest positive value of 0.121.

Table 4: NDVI and NDBI for 2000 (March, September) and 2020 (March, September).

Years	NDVI			NDBI		
	Max	Min	Mean	Max	Min	Mean
M-2000	0.44	-0.39	0.025	0.37	-0.27	0.05
S-2000	0.44	-0.16	0.14	0.12	-0.33	-0.105
M-2020	0.52	-0.027	0.24	0.16	-0.36	-0.1
S-2020	0.49	-0.074	0.28	0.18	-0.30	-0.06

These highest positive values depict the built-up area covered and other negative values cover the green and yellow area that represents agricultural, vegetative, and other land cover classes. The first and medium values (-0.33 to -0.15, -0.15 to -0.019) given in table 4 show it. Figure 6 exhibits the maps of NDBI for March 2020 and September 2020. Figure 6 maps show different values in March 2000 and September 2000. In March 2020 the minimum value is -0.36 and the maximum positive

value is 0.169. The maximum values show the construction sites in Bahawalpur city including roads network settlements, and commercial areas. In September 2020 the values of NDBI have a different trend. The highest negative value is -0.305 and the highest positive value is 0.184 (Table 4). These positive values show the sprawl of Bahawalpur city is from center to outward. The population and settlement are concentrated in the center and the periphery are mostly capture with agriculture.
The Normalized Difference Vegetative Index (NDVI) is calculated for 2000 (March and September) and 2020 (March and September) represented in figures 5. The NDVI is used to calculate the vegetative areas of Bahawalpur city. It has a standard value from -1 to +1. It shows the maximum and minimum values for the NDVI. In March 2000 Bahawalpur city shows an NDVI index with the lowest -0.39 to the highest value of +0.44. The indices value that is from 0.078 to 0.44 shows the agricultural land pertaining to green areas in maps. In September 2000 shows the values of NDVI. September 2000 shows a minimum negative value of -0.160 and a high positive value of 0.44. Figure 5 and table 4 shows NDVI values for March 2020 and September 2020. In March 2020 the negative value is -0.027 showing other land use other than agriculture. The maximum positive value shown is +0.526. In September 2020 the negative value was -0.074 with high a positive value of +0.494. The values interpret the distribution of agricultural areas in Bahawalpur city. NDVI values near the Shashmai canal in the southwest are high giving the agriculture land.

Regression Analysis

Regression analysis is done to check out the relationship between NDVI and NDBI (Fig 5, Fig 6). To determine how variations in LU intensity inside LULC units vary across space and bring about the intra-LU fluctuation of NDBI, regression analysis (R2) is conducted. A negative relationship exists between NDBI and NDVI with a correlation coefficient (*R*2). It is 0.75 for March 2000, 1 for September 2000, 0.75 for March 2020, and 0.75for September 2020. Regression analysis reveals that NDVI values were lowest in the area where NDBI values were highest (Fig 5, Fig 6). Average NDBI and NDVI values are observed and regression analysis is calculated. The NDVI and NDBI average values for March 2000 are 0.025 and 0.05, for September 2000 are 0.14 and -0.105, for March 2020 are 0.24, and -0.1, and September 2020 are 0.28 and -0.06 respectively. The linear relationship is calculated between two classes of vegetation and built-up using two different indices.

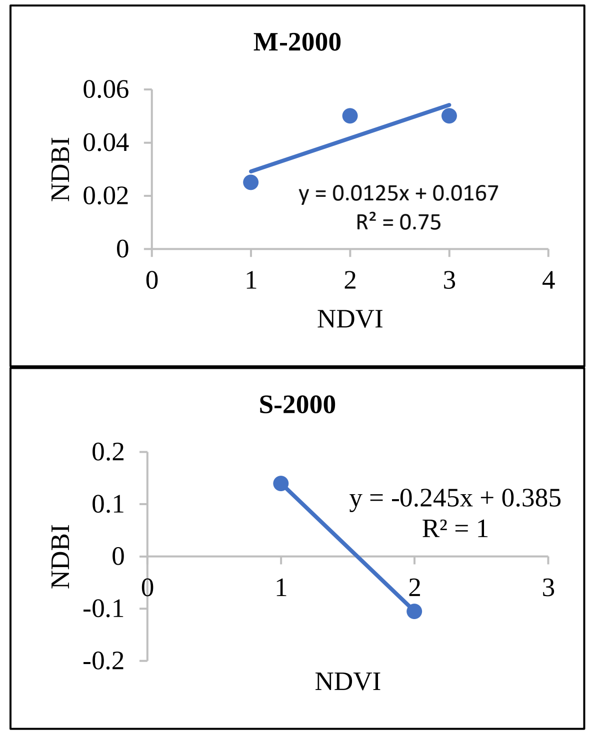

Figure 10. Regression analysis between NDVI and NDBI for March 2000 and September 2000.

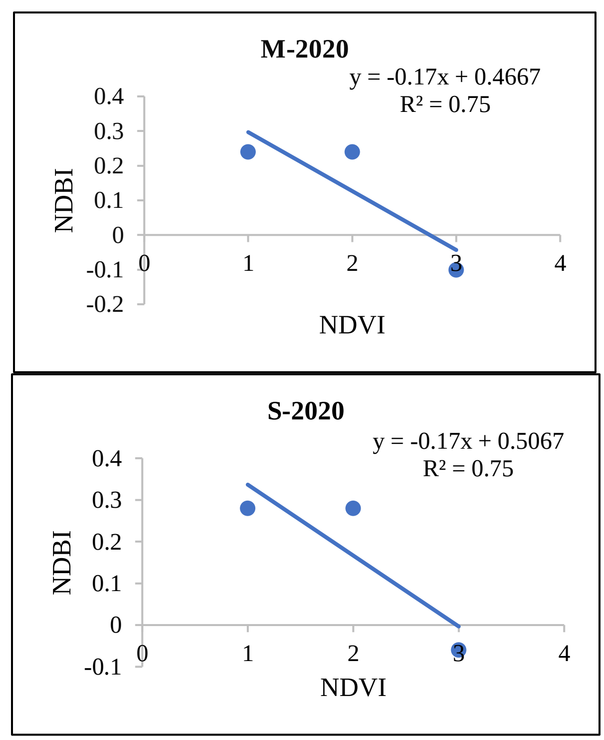

Figure 11. Regression analysis between NDVI and NDBI for March 2020 and September 2020.

Impact of LULC Changes on Urbanization and Livestock

In the LULC classification of Bahawalpur city, different classes show different trends. The major concerns of study are built-up, desert, and agricultural land. The changes in these classes are given in figure 4. There is an increase in the built-up area, and vegetation, a decrease in desert, and waterbody with varying trend of agriculture in classifications from 2000 to 2020. This classification is explaining different dynamics of human perspectives and ecological perspectives. Increasing built-up area is supporting the increasing population in the city. Different censuses of 1998, 2008, and 2017 depict the increasing population in the city (Fig 12). This complement increase of built-up with population can cause various problems. The increasing population is degrading the natural desert environment of this region. This increase also puts pressure on the natural resources of this area. This increasing population is the crucial cause of rise in unemployment high cost of living, water shortage, and pandemics. Bahawalpur city is facing some of them like poor sanitation conditions, and the flowing of gutter water on roads due to overpopulation. This urbanization is

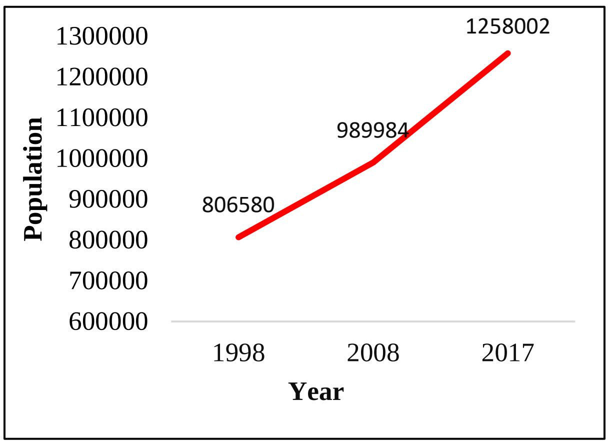

Figure 12. Population growth of Bahawalpur city in 1998, 2008, and 2017.

coaxed by increasing built-up, and reversal of desertification in Bahawalpur city.

The impact of LULC along with its increasing population also altered the livestock preferences in the city. The livestock data in figure 13 suggest a few things with a varying pattern of LULC classification. The number of cattle, sheep, and horses increased in the city according to milk meat demand as well as the number of horses for transportation means of people in the city. Similarly, the number of goats, buffaloes, camels, mules, and asses decreased in the studied time span. One of the possible decreases in the number of buffaloes and goats is the changing pattern in LULC that is not available of the waterbody and the forged land decreased that also decreased the number of camels mules and asses. In thickly populated areas the sudden decrease in open lands for the above-mentioned animals decreased and forming practice of local people altogether changed with the passage of time in addition to climatic factors of the city. But the overall trend of

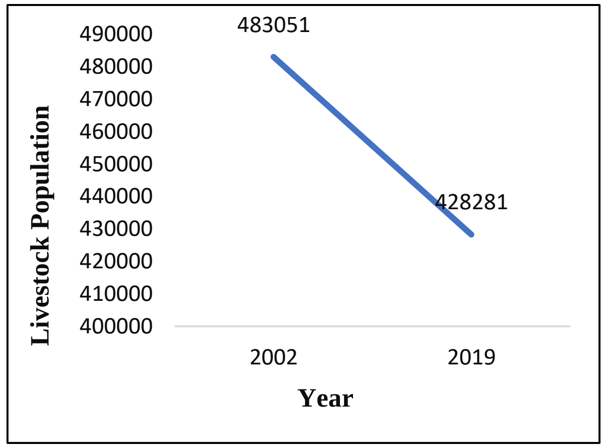

Figure 13. Livestock domestic Population growth of Bahawalpur city in 2002, and 2019.

livestock is showing a decreasing trend with population and built-up as indicated in figure 13.

Over all the main goal of this study is to highlight the interactions of LULC with the population and livestock of the city. The individual aspects of the above-mentioned factors have been studied but the combined impact for the comprehensive results for researchers, and policy members were missing and this study addresses that missing link.

DISCUSSION

The Bahawalpur city encircles a total area of 19,110.87 hectares. The major areas are occupied by five classes of built-up, desert, agriculture, waterbody, and vegetation. All five classes have different areas with respect to each other. The classification of March 2000, September 2000 March 2020, and September 2020 show the areas in hectares. The results of this classification show that built-up areas have an area of 7824.69ha (40.9436%) and increase to 9515.79ha (49.7925%). The desert area was 2474.73ha (12.94%) and become 1237.32ha (6.4744%). The agricultural area changed from 7850.7ha (41.0797%) to 7364.43ha (38.5352%). The vegetative trees remain in an area of 784.62ha (4.1056%) to 840.96ha (4.400%). The waterbody in the city contains an area of 176.13ha (0.9216%) and decreases to 152.37ha (0.7972%). The interconversion of all these five classes into each other has been detected through change detection analysis. The major conversion is; desert into built-up with an area of 1252.534ha (6.55%) and agriculture into built-up with 1252.534ha (6.555%). Big patches of desert in the south and southwest of the city have been converted into construction and built-up, which were once covered up with sand and sand dunes.

The population in this area goes on increasing from 1998 to 2017 with a percentage of 35 showing a complement increase in built-up areas in the city. The reasons for the increase in population are better health, education, and commercial facilities that are making it a pivot city on the margin of legendary and vast Cholistan desert. Migration from connecting villages and far from Cholistan desert for selling products and other commercial activity is another reason for the increase in city population. The increasing population will not assist the balance utilizing of natural resources and leading cause of the poor sewerage system in the city that is causing water pollution and many diseases associated with it. An increasing population may cause other types of pollution with water pollution like air and soil pollution within the city. Livestock data shows that it goes on decreasing by 12.7% from 2002 to 2019. The data shows that goats, buffaloes, camels, mules, and asses decreased in number. This happened due to a decrease in water availability and a decrease in open lands found in city. Another trend is that the numbers of sheep cattle and horses increased within available years of data. It shows the farmers' preferences with changing environments and changing needs of the city that they reared meat and milk animals and preferred horses on mules, asses, and camels in the city. It shows the feasibility of these animals in the city.

CONCLUSION

The result of this geospatial study shows that there are changes in the LULC categories following the impact on population agriculture livestock and desert from the year 2000 to 2020. The study area of Bahawalpur city shows that the following conclusion can be drawn from this study

1. Bahawalpur city shows changes from 2000 to 2020. The geospatial analysis of change detection shows that the built-up area (Settlements, roads, constructions, industries, commercial areas) increased by 18%. The population of the city increased with an increase of the built-up area by 35% from the year 1998 to 2017.
2. Desert in Bahawalpur city constantly declined and ultimately almost disappeared at the end of 2020 within the boundaries of city. The big patches of desert areas and sand dunes were mainly replaced by DHA Bahawalpur and Cholistan University of veterinary and animal sciences Bahawalpur. This resulted in an almost 100% decrease in the desert from 2000 to 2020.
3. Agriculture found on the outskirts of the city of Bahawalpur. The desert areas have been converted into agricultural area. Agriculture shows variable trends first increasing to fulfill the demand of the city and later decreasing due to a decrease in land available within the boundary line of city. The settlements occupied the desert and agricultural land so agricultural land shows a decreasing trend at the end of 2020.
4. Livestock of Bahawalpur depends on agriculture as well as on the bushes of the desert found within boundary of Bahawalpur. The domestic livestock of Bahawalpur decreases overall from 2002 to 2019 by 12.7%. But some of the major livestock like cattle, sheep, and horses increase from 2002 to 2019 to meet the food and transportation demand of city.
5. The waterbody decreased by 15% within the city because of declining the agricultural areas and conversion into built-up. The vegetative areas (trees, all kinds of green plants) increased by 6% found in the housing colonies, around the roads and along the canals.

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