LAND USE MAPPING AND GEOSPATIAL ANALYSIS OF THE BAHAWALNAGAR LANDSCAPE TRANSITION: UNRAVELING CLIMATE CHANGE FORCES

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ABSTRACT: The study was conducted to monitor the transformation of Bahawalnagar Landscape due to Climate Change through GIS & RS techniques. Data was collected from the past 30 years from 1990 to 2020 with a 10-year interval. Similarly, climate data, which includes temperature and rainfall also collected for respective years. With the help of supervised classification, NDVI, and NDBI, it is revealed that change occurred in the landscape in the proceeding years. The built-up land increased with the passage of time. Similarly, open land and water resources are reduced with time due to low rainfall, which declines the ratio of water sources from 1990 to 2020. So, in 2020, the construction area showed a further increase and covered 20.04%, agricultural land increased to 1.46% and open land decreased by 18.58% (the decrease in open land portion is directly linked with built-up and a small portion with agricultural land) and water bodies decreased by 2.8% in the thirty-year time period. Comparison graphs and figures further highlight the relation of climate change with the landscape. The relationship has a direct link such as high temperature reducing the agricultural land and change occurring more. In the same way, low rainfall also changes or fluctuates the landscape pattern of Bahawalnagar. In short, recommendations have been given to minimize the impacts of climate on the landscape.

Key Words: Climate Change; Land Use Mapping; Supervised Classification; NDVI; NDBI; Conservation; Remote Sensing.

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INTRODUCTION

The land is the most significant feature of nature. It plays an essential role in the development of all human activities and the primary source of developing them for future life. Climate change in urban areas is a national focus since urbanization is currently one of the profound features of our biome (Chandra *et al*., 2018; Grimmond, 2007; Sarvari, 2019; Seto and Shepherd, 2009; Tang *et al*., 2018). One of the factors that change the climate is urbanization (Chapman *et al*., 2017; Li *et al*., 2020; Wen *et al*., 2019; Zhou *et al*., 2019). There are numerous factors like cultural, economic, historical and political points that are putting effects on Land-use patterns (Aguilar *et al*., 2003; Gadanho *et al*., 2014; Jacobson *et al*., 2015; Liu *et al*., 2005; Zhang *et al*., 2018). Therefore, the need for more accurate land use is gaining much more important for better development (Habib *et al*., 2020). The world has seen a stunning increase in urban development in Asia over the last decade 2000-2010(Amjad *et al*., 2023; Mustafa *et al*., 2021; Ahmad *et al*., 2021; Ahmad *et al*., 2022; Raza *et al*., 2022). No doubt that the population is increasing day by day, so people need more houses to live in and this can be done with the more built-up area (Ahmad *et al*., 2023; Sajjad *et al*., 2023; Aslam *et al*., 2023).

Consequently, it is important to check and observe these changes otherwise, these come with negative impacts on the population and effects on societal norms. Moreover, the monitoring of urban changes leads to the prediction of changes and the exact location of the future metropolitan area, and it is valuable and very reliable (Kafi *et al*., 2014). It will be helpful to the planners to make future strategies for even and planned development of the city (Ban-Weiss *et al*., 2015; Falasca *et al*., 2019; Santamouris and Fiorito, 2021; Stone *et al*., 2012; Coskun *et al*., 2008) mostly done their research on land-cover and land-use (in the context of precise and timely information) and urban area changes that become critical for monitoring ecosystem, urban planning and decision making for the management of urban land. The combination of remote sensing (RS) and the Geographic Information System (GIS) method makes a proposal for an approach that increases the planning, monitoring of land use and management of urbanized watersheds as a tool effective. (OLALEYE and Abiodun, 2023) studied land-use change detection of the Lekki Peninsula area of Lagos, Nigeria, between the duration of 1964 to 2003.

The findings of the study revealed that in both humans and infrastructure manner, marvelous changes occur in the Lekki Peninsula. (Deyong *et al*., 2009) study revealed that since the Reform and Opening policy implementation, China had made great economic achievements. In the representative city of Shenzhen, there is rapid urbanization and population growth (Aslam *et al*., 2023; Mustafa *et al*., 2022; Mustafa *et al*., 2021; Shahzaman *et al*., 2021).

There is a great impact on regional ecosystems and great changes such as the land surface due to urbanization. To drive the CASA productivity model and obtain the net primary productivity for the study area, a land cover map based on Landsat, meteorological data, data from the moderate resolution imaging spectro-radiometer (based on MODIS) and the Index of Normalized Difference Vegetation (NDVI) (Amjad *et al*., 2019; Khanna *et al*., 2017; Longobardi *et al*., 2016) studied Sargodha, Pakistan, using satellite imagery from 1992 to 2010 for the temporal analysis of urban development. People's perceptions are more relevant to investigate about land-use changes, and primary data was also utilized in the research. The results of the study indicate that the forest area increased significantly by 600 ha in a built-up area and decreased by up to 4%. (Pandian *et al*., 2014) revealed that with regard to sustainable development, monitoring and detection of land use or land cover is important. Between 2000 and 2009, two districts of India, Coimbatore and Tiruppur, used LANDSAT imagery to detect changes in land use and cover. The results showed that from 0.1% to 0.3% of the built area increased while it was detected that from 33.9% to 26.3% of the agricultural land decreased. (Grunewald *et al*., 2017) revealed that urban green spaces provide multiple benefits for city dwellers, standard key parameters and proximity approaches that provided an overview for green-space quantification cities. In a German and European context, they discussed the orientation and values of the proposed and quantified indicators. (Haque and Basak, 2017) studied Tanguar Haor, which contains a large amount of biodiversity and a fertile ecosystem. But a priceless landscape of absolute change suffers in its form over decades, for the typical change in the landscape in recent decades and recently used by the satellite. (Grunewald *et al*., 2017) revealed that urban green spaces provide multiple benefits for city dwellers, common key parameters and proximity approaches that provided an overview for green-space quantification cities. In the city on a national scale, the proposed indicators for the assessment of the ecosystem service. (Tomao *et al*., 2017) found out that for Nature-Based Solutions (NBS) urban and pre-urban forests are the basic elements. In urbanized contexts, they may increase and preserve environmental quality.

MATERIALS AND METHODOLOGY

Study Area: Bahawalnagar was initially known as Rojjhanwali. It changed the name Bahawalnagar took place in 1904. Bahawal Khan was the pioneer ruler of Bahawalpur State by whom the city name was owed. Nobody could ever imagine that this area would be developed as a district and a big trade market. New building in that area show remarkable change in30 years (Raza and Shirazi, 2014). Headquarter of the District is situated on the South-East regional side of Punjab Pakistan which is a tehsil of Bahawalnagar district, Bahawalnagar is a developed city. Like all other developed cities in the world, it has also experienced a major change in land-use with further development (Aziz and Ghaffar, 2017). Increased in urban areas and decreased in agricultural areas are the most remarkable land-use changes observed during the development phase of a city. In summer, the winds are called "loo" during the day in the hottest months such as June, July and August. The average minimum temperature in summer is 75.4° Fahrenheit and the maximum is 111.4° Fahrenheit. At the end of June, the Monsoon season starts in Bahawalnagar. The city receives about 11.2 inches of rainfall annually. Humidity often takes place after the rainfall and it continues till mid of September. Winters are said to be dry in this season with very less amount of rain.

Classification of Supervised image: The classified theme about the supervised image, adopted by the present analysis, for the Landsat satellite Imageries of 1990, 2000, 2010 and 2020. These statistic images were non-inheritable set ahead like database specifically for the analysis aim (Figure 2). The initial step of the classification is that the images were arranged and then revised; the next point is within the onward stages. All the images were increased then expanded to a range to handle the visible decoding in a systematic approach. All the systems of developed discernment regarding to the tonal introductions were done simultaneously. After that, the aspects and classes of every form of land cover were more visible from images several. The study base gathered once the supervised classification grouped the Bahawalnagar city land cover into four classes for the aim of analysis. The class dealing with the land use has been shaped on the base of practices already existing concerning them within the involved space (Lu and Weng, 2007). The land was subdivided into four different classes 1) Built-up area 2) Open Land 3) the agriculture land 4) all the Water bodies.

Normalized Difference Vegetation Index (NDVI): To assess and match the distribution and presentation of vegetation over large different spatial and temporal patches, NDVI can be a very useful tool. Sensors used in remote sensing acquire data about a device or area that has no physical connection to it. These objects are identified based on their unique spectral properties (Xie *et al*., 2008). The vegetation is very reactive in the red and near-infrared regions. These regions are then incorporated to develop the vegetation index.

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

The software named ERDAS imagines 2014 was helpful for the calculation of NDVI. In this software, the tool built-in indices calculation option was used. For further detailed resulted images, Arc Map 10.1 used so also more layer outing carried out (Aslam *et al*., 2023).

Normalized Difference Built-up Index (NDBI): In extracting the built area, the cumulative normalized difference built-up index has been found to be very useful. Using NDBI for the path of mapping to develop the entire constructed area from a satellite image. A diverse response from urban areas comes to the fore in several sets of satellite images. The formula used for the NDBI count is:

NDBI = (Band 5 - Band 4)/ (Band 5 + Band 4)

The Built-in Indices calculation option of ERDAS 2014 helped calculate the NDBI. ARC GIS 10.5 further used for the layering of resulted images (Zhao *et al*., 2024).

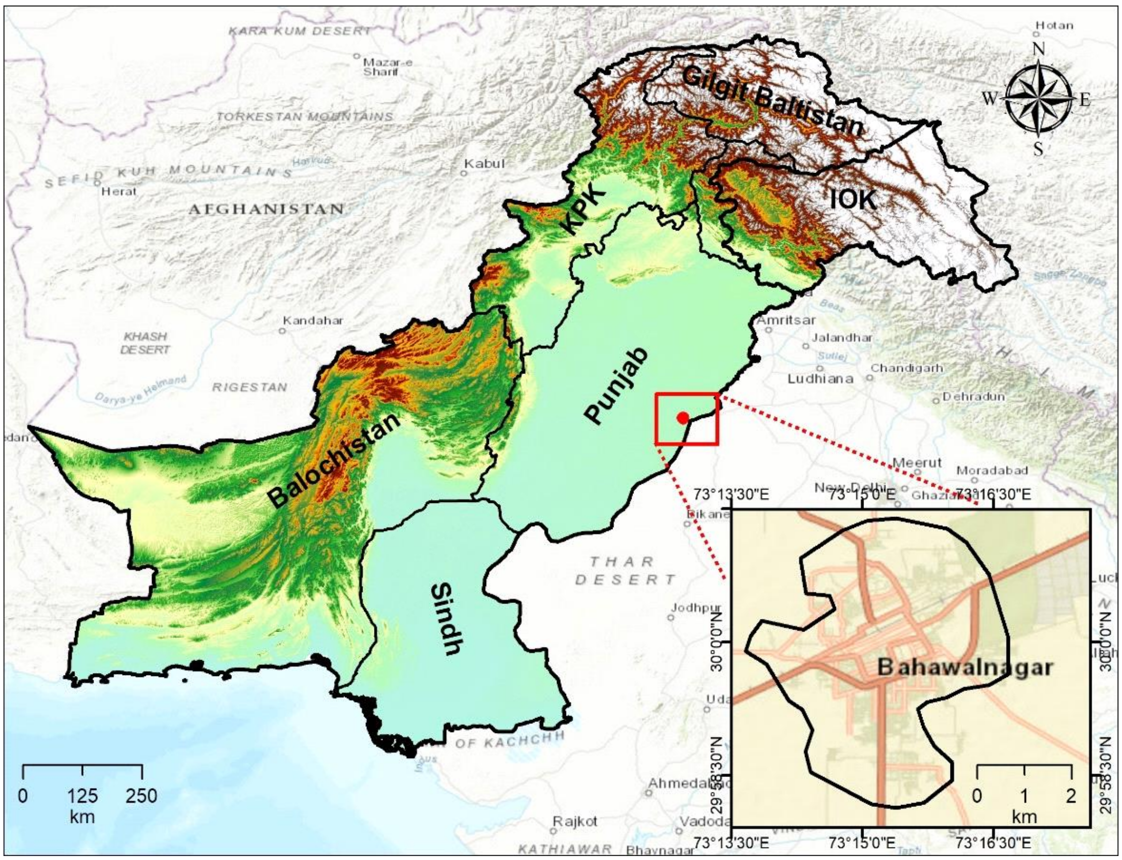

Figure 1: Study area map

RESULTS

Change in Landscape due to Climate Change: The distribution of land use resulted from different maps for specific study years shown in table 1.

Figure 2 shows the maps of Bahawalnagar of different years, such as landscape map of 1990, 2000, 2010 and 2020. Red color highlights the urban area while the green color used to show the agricultural land of the city. While the open land described with the help of white color and blue explains the water sources. In 1990, the large area of city Bahawalnagar was occupied by some agricultural land which was 33.24% of all land use and showed with green color because Bahawalnagar was a fertile area and more suitable for the production of rice and wheat While the red area is sparsely seen in 1990 because at that time urbanization was not much spread that was 43.95 percent. In the year 2000, agricultural lands showed a decrease in area of 0.7% over the past ten years. In 1990, a large area of Bahawalnagar city occupied some agricultural land, accounting for 33.24% of the total land use. In 2000, agricultural land showed an decrease in area of 0.7% over the past ten years. The main reason for agriculture decrease was the conversion of agriculture land into builtup area. In 2010, agriculture land was decreased by 3.65% and the reason behind the decrease was drought of 2010 and builtup activities. In 2020, agricultural land showed the tremendous increase of 5.81% from 2010. The builtup class in 1990 was 43.95% which was increased by 7.55% in 2000 and reached at 51.50% of total landuse. And in 2020 it stands at 63.99% of total landuse and main reason behind this alarming increase is population growth and increase in construction activities. Water continues to occupy the lowest proportion of space among all categories. However, it has decreased. In 2010, its share decreased by 0.6% as compare to 1990. In 2000, water bodies occupy 1.96% and by decreased in 2020 it stands at 0.37%. Also, in 2020, the construction area showed a further increase and covered 20.04%, agricultural land increased to 1.46% and open land decreased 18.58% (decrease in openland portion is directly linked with builtup and a small portion with agricultural land) and water bodies decreased by 2.8% in thirty-year time period. A significant construction of different colonies was done. Many new but small settlements were built during the period from 1990 till 2000, named as Faisal colony, Wokla colony, Officers colony, Alhamd housing scheme and some area of Madni colony. Water bodies show a minor decrease. And highlights with blue color in the maps. A total of 16 new or minor colonies were established during this period on all corners of the city Bahawalnagar. In 2020, the built-up area to create a large extent, shown with red color in figure 2.

Rainfall and temperature are the leading climate change indicators. Table 2 and figure 3 show the relation between changes values of landscape with climate change indicators. Bahawalnagar is a dry region where summer is intense hot due to high temperature along with this region receive the very low intensity of rainfall. Due to which its agriculture sector severely impacts and land convert into an urban landscape that is clearly seen in the trend of temperature and rainfall from 1990 to 2020. Agriculture land in 1990 has a figure that was 33.24 percent, which improved with time and becomes 34.70 percent in 2020.

In the same way, due to high temperature and low rainfall water sources of the city face decline trend such as in 1990 water was 3.17 percent which reduced in 2000 and becomes 2.57%, such as it further reduced in 2010 and 2020 and have a value of 1.96 percent and 0.37 percent respectively. Changes in the landscape also observed for the built-up area and open land, which faces an increase and decreases ration in respective years with relation to climate change. High temperature destroys the qualities of open land due to which it directly converts into build-up area and agricultural land in 2020 for utilization of land have analyzed from the graph of figure 3.

NDVI for Vegetative Area: The Normalized Difference Vegetation Index (NDVI) is known as the most widely used indicator regarding the quantity and control of vegetation or agricultural areas. The display of vegetation spectroscopy provides the basis for accurate measurement of vegetation parameters found at the Earth's surface. The NDVI is an excellent indicator of vegetative growth conditions and vegetative cover degree. If a region is vegetated, its NDVI value is a positive number that increases as the vegetation cover improves (Faisal & Rehman, 2020). Bahawalnagar NDVI maps were produced for four different years, namely 1990 to 2000, then 2010 and 2020. In these maps, an important change in agricultural areas can be clearly seen in recent years. These indices have characteristic values between −1 and 1 (Murshed *et al.*, 2020). NIR is reflected by leaves in plants, while chlorophyll absorbs it. If NDVI is high, it indicates that vegetation is abundant. Alternatively, if NDVI is low, there is little or no vegetation potential. Extremely low NDVI values (below 0.1) correlate to bare rock, sand, or snow regions. High levels imply temperate and tropical rainforests (0.2 to 0.3), whereas moderate values depict shrubs and grasslands (0.6 to 0.8).

In 1990, the Bahawalnagar district had more green areas, which are agriculture land, which highlighted in fig.4 with green shade while purple shade highlighted the infrastructure lands which cause high temperature that has negative impacts on the green land and converts it into useless land which ultimately used to build-up area. Development started in the city, the urban area increases in 2000 and agriculture land reduce in its extent such as in figure 4, in which green shade reduced in its extent while the purple shade has more area in the central, northern and southern side of the district. The same case happened in 2010 when agriculture faces further reduction and attains the lowest land for cultivation, which is depicted in figure 4. At last, all years have low urban land than 2020, as shown in figure 2. This map gave a detailed look at the description of land-use and land-cover conditions. Such as by comparison with other years, it indicates that in 2020 the agricultural land reduced and urban land attain maximum point that was 63.99 percent, as illustrated in table 1. To drive the CASA productivity model and obtain the net primary productivity of the study area, Landsat-based land cover map, meteorological data, moderate-resolution imaging spectrometer (based on MODIS) and data from use the Natural Difference Vegetation Index (NDVI) by (Deyong *et al.*, 2009), who illustrated that NDVI gave the best description about the status of vegetation which reduced with time due to urban development.

Table 1 Landuse distribution of Bahawalnagar.

Land use	1990		2000		2010		2020	
	Area Hect.	**Area (%)**	**Area Hect.**	**Area (%)**	**Area Hect.**	**Area (%)**	**Area Hect.**	**Area (%)**
Built-up Area	796.73	43.95	933.50	51.50	992.61	54.77	1159.86	63.99
Agricultural Land	602.64	33.24	589.77	32.54	523.58	28.89	628.87	34.70
Open Land	353.89	19.52	242.65	13.39	260.72	14.38	17.03	0.94
Water bodies	57.62	3.17	46.59	2.57	35.59	1.96	6.74	0.37
Total	**1,812.51**	**100**	**1,812.51**	**100**	**1,812.51**	**100**	**1,812.51**	**100**

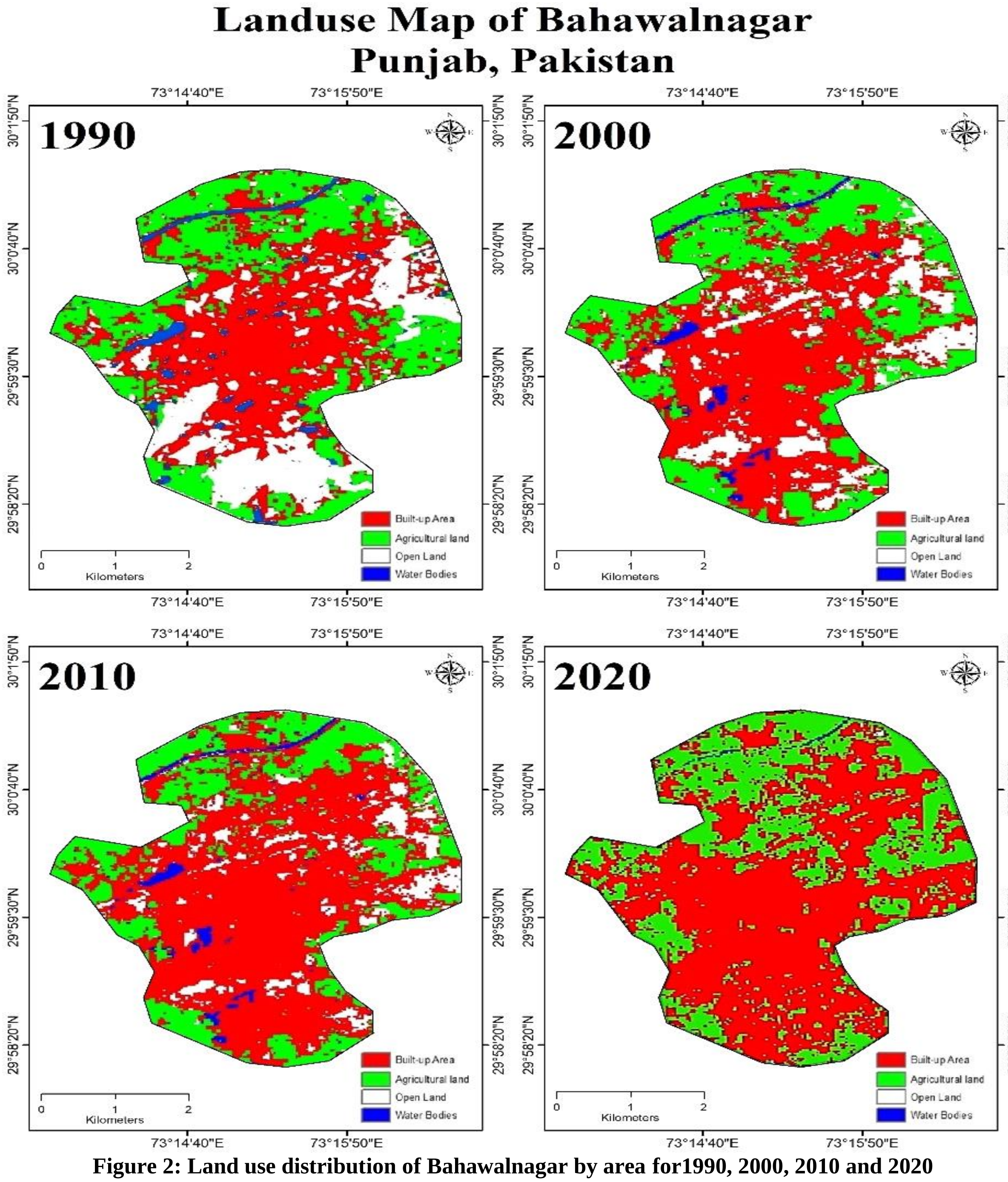

Figure 2: Land use distribution of Bahawalnagar by area for1990, 2000, 2010 and 2020

Table 2 Change in Landscape due to Temperature and Rainfall.

Year	Temperature °C	Rainfall	Built-up Area	Agriculture	Open Land	Water bodies
1990	51.41	30.11	43.95	33.24	19.52	3.17
2000	52.92	14.18	51.5	32.54	13.39	2.57
2010	53.14	16.25	54.77	28.89	14.38	1.96
2020	36.02	14.1	63.99	34.7	0.94	0.37

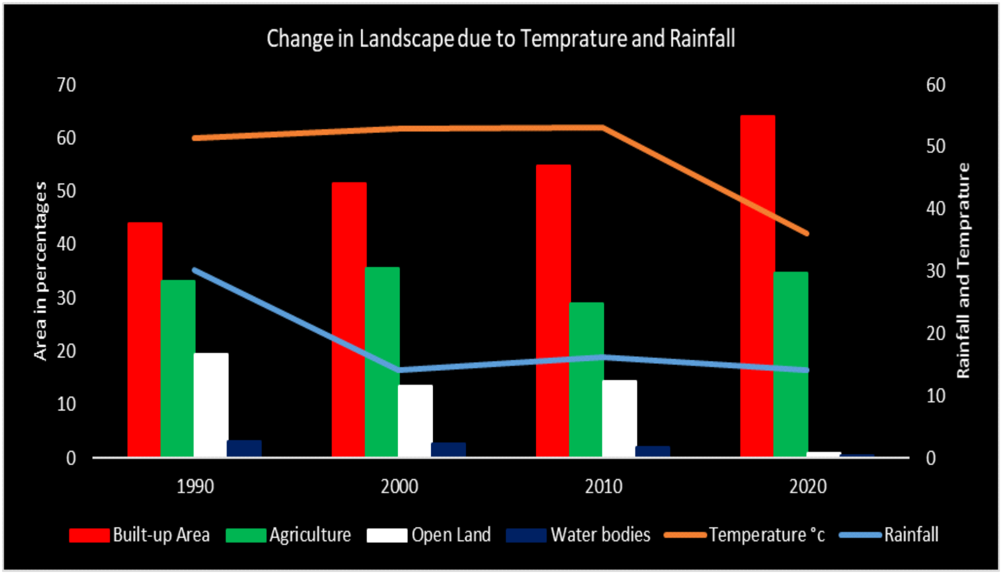

Figure 3: Change in Landscape due to Climate Change

NDBI for Built-up Area Extraction: NDBI is the tool used to view the region configuration. Basic treaty maps provide a significant note of the built-up area over several years. For different years, NDBI maps are shown in the figure below for the study area. These maps show the high and low values of the building at different years. The construction area is also directly related to precipitation and temperature, due to the high temperature in the landscape, the expansion of urban areas can be clearly seen with the help of these maps. It was observed that the built-up area was less in 1990. However, in 2020, an urban agglomeration is observed in the central regions with the south and the southwest. In addition, some eastern parts of the city, which provide clear evidence of urban expansion according to urban areas 1 and -1, are used for high and low values respectively. Graduated red indicates the heavily constructed area, while the width of the less congested area is described by different shades of red. The NDBI statistical calculation is presented in the table below.

NDBI is used to increase the built-up area. These maps provide the basis for a major mid-year review. Figure 5 shows the NDBI maps of the five-year study area. These maps show the high and low estimates of construction in different years. Urban sprawl can be seen unambiguously on these maps. In 1990, the percentage of construction was lower, which increased gradually over the years (Fig. 1). In 2020, it shows its strong appreciation in the central, northwest, south, southeast and southwest parts of the study area, clearly showing its impact on development (Fig. 4) The high and low values are indicated by the codes 1 and -1 separately. High scoring areas are shown in red. However, less developed regions appeared with relatively variable degrees of yellow and green. The statistical calculation for the NDBI is introduced in table 4.

Table 3: Statistical data of NDVI.

Image acquisition date	Minimum Value	Maximum Value
1990	-0.23	0.66
2000	-0.39	0.44
2010	-0.23	0.65
2020	-0.07	0.49

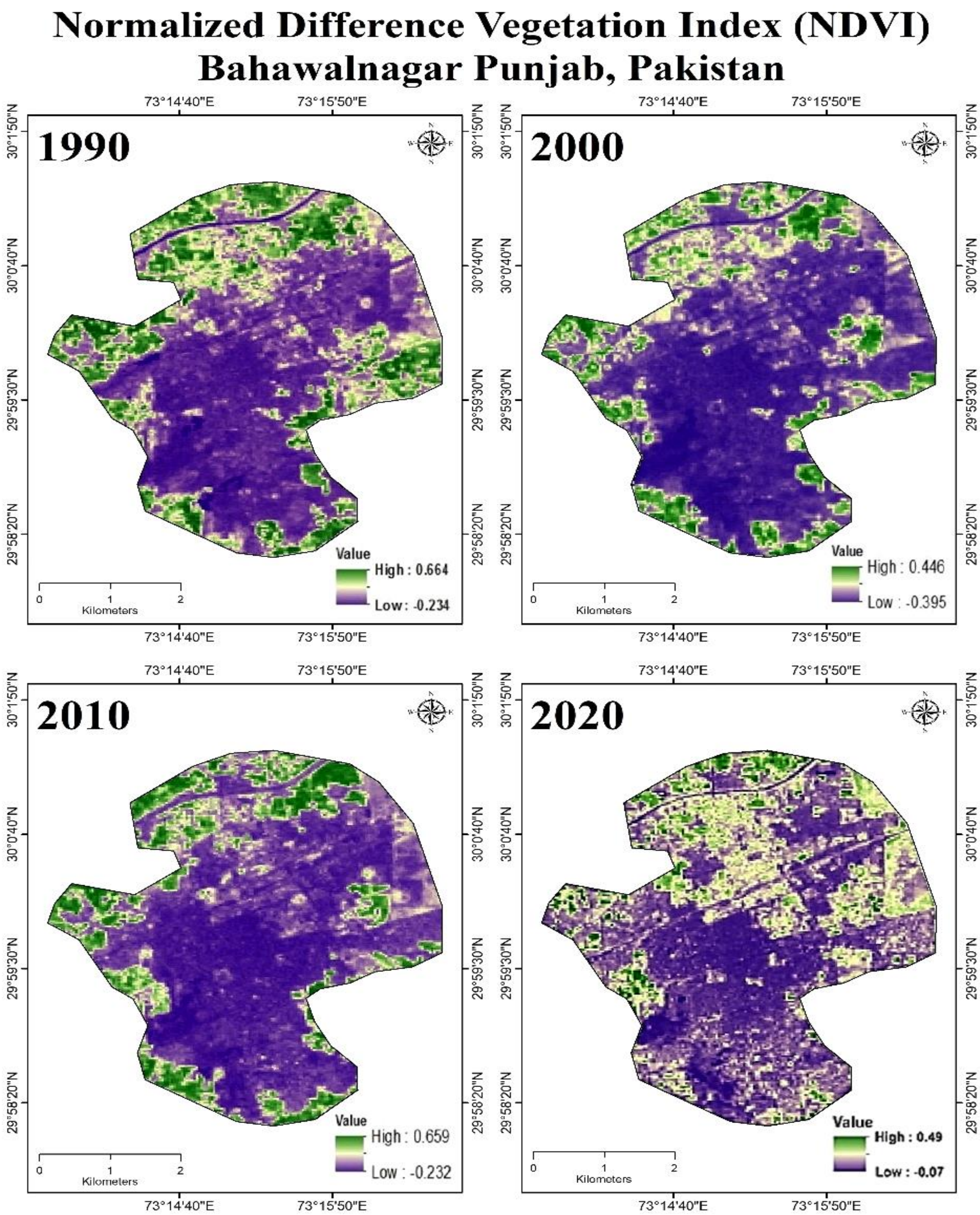

Figure 4: Pattern of Agricultural land in Bahawalnagar in 1990, 2000, 2010, and 2020.

Table 4: Statistical data of NDBI.

Date of Image Acquisition	Minimum Value	Maximum Value
1990	-0.33	0.41
2000	-0.29	0.35
2010	-0.33	0.32
2020	-0.31	0.09

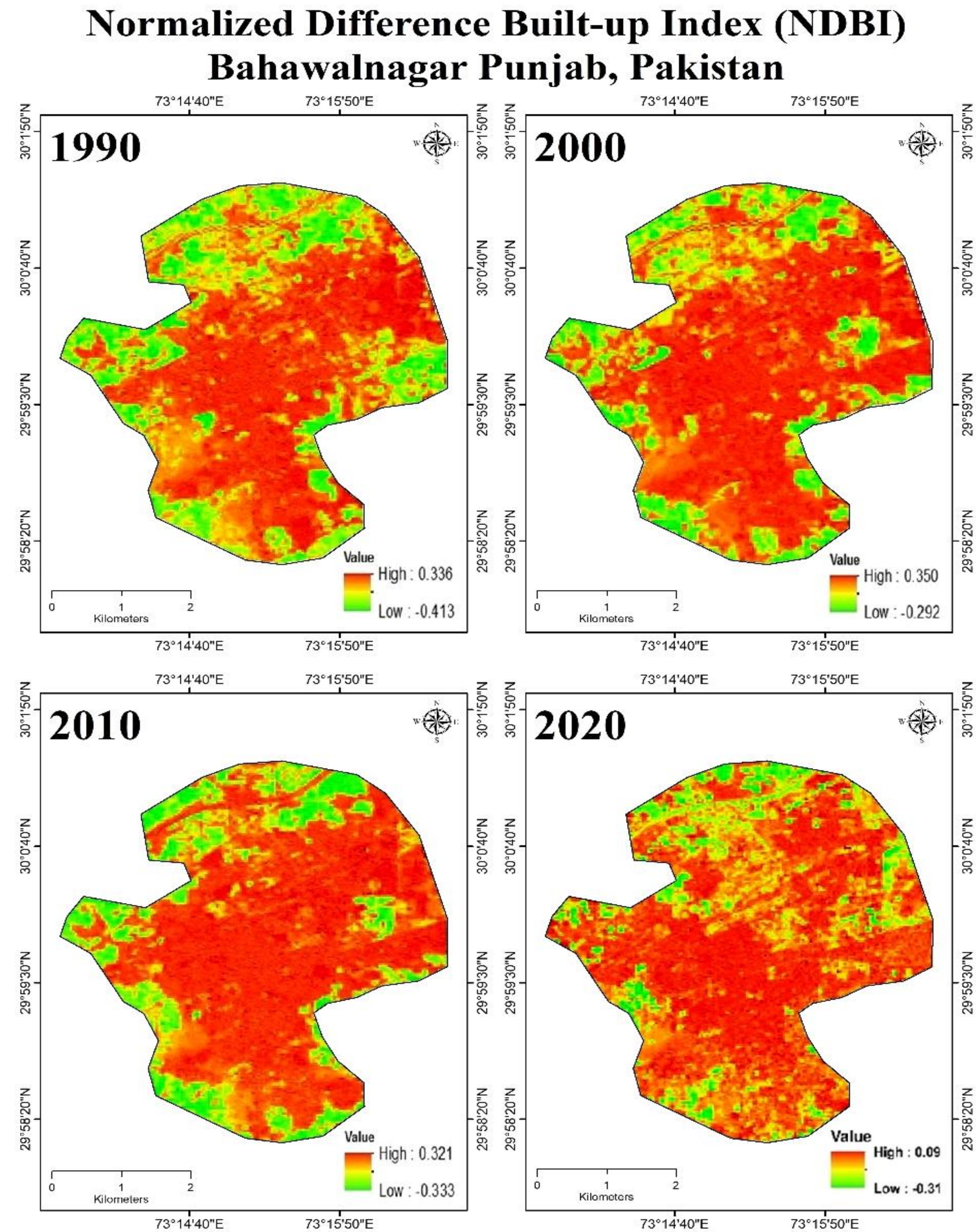

Figure 5: Pattern of the built-up area of Bahawalnagar in 1990, 2000, 2010 and 2020

DISCUSSION

The major goal of this study was to determine changes in LULC patterns and to investigate urban development phenomena in Bahawalnagar over 30 years. The findings indicated that the study had undergone significant changes, particularly in the urban built-up region, as a result of expanding urban population and construction programmes to support the growing population. C. (Chadchan & Shankar, 2012) in their study concluded that the urbanisation in India has taken place at a much unparalleled rate during last few decades, most importantly after the 1990's economic reforms. According to the findings of spatial and non-spatial studies of forest area changes, LULC has been influenced by various causes during the time, Monadal and Debinath (2017). The results of this study highlight several important findings regarding land use change and climate change in Bahawalnagar from 1990-2020. The analysis shows that built-up area has steadily increased over time, from 43.95% of total land area in 1990 to 63.99% in 2020. This rapid expansion of urban development has mainly occurred at the expense of agricultural and open land, as well as water bodies. Land is a vital and natural resource that humans may utilize for a variety of reasons; as a result, population growth dynamics can influence the pattern of land use in a given location (Nelson *et al*., 2010).

The growth of built-up area corresponds with increasing temperatures and declining rainfall over the study period. Average annual temperatures have risen by over 15°C from 1990 to 2020, while rainfall has fallen by more than 50%. These climatic changes appear to be driving land use conversion, as hotter and drier conditions make agriculture more challenging, leading to abandonment of croplands which are then utilized for construction.

The declines in vegetation cover revealed by the NDVI analysis provide further evidence of this effect. The NDVI is a useful vegetation indicator because it is steady enough to allow detailed comparisons of seasonal and inter-annual variations in plant growth and activity (Ahmed, 2012). NDVI values decreased between 1990 and 2020, indicating loss of greenness and photosynthetic activity. This aligns with the observed contraction in agricultural land area detected through image classification. Rising temperatures likely increased crop water demand while decreasing water availability, resulting in lower yields and ultimately cropland abandonment.

In addition to climate factors, population growth has been a major driver of built-up area expansion in Bahawalnagar. As the population has increased, demand for residential and commercial real estate has risen exponentially. Developers have targeted open spaces and agricultural lands to meet this demand. Weak zoning laws and land use planning have allowed uncontrolled urban sprawl.

The loss of open and agricultural land has multiple environmental consequences beyond loss of food production capacity. Previous studies such as Chen *et al*. (2014), Dutta (2012), Kleeman *et al*. (2017), have also suggested that change in land use pattern in any areas mostly occurs at the cost of vegetation or barren land. It has been noticed that the agriculture land conversion is one of the major land use change which takes place as a result of urbanisation (Mohan *et al*., 2011). Soil erosion is expected to increase due to vegetation removal, leading to greater dust storms, reduced soil fertility, and sedimentation of water bodies. Biodiversity will decline from habitat loss and fragmentation. Higher runoff levels as a result of increased impervious surfaces will amplify flood risks during extreme rainfall events. As Bahawalnagar continues to urbanize, adaptation measures will be needed to enhance resilience to climatic and hydrological changes. By using multi digital satellite, the study presented imagery analysis of LULC and the change (H.Gonca Coskun *et al*., 2008). In summary, the results provide clear evidence that land use changes in Bahawalnagar over the past 30 years have been driven largely by climate factors and population growth. The expansion of built-up area has come at the expense of agricultural land, open space, and crucial water resources.

Conclusion: The basic aim of this study was to research and investigates the change in landscape occurring in Bahawalnagar City during the years 1990-2020 due to climate change. As a result of the study area, the temperature of the city changes because the area loses its capacity. The agricultural area was reduced at 28.89%, which is almost 4.35 percent less than in 2010. The built-up area was more increased and reached 63.99%. Open land was 19.52% in 1990 while it reduced and become 0.94 percent in 2020 an enormous change occurs in this land. From 1990 to 2020 water bodies reduced to 2.8%. In general, we notice a difference between farming and construction area, which is seen both in the pictures and in people's perception. These changes are caused by climate change. All classes of land use for the pattern identification were exclusively produced for each research. It was more suggested that in the coming years, the future change is to go behind the same pattern just as in the past. Targeted land use planning and climate adaptation policies are urgently required to guide sustainable urban development while supporting vulnerable rural livelihoods. Findings from this study can inform policy decisions regarding zoning, infrastructure siting, and disaster risk reduction. Further analyses should investigate specific local level adaptations and mitigation strategies.

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