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Spatiotemporal Variation in Land Use Land Cover in the Response to Local Climate Change Using Multispectral Remote Sensing Data

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Citation: Hussain, S.; Lu, L.; Mubeen, M.; Nasim, W.; Karuppannan, S.; Fahad, S.; Tariq, A.; Mousa, B.G.; Mumtaz, F.; Aslam, M. Spatiotemporal Variation in Land Use Land Cover in the Response to Local Climate Change Using Multispectral Remote Sensing Data. *Land* **2022**, *11*, 595. https://doi.org/10.3390/land11050595

Academic Editors: Baojie He, Ayyoob Sharifi, Chi Feng and Jun Yang

Received: 25 March 2022
Accepted: 17 April 2022
Published: 19 April 2022

Abstract: Climate change is likely to have serious social, economic, and environmental impacts on farmers whose subsistence depends on nature. Land Use Land Cover (LULC) changes were examined as a significant tool for assessing changes at diverse temporal and spatial scales. Normalized Difference Vegetation Index (NDVI) has the potential ability to signify the vegetation structures of various eco-regions and provide valuable information as a remote sensing tool in studying vegetation phenology cycles. In this study, we used remote sensing and Geographical Information System (GIS) techniques with Maximum Likelihood Classification (MLC) to identify the LULC changes for 40 years in the Sahiwal District. Later, we conducted 120 questionnaires administered to local farmers which were used to correlate climate changes with NDVI. The LULC maps were prepared using MLC and training sites for the years 1981, 2001, and 2021. Regression analysis (R^2) was performed to identify the relationship between temperature and vegetation cover (NDVI) in the study area. Results indicate that the build-up area was increased from 7203.76 ha (2.25%) to 31,081.3 ha (9.70%), while the vegetation area decreased by 14,427.1 ha (4.5%) from 1981 to 2021 in Sahiwal District. The mean NDVI values showed that overall NDVI values decreased from 0.24 to 0.20 from 1981 to 2021. Almost 78% of farmers stated that the climate has been changing during the last few years, 72% of farmers stated that climate change had affected agriculture, and 53% of farmers thought that rainfall intensity had also decreased. The R^2 tendency showed that temperature and NDVI were negatively connected to each other. This study will integrate and apply the best and most suitable methods, tools, and approaches for equitable local adaptation and governance of agricultural systems in changing climate conditions. Therefore, this research outcome will also meaningfully help policymakers and urban planners for sustainable LULC management and strategies at the local level.

Keywords: Land Use Land Cover (LULC); Maximum Likelihood Classification (MLC); Climate change; NDVI; Remote sensing and GIS

1. Introduction

Climate change, with changing temperature and precipitation levels, has mostly affected Land Use Land Cover (LULC) throughout the whole world [1–3]. The LULC changes are useful for visualizing and analyzing the effect of various development pathways and helping decision-makers formulate scientific strategies [4,5] and implement plausible policies that conserve natural resources and provide ecosystem services [6–8]. The LULC impacts sustainable ecosystem services, which are becoming increasingly significant problems in the world [9,10]. The LULC direct relationship with the Earth's primary features and procedures, for example, land degradation and productivity, water cycle, and ecological environments, are the foremost concern [11]. The LULC changes were examined as a significant tool for assessing changes in the world at various temporal and spatial scales [5]. It is an extensive, quick, and symbolic process directed by anthropogenic activities, and in several cases, humans are affected by these changes [12]. The anthropogenic activity also seems to conduct extreme changes in the existing state of the Earth's surface [13]. The LULC changes increased the interaction of resources, governmental doubts, and societies to global warming and socioeconomic disasters via decreasing ecology facilities [14–16].

With the Normalized Difference Vegetation Index (NDVI), the possibility of understanding the crop phenology escalates as it explains the crop chronology and its relationship with weather and climate [17,18]. The NDVI was measured using a mathematical calculation of spectral bands within the satellite image, which measures the healthiness of vegetation, as it has a robust correlation with green biomass, indicating healthy vegetation or crop [14,19]. The NDVI relates spectral information of the red color and near-infrared, generating a variable to estimate vegetation's quantity, quality, and development [20]. The NDVI is highly used in environmental and vegetation studies; now, high-resolution satellites are available to derive the NDVI at regional [21] and global scales such as Landsat series, Sentinel series, and multiple on-board sensors [22,23]. The climate is an important factor that negatively influences vegetation dynamics recently, and many research publications have described the relationship between Land Surface Temperature (LST) and NDVI [17,18,24].

Remote Sensing and GIS combined location data with both quantitative and qualitative information about the location, allowing you to visualize, analyze, and report information through maps and charts [12,13,25,26]. Using this technology, we can answer questions, conduct what-if scenarios, and visualize results. The remote sensing and GIS were identified as systems used to manage infrastructure assets, natural resources, and any objects as per requirement [25,27–29]. Remote sensing has been used to categorize and map LULC changes with various data sets and techniques [30]. Landsat images have assisted a huge arrangement in image classification of various land elements at a higher scale [31–33]. Landsat images by the use of sensors including a Thematic Mapper (TM), Enhanced TM Plus (ETM+), and Operational Land Imager (OLI) were used to assess the LULC changes as well as NDVI [34–36]. Remote sensing has become essential for changes in vegetation monitoring, as it delivers efficient satellite information about vegetation cover and LST changes [37]. Between the various remote sensing sensors, Landsat offers related resources for calculating vegetation degradation (e.g., modifications and conversions of natural vegetation). It is easier to analyze and manage facility and asset data stored in GIS, making design, construction, and maintenance more efficient and profitable [32].

Climate change is also the main challenge for rural livelihoods, agriculture, and food security for millions of people in Pakistan [38–40]. Disappointingly, the deterioration of ecosystems due to climate change in Punjab is deliberated as a serious problem and has a significant negative impact on the economy [33,41]. In Sahiwal District, agriculture is very significant to the local economy. However, during the last few years, main crops have decreased due to urbanization in Punjab, including Sahiwal District. Intense agricultural activities are engaging industries that increase migrations of people towards the Sahiwal District. The increasing population is now putting drastic effects on agriculture as build-up area is increasing for meeting the necessities of human livelihood [42]. Sahiwal District is the 21st largest city of Pakistan by population and has faced environmental and climate change during the last few years. Therefore, it is necessary to study the impact of climate change on agriculture and various land cover in the Sahiwal District. This research mainly examined spatial pattern analysis of LULC changes, which refers to the process of increasing focus on population and some drastic effects of climate variability on the socioeconomic conditions of rural and local community in the Sahiwal District. So, the important objectives of this research were:

(1) To study the farmers' perception of climate change and LULC in the study area.
(2) To analyze the LULC and NDVI changes in Sahiwal District, Punjab, Pakistan, using remote sensing techniques.
(3) To analyze the relationship between NDVI and climate change (temperature and rainfall) in Sahiwal District.

2. Material and Method

2.1. Study Area

The study area was conducted in the Sahiwal District of Punjab, Pakistan, showed in Figure 1. It lies approximately between 30.0442° to 30.6682° N and 72.3441° to 73.1114° E [43,44]. The Sahiwal District comprises two subdistricts, namely Chichawatni and Sahiwal City. The Sahiwal District is also famous for its breed and cattle of buffaloes. This area is irrigated by the water from the rivers Ravi and Sutlej. The major crops of this area are wheat, rice, cotton, sugarcane, and fodder. Geologically, it is composed of fertile land with semiarid conditions where May, June, and July are the hottest months, with average temperatures ranging from 38 °C to 48 °C with occasional extreme temperatures of 55 °C. The coldest months are December and January, with an average lowest temperature ranging from 5 °C to 22 °C. It has intense agriculture and some natural forest reserves with (150 to 300 mm) of annual rainfall [43,45].

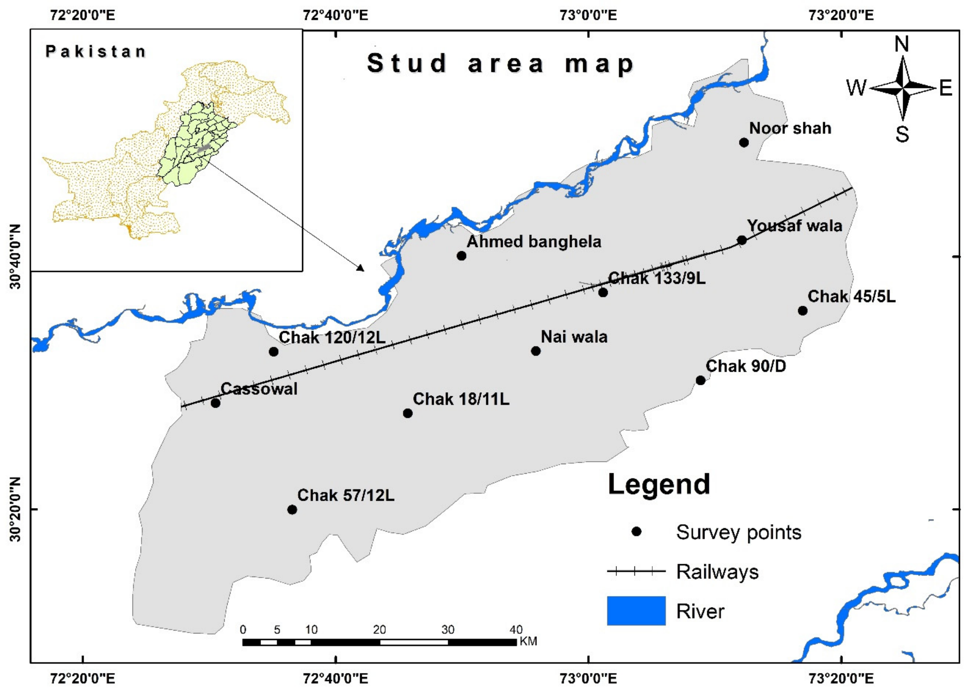

Figure 1. Study area map of the Sahiwal District.

2.2. Field Survey

The survey was conducted in 120 locations within the whole study area. Moreover, a questionnaire was designed to collect information from the study area using a survey method. A questionnaire-based field survey technique was adopted, along with discussions with farmers and the collection of local information. The Global Positioning System (GPS) co-ordinates show the positioning of each village, and data related to LULC and climate change were recorded [46,47]. The GPS map camera software was used to collect and save the latitude and longitude points as well as other information from the survey. To select the survey locations, stratified random sampling was used during the survey. A total of 120 educated and experienced farmers were interviewed, which included 60 farmers from each of the sub-districts of Sahiwal. The main parameters that were addressed in the questionnaire were the adoption and application of LULC technologies at their farms. The information related to the change in vegetation cover area was recorded with the help of a preplanned questionnaire introduced to farmers' discussion during a face-to-face meeting with them. Microsoft Excel was used to analyze the survey data and make more graphs [48].

2.3. Landsat Data

Landsat-based images of 30 m $\times$ 30 m spatial resolution covering the study area were collected for the years 1981, 2001, and 2021 and downloaded from the United States Geological Survey (USGS) website (https://earthexplorer.usgs.gov/ (Last accessed on 15 February 2022) with mixed vegetation, build-up area, an agricultural area, water area, and bare surface as mapped LULC types [20,49]. For this study, images of Landsat 5, Landsat 7 (TM), and Landsat 8 (OLI) were used (Table 1).

Table 1. Specification of Landsat satellite data was used in this study.

S.No.	Satellite/Sensor	Date	Path/Row	Spatial Resolution	Spectral Resolution	Band Used
1	Landsat 4-5 (TM)	12 March 1981	149/039 150/039	30 m	Multispectral (8 bands)	1,2,3,4,5,7
2	Landsat 7 (ETM+)	25 March 2001	149/039 150/039	30 m	Multispectral (8 bands)	1,2,3,4,5,7
3	Landsat 8 (OLI/TIRS)	17 March 2021	149/039 150/039	30 m	Multispectral (11 bands)	1,2,3,4,5,6,7,9

2.4. Temperature and Rainfall Data

The previous data of minimum and maximum temperature and rainfall of 40 survey points of Sahiwal District was attained from the website of *National Aeronautics and Space Administration* (NASA) (http://power.larc.nasa.gov) (Last accessed on 21 December 2021). Maximum and minimum temperature and precipitation data of 40 years (1981 to 2021) for all survey points were taken in the study area. The 40-year data sequence for all the survey points was analyzed by running a test at a 95% significance level to check the homogeneity of the data [44,50].

2.5. Land Use Land Cover (LULC) and Accuracy Assessment

Landsat 5 and 7 images contain eight spectral bands. In this study, bands one to five and seven were used to assess the LULC. Band six is a thermal band used for LST change analysis [51,52]. In Landsat 8, we used band two to band nine for LULC changes [53]. Satellite images were imported using ArcGIS software (version 10.8) for processing and analysis from various years. First, image analysis and processing, image clipping and composite, and atmospheric correction and rectification of the image were carried out with ERDAS imagine software. Second, Landsat images were preprocessed in ERDAS imagine 2015 for layer stacking (stacking is the method used to produce a multiband image from discrete bands.), mosaicking (to combine the two stacked images), and subsetting (after stacking, the study area was extracted) of the image based on Area of Interest (AOI) [51,54]. All satellite data were studied by assigning per-pixel signatures [32]. The LULC maps were prepared using the supervised classification Maximum Likelihood Classification (MLC) and training site selections for the years 1981, 2001, and 2021. Training sites were determined, and spectral signature files of selected LULC classes such as vegetation, build-up area, bare soil, and bodies of waterbodies of water (Table 2) were created for uses in the classifications using ERDAS imagine software. The classified images were compared with ground truthing (field visit) of the study area. For each of the predetermined LULC types, training samples were selected by delimiting polygons around representative sites [54,55]. Spectral signatures for the respective land cover types derived from the satellite imagery were recorded by using the pixels enclosed by these polygons [8,9,33].

Table 2. Detail description of Land Use Land Cover (LULC) classes.

LULC Types	LULC Description
Vegetation area	Agricultural lands, forest, Crop fields, vegetated lands, parks, etc.
Build-up area	Commercial, and residential buildings, and road systems.
Water bodies	River, lakes, low lying lands, canals, marshy lands, ponds, swamps, etc.
Bare soil	Open land, unused and empty areas, fallow areas, bare soil, and others.

For accuracy assessment, ERDAS imagine software was used to compare the pixels of the supervised image with reference pixels for the given classes. Accuracy assessment was completed using satellite imageries with a Stratified Randomization Technique (SRT) to show several LULC classes in the study area [56,57]. It was performed by using 120 points for each class, constructed from visual interpretation and data based on ground-truthing. Error matrices accomplished statistical evaluations of classification results and reference data. Error matrix is the general and common tool to present accuracy assessment. Finally, the usual statistical accuracy comparison was made with general accuracy [57].

2.6. Estimation of NDVI

The NDVI data were used to assist in identifying various vegetation stages' dates during seasons. Software ERDAS Imagine 2015 was applied to identify NDVI and their change analyses based on vegetation. Software Arc GIS 10.8 was used for preparing NDVI maps [18].

$$\mathrm{NDVI} = \frac{NIR - RED}{NIR + RED}$$

RED is the reflectance in the red band of the spectrum and *NIR* is the reflectance in the near-infrared band in a spectrum [58,59]. Detailed description of methodology is presented in Figure 2.

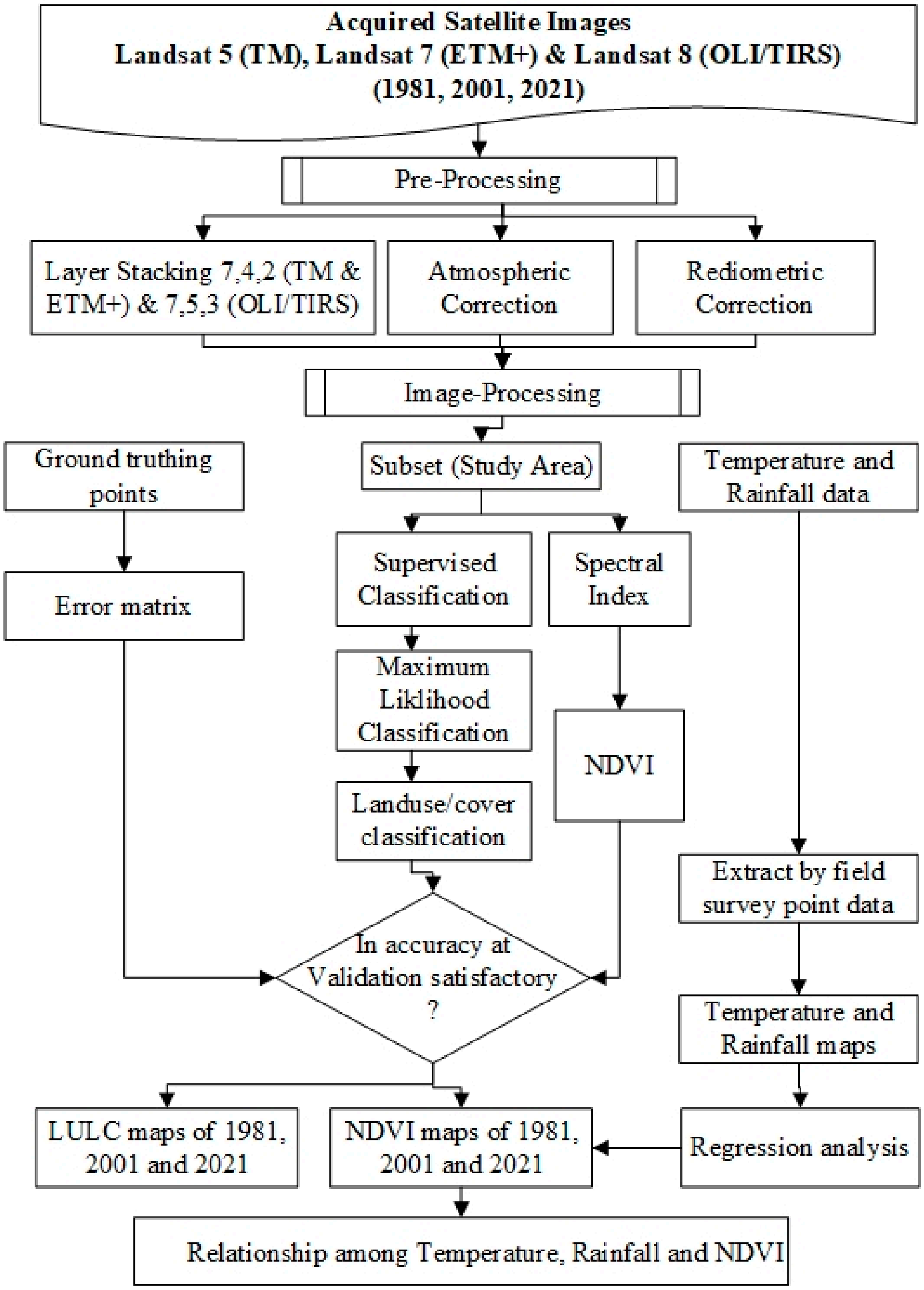

Figure 2. Flow chart for methodology.

3. Results

3.1. Perceptions of Farmers about Climate Change and LULC

A questionnaire was designed to find out the awareness level of farmers about climate change, the farmers' responses regarding the effect of climate change on agricultural practices, and which mitigation strategies are followed by farmers [6,60]. For this purpose, the questionnaire was divided into a number of sections, and the results of each section are described one by one in the study area. According to farmer response regarding climate change variables, the majority of respondents' report that the climate is changing and that it also influences agriculture. According to Table 3, most respondents, 78%, considered the climate is changing, 72% farmers observed climate change effecting the agricultural practices, and 53% of farmers thought that rainfall intensity had also decreased (Figure 3).

Approximate 48% of respondents reported that the cutting of the trees is the main reason behind the increase in temperature and climate change. Additionally, 69% of farmers predicted that in the future, climate change will be a great risk for the agricultural sector in Sahiwal District.

Table 3. Perceptions of farmers about climate change information and awareness.

Statement	Agree	Disagree	Not Sure	Do Not Know
Climate is changing	78%	7%	6%	9%
Climate change is effecting the agriculture	72%	2%	12%	6%
Deforestation is the main reason for climate change	53%	23%	12%	12%
Climate change will be a big challenge in future	69%	6%	15%	10%

The vast majority of farmers, 64%, stated that crop production is decreasing due to an increase in temperature. About 78% of respondents reported that the demand for irrigation increased due to climate change (Table 4). Regarding the irrigation method, most farmers used tube-well and canal-system irrigation (78%), with the remaining few farmers depending on rainfall for irrigation in Sahiwal District. More than half of the interviewees stated that they changed the crop sowing dates due to climatic variations, and 52% of respondents stated that the demand for fertilizer increased. Most of the farmers (54%), perceive that water availability for irrigation decreased with the passage of time due to climate change (Figure 3). About 62% of respondents mentioned that climatic variations, especially variations in rainfall and temperature, are the major reason behind the increase in insect and pest attack. Food prices have increased overall the world, and 86% of respondents agree food prices increased due to climate change. Figure 4 shows that more than half of farmers (50–60%) used the canal water for irrigation, and about 20–30% of farmers are dependent on the tub-well water in the study area.

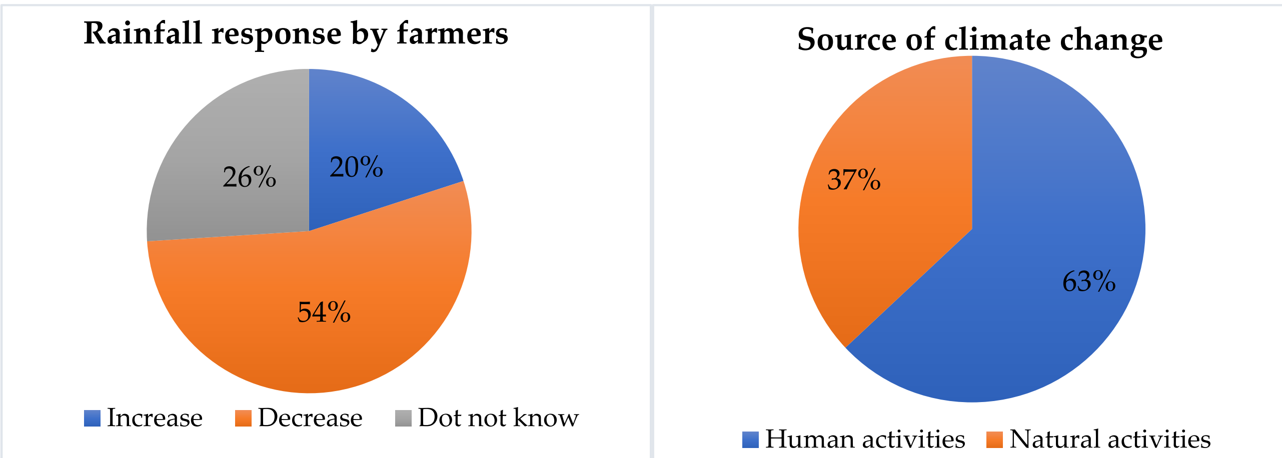

Figure 3. Perceptions of farmers about the reason for climate change and rainfall.

Table 4. Perceptions of farmers about risk due to climate change.

Statement	Agree	Disagree	Not Sure	Do Not Know
Increase in temperature reduced crop production	64%	12%	16%	8%
Demand of water increased for irrigation	78%	6%	12%	4%
You are dependent on rainfall water for irrigation	8%	84%	8%	0%
Water availability for irrigation decreased due to climate change	72%	14%	10%	4%
Time of crop sowing is changed due to climate change	52%	18%	14%	16%
Food prices increased due to climate change	86%	6%	8%	0%

3.2. LULC Changes

The analysis of LULC classification of the Sahiwal District was performed in 1981, 2001, and 2021, and the area was enclosed with different land features (vegetation area, build-up area, water bodies, and bare soil). The LULC classification was engaged along with a reconnaissance survey and GIS in addition to additional data for the study area of Sahiwal District. The "build-up area" was increased 7203.76 ha (2.25%) to 16,653.81 ha (5.20%) from 1981 to 2001 respectively. Moreover, in 2021, the build-up area was increased 31,081.3 ha (9.70%) in the study area (Table 5). However, there was a large increase in the "build-up area" from 1981 to 2021, raising by 23,877.54 ha (7.45%). In 1981, the overall population of Sahiwal was 1.28 million, which has increased to 2.51 million in 2017, which is showing the increase of more than 1.23 million residents in the Sahiwal District, which has caused the expansion of the urban areas (Table 6).

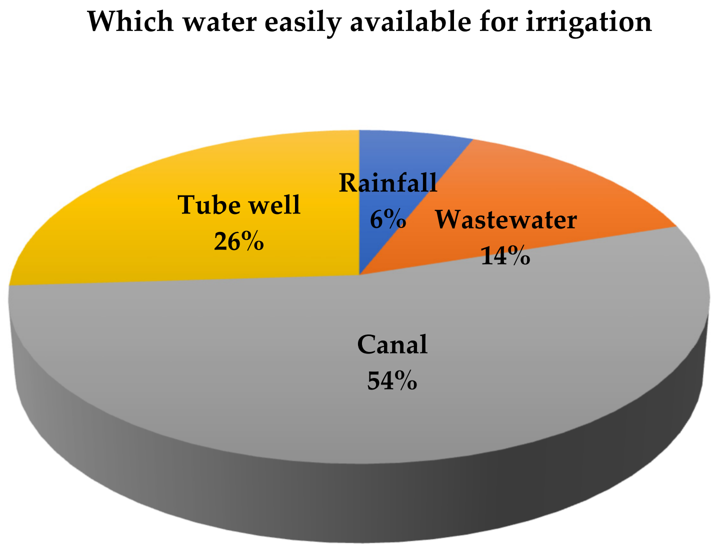

Figure 4. Availability of water for irrigation.

Table 5. Area of LULC classes for the years 1981, 2001, and 2021.

LULC Classes	1981		2001		2021		Change 1981 to 2021	
	Ha	%	Ha	%	Ha	%	Ha	%
Vegetation area	293,282.18	91.57	290,096.44	90.58	278,855.1	87.07	−14,427.1	−4.50
Build-up-area	7203.76	2.25	16,653.81	5.20	31,081.3	9.70	23,877.54	7.45
Bare soil	15,676.85	4.89	10,286.34	3.21	7701.5	2.40	−7975.35	−2.49
Water bodies	4118.12	1.29	3244.32	1.013	2643.01	0.83	−1475.11	−0.46
Total	320,280.91	100	320,280.91	100	320,280.91	100	0	0

Table 6. Census of Sahiwal District from 1981 to 2017.

Census	Urban	Rural	Total	Urban Ratio	Rural Ratio
1981	201,195	1,080,331	1,281,526	15.70%	84.30%
1998	301,990	1,541,204	1,843,194	16.38%	83.62%
2017	517,120	2,000,440	2,517,560	20.54%	79.46%
Change 1981–2017	315,925	920,109	1,236,034	4.84	–4.84

Vegetation area covered 91.57%, 90.58%, and 87.07% of total land area during the years 1981, 2001, and 2021, respectively, in Sahiwal District. Although 'vegetation area' had decreased between 1981 to 2021, there appears to be a negative change in "vegetation" (a decrease of 4.50%) in the study area. The next class of water bodies has consisted of 4118.12 ha 1.29% in 1981, but water bodies decreased by 2643.01 ha (0.83%) between 1981 to 2021 (Figure 5). It was observed that during 40 years, vegetation area and bare soil have changed to roads and build-up areas. In 1981, a 15,676.85 ha (4.893%) area was covered by bare soil, which was reduced to 7701.5 ha (2.40%) in 2021. It has been found that 'bare soil' decreased during the last few years. Sahiwal District is growing day by day not only for vegetation growth but also for a large number of people from the rural areas and further small urban areas.

3.3. Accuracy Assessment

Detail of producers' accuracy and users' accuracy as well as KHAT (k) values for different LULC classes for the years 1981, 2001, and 2021, are shown in Table 7. Average producers and users accuracies were 86.15% and 85.45% for 1981, 88.12%, and 87.37% for 2001, and 86.32% and 86.07% for 2021, respectively. The highest and lowest producers' and users' accuracy values observed for the 'build-up area' were in the range of 85.3% to 84.4% and 90.8% to 83.7%, respectively. Similarly, the highest and lowest producers' accuracy as well as users' accuracy values observed for 'vegetation area' were 87.1% to 83.3% and 91.3% to 84.3% for the study duration. Overall classification accuracy for the studied years was also reasonable (85.45% to 87.0%) (Table 7). Overall accuracy was observed at 85.45%, 86.5%, and 87% for the years 1981, 2001, and 2021, respectively, in the study area. Similarly, K values were observed at 80.7%, 82%, and 85.3% for the years 1981, 2001, and 2021, respectively, in Sahiwal District. In our results, the two accuracies were in a fairly good range, which showed less error in classification.

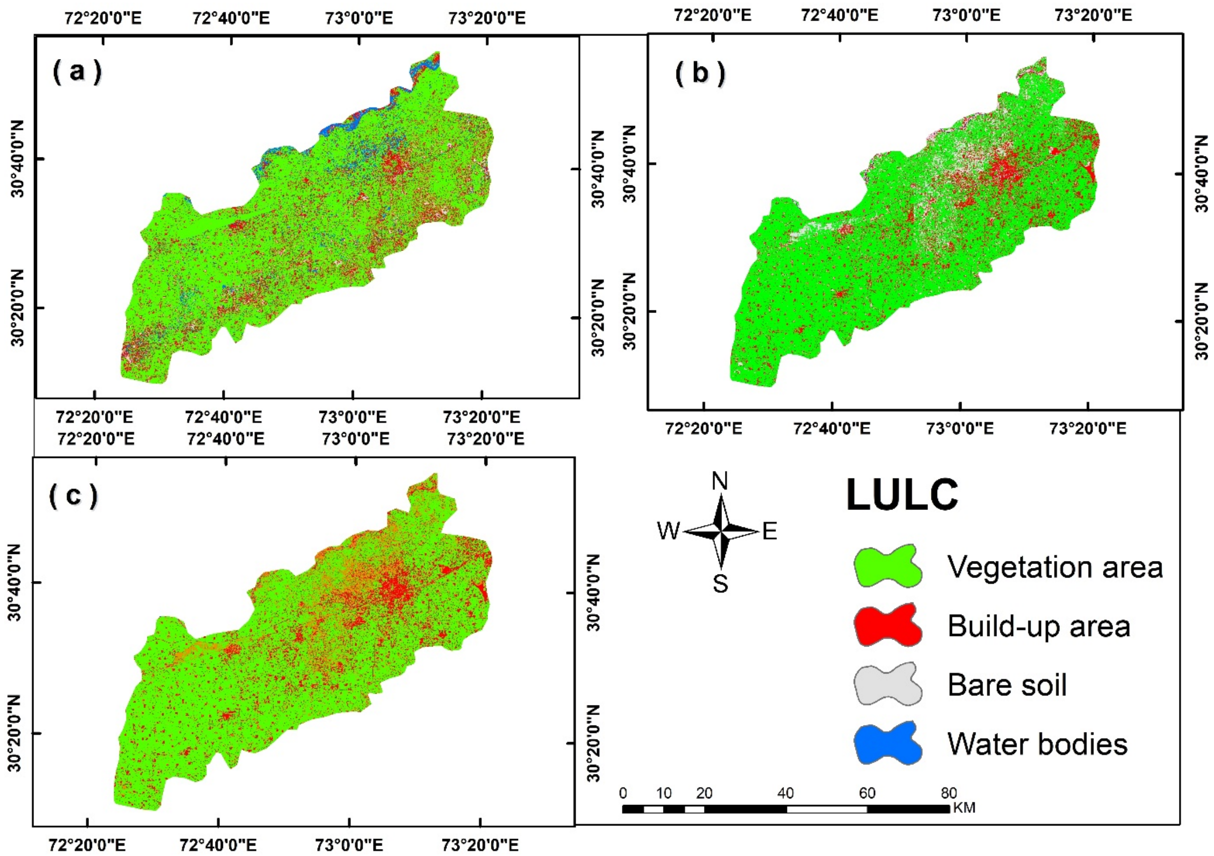

Figure 5. LULC maps for the years (**a**) 1981, (**b**) 2001, and (**c**) 2021 of the Sahiwal District.

Table 7. Summary of producers' and users' accuracy and kappa (K) coefficients in Sahiwal District.

LULC Types	1981				2001				2021			
	PA	UA	OA	K	PA	UA	OA	K	PA	UA	OA	K
Vegetation area	87.1	86.5	85.3	80.7	86.7	91.3	86.5	82.0	83.3	84.3	87.0	85.3
Build-up area	84.4	83.7			85.0	88.1			85.3	90.8		
Bare soil	86.7	86.5			87.5	88.7			84.7	84.8		
Water bodies	86.4	85.1			93.3	81.4			92.0	84.4		

Note; PA = Producers' Accuracy; UA = Users' Accuracy; OA = Overall Accuracy; K = Kappa Coefficient.

3.4. Normalized Difference Vegetation Index

The analysis of vegetation parameters such as NDVI using satellite images is based on the spectral properties of vegetation [61,62]. Vegetation absorbs visible light, uses energy for photosynthesis, and strongly reflects NIR. Different Landsat bands were calculated to estimate the amount of vegetation in LULC based on the vegetative index. ERDAS Imagine 2015 is used to identify vegetation cover (NDVI) in the study area for the years 1981, 2001, and 2021. Arc GIS 10.8 was used for mapping identification of NDVI values as well as the area of LULC classes. On average, from 1981 to 2021, the NDVI max values decreased from 0.77 to 0.57, and NDVI min values also decreased from −0.28 to −0.17, and the mean values show that overall NDVI values from 1981 to 2021 decreased from 0.24 to 0.20 (Figure 6). The overall study area has faced a decrease in vegetation cover (NDVI) in the study area. In 1981, the maximum NDVI value was 0.77, which shows that vegetation cover (crops, grassland, shrubs, and forests) was maximum and that this area has forests, and the minimum NDVI value is −0.28, which shows that Sahiwal District has a sufficient amount of water bodies. In 2001, the maximum NDVI value was 0.69, which shows that vegetation cover is maximum, and the least NDVI value is −0.23, which shows enough water bodies and bare soil (Table 8).

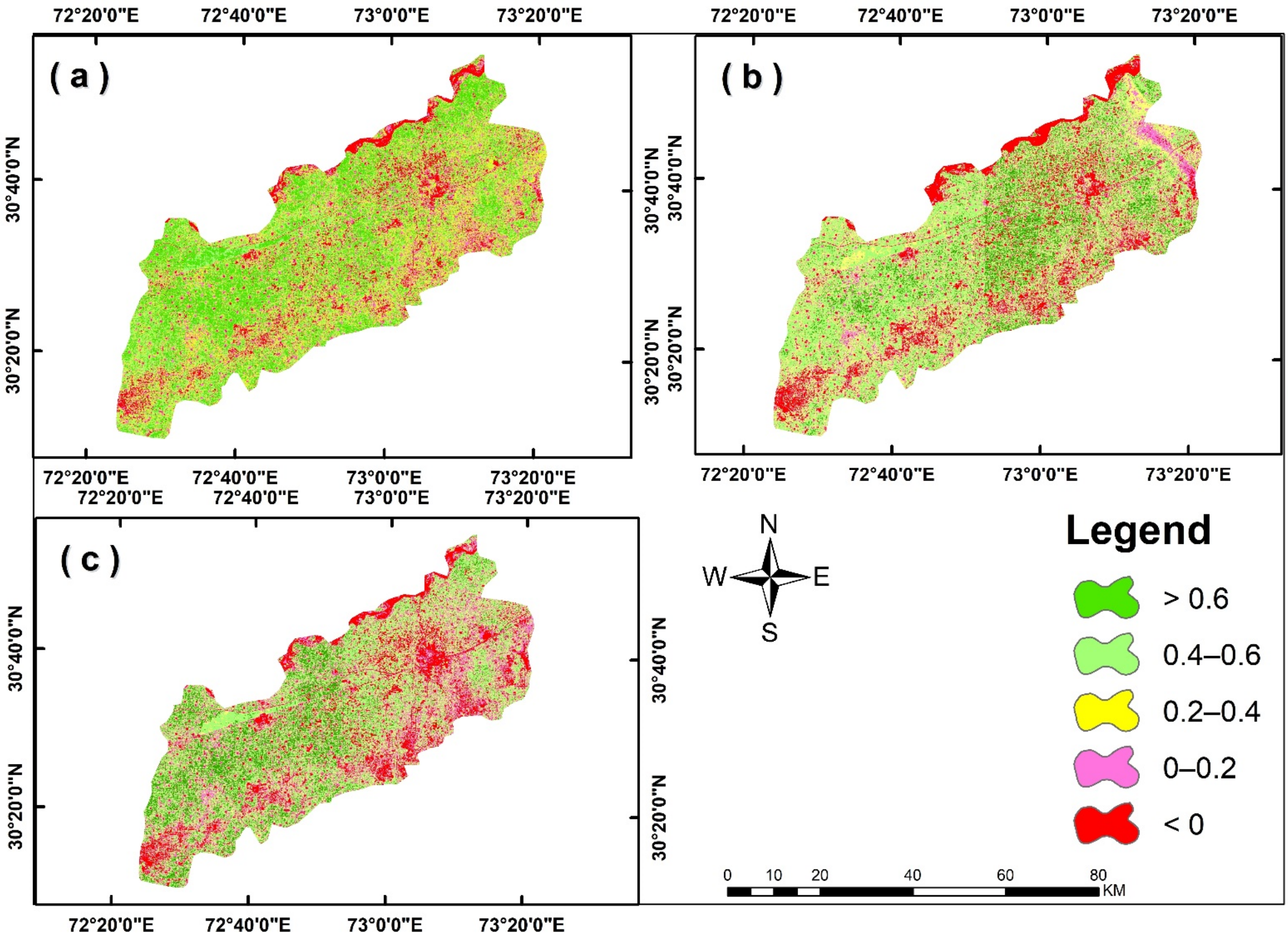

Figure 6. NDVI maps for the years (**a**) 1981, (**b**) 2001, and (**c**) 2021 of the Sahiwal District.

Table 8. Maximum and minimum temperature and NDVI values for the year from 1981 to 2021.

Years	NDVI				Temperature			
	Min	Max	Average	SD	Min	Max	Average	SD
1981	–0.28	0.77	0.245	8.7	9.2	44.8	27	5.2
2001	–0.23	0.69	0.23	8.04	9.7	45.1	27.4	5.56
2021	–0.17	0.57	0.2	7.8	10.3	45.5	27.9	6.05

In 2021, the maximum NDVI value was 0.57, which is the same as the previous year and has a sufficient amount of vegetation cover, and the minimum NDVI value was −0.17, which shows the bare soil in this area, as vegetation is much less in this year, and it receives less rainfall, which means it has less water. In 2021, NDVI values decreased more than in last 40 years, and now its value is 0.05, which demonstrates a large decrease from 1981 to 2021 in the study area. Overall, the average NDVI value of the study area showed that it has heavy vegetation cover and enough water bodies with a much lower amount of bare soil and water bodies. Higher NDVI values showed the productive and most productive areas, such as vegetation and forest, in the study area. Similarly, lower values of NDVI showed that there are less and least productive areas, such as build-up areas, water bodies, and bare soil. So, the model indicated a major decrease in production areas in the study area. Overall, the NDVI value is higher in croplands than in bare soil, and therefore, the enlarged cropland and forest reserves may have contributed to the satellite-observed greenness of vegetation in the study area. It was noted that there was a large NDVI-value change in 2021 compared to 1981.

3.5. Climate Factor of the Study Area

The temperature and rainfall data were collected from National Aeronautics and Space Administration (NASA) and corelate with field survey according to coordinates field surveys and transferred in the software Arc GIS 10.8. Next, an IDW tool was used for interpolation of the spatial map of rainfall and temperature. Figure 7 represents the average temperature maps of the Sahiwal District. The low temperature was noted at 27 °C, as was the high-temperature rise to 27.89 °C (Figure 7). It is clearly understood that three survey points such as Yousaf Wala, Chak 133/9 L, and Nai Wala were calculated as minimum temperatures in Sahiwal District. Similarly, Chak 45/% L, Chak 18/11 L, and Chak 120/12 L were noted as maximum temperatures in the study area. The average temperature was noted as 27.38 °C to 27.51 °C at Ahmed Banghela during 1981 to 2021 in Sahiwal District. We observed that average temperature values increased from 27.6 to 28.5 °C during the last few years due to an increasing build-up area. Our study observed that maximum temperature was observed in the build-up-area, and minimum temperature was noted in vegetation areas and water bodies (Figure 7a). The rainfall trend showed the average minimum and maximum rainfall in Sahiwal District from 1981 to 2021 (Figure 7b). The minimum rainfall value was observed at 39.57 mm, and the maximum rainfall rises to 87.32 mm. It is clearly observed that Chak 45/5 L, Chak 133/9 L, and Noor Shah noted minimum rainfall in the study area. Similarly, Yousaf Wala and Chak 18/11 L were calculated to have maximum rainfall in Sahiwal District. Average rainfall was observed from 59.04 mm to 65.22 mm at Chak 57/12 L from 1981 to 2021 in the study area.

3.6. Relationship between NDVI and Climate Factors

In the past, worldwide change in the atmosphere has affected vegetation cover [8]. Between different climatic components, rainfall and temperature were increasingly connected with LULC. To identify the relationship between temperature and vegetation cover (NDVI) in the study area, regression analysis (R^2) was performed. The regression R^2 tendency showed that temperature and NDVI were negatively connected. In the present study, regression coefficients (R^2) 0.21, 0.06 and 0.05 were noted in 1981, 2001, and 2021, respectively, while rainfall showed postive corelation with NDVI 0.84, 0.80 and 0.77 from 1981 to 2021 (Figure 8). Regression analysis showed that NDVI must decrease in the study area in such areas where temperature increases. The analysis showed that the temperature in the built-up area was higher than the temperature covered by vegetation and other land than the temperature covered by vegetation and other land features. Assessment and evaluation of the urban environment require information and knowledge about surface temperature. Increased comfort adversely affects the rapid increase in surface temperature in the study area. Our outcome also suggested that the cumulative temperature in the growing season had a dominant effect on the vegetation dynamics. These changes resulted in an increase in the LULC changes and temperature values.

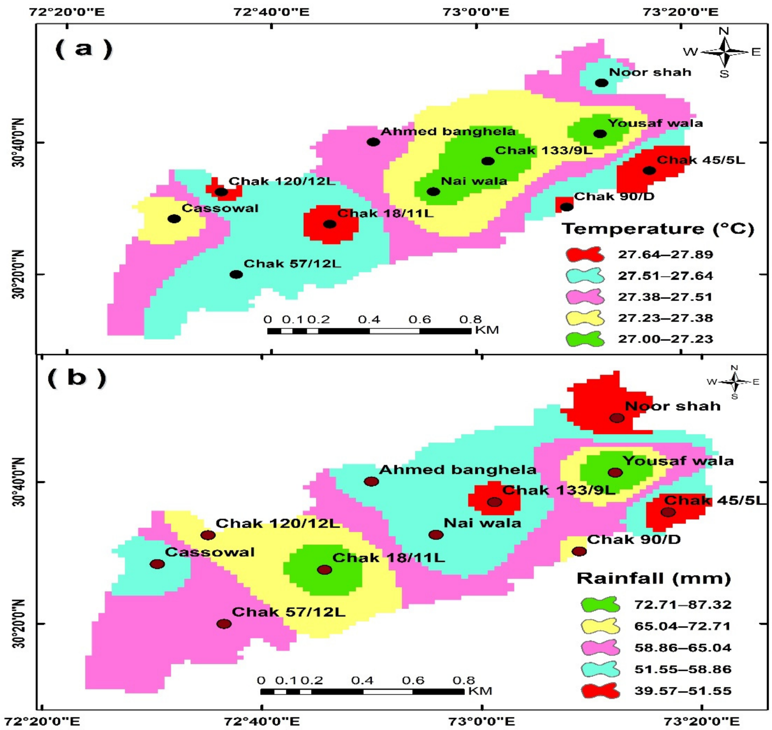

Figure 7. (**a**)Average temperature and (**b**) rainfall maps of the Sahiwal district from 1981 to 2021 by survey points.

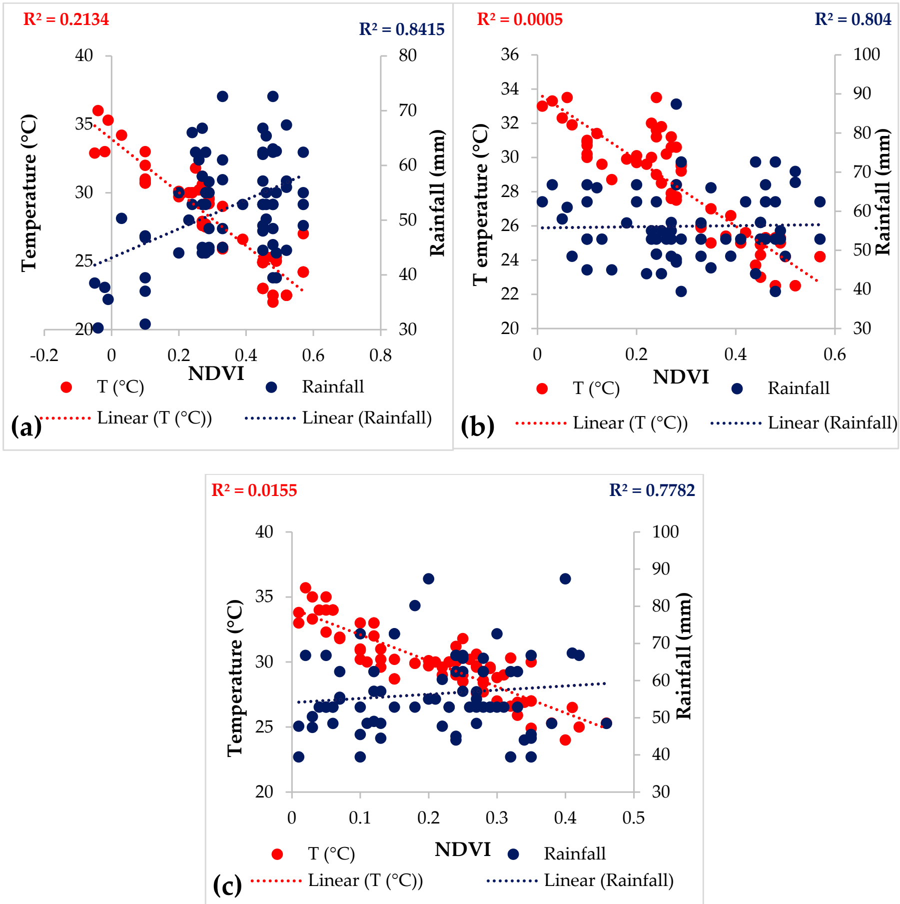

Figure 8. Relationship of temperature rainfall and NDVI of the Sahiwal District, (**a**) 1981, (**b**) 2001, and (**c**) 2021.

4. Discussion

This study explored the influence of climate change on the natural resources of the Sahiwal District during the period of 1981 to 2021. We used multitemporal remote sensing data to classify the LULC classes which are most vulnerable to environmental changes in the study area. This method plays an important role in better understanding the dynamics of LULC and environmental changes. According to Fazal et al. [63], urban areas have increased in previous years; however, the increase in a population was a bit less. This pattern suggests that fast expansion in an urban area in future years is projected, which would finally cause a loss in vegetation cover in Sahiwal District [64]. There is no doubt that the fast population growth in the study area had a maximum effect on LULC. The decrease in some of LULC underlines the unsafe trend that the pressure that financial globalization will have on LULC, signified by changing functionality of the study area and her importance in the biosphere. For the current administration and control of LULC, it is essential for federal and state governments to work together to train and strengthen proposers as well as associated professionals with the latest methods of remote sensing.

The finding by Mumtaz et al. [29] identified that there was a net increase in NDVI values in the Lahore City. One of the most successful methods is tracking the historical change of a vegetation index such as NDVI [4]. The development of NDVI reveals a robust relationship with the typical growth stages in natural vegetation. Jensen et al. [65] said that most respondents (85%) observed that climate change, characterized by changeability in precipitation patterns and increasing temperatures, has been happening during the last 30 years. As a response, respondents have changed farming practices, such as methods and timing of planting [27]. Our study also revealed that about 59% of respondents think rainfall is good, but 76% of respondents reported that an irrigation system is much better to fulfill the water demand for crops. Our results are also compatible with the already conducted various studies during the last few years, and it shows the reliability of our results.

According to the applicable field and sensors, carrying platform imaging spectroscopy is divided in two categories: one category is based on the aircraft and satellites platform; the other category is based on the ground platform applications such as ground remote sensing system [66]. The remote sensing techniques compact the mobility, size, and flexibility, which is used to estimate biochemical parameters, crop disease, and pest monitoring in weed and crop-weed discrimination. Both imaging spectrometers and sensor spectrometers give detailed information about plant leaves. For example, discolored spots on leaves demonstrates their nutritional stress and health condition. [30]. These spatial differences are retrieved from image spectroscopy, and spatial differences occur when chlorophyll content has various health statuses. Now, in ground-based studies, data are generated from the spectral analytical devices to retrieve information about plant leaf chlorophyll [67].

According to Zhang et al. [68], studying the relationship between LULC and the local climate is necessary to improve agricultural production. The LULC change is a significant driver of local climate change, and a changing climate can lead to changes in LULC and vegetation cover [69–71]. For example, farmers might shift from their normal crops to other crops that will have higher economic returns due to changing local climatic situations. Greater LST values had an effect on vegetation cover and water needed for irrigation [72–75]. The understanding of the relationship between LULC and the local climate is improving, but sustained scientific study is required. Our results also indicated that farmers observed temperature increase and rainfall decrease in the study area. These results showed that local farmer observations about climate change and satellite data results match each other in the Sahiwal District. The environmental authorities and government can use the results as a scientific tool to guide decision making on deforestation control and land management. From an economic standpoint, these steps can benefit the country by allowing us to develop plans and improve the quality and quantity of our agricultural production at the village level by selecting crops that will yield the highest yield within the found soil and temperature range of that village. Therefore, increases in agricultural production would improve the economy of the people, and there will be social welfare, and the country will progress by leaps and bounds [76–80]. Likewise, the sustainable management of land showed the implementation of sustainable, productive restoration practices in transformed lands and the protection of vegetation cover. The assessment of the LULC and climate-changing effects discussed in this research would support managers and policymakers through the given spatiotemporal analysis that helps incorporate basin management and development. This research will help enhance the local government's capacity to implement sound plans at the local level for the betterment of agriculture. The LULC management creates secondary fragmented forests and increases the cover of these forests, which are important for biodiversity recovery and ecosystem services.

5. Conclusions

In this research, we studied climate change's impact on LULC changes as investigated using remote sensing and GIS techniques combined with a field survey at the local level in the Sahiwal District from 1981 to 2021. Build-up area increased from 7203.76 ha (2.25%) to 31,081.3 ha (9.70%), while vegetation area decreased by 14,427.1 ha (4.5%) from 1981 to 2021. The mean values of NDVI showed that overall NDVI values from 1981 to 2021 decreased from 0.24 to 0.20. The spatial distribution of the NDVI resulted mostly in the variations of the meteorological variables such as the occurrence and intensity of the temperature. There were massive changes in the NDVI from 1981 to 2021 owing to the impact of both climate and anthropogenic influences.

As a result of these changes, we have lost biodiversity and our natural ecology. The unwanted impact of difficult ecological dynamics would be compacted by giving particular attention to recovering the affected area to protect the natural resources in the study area. Increasing the build-up area can lead to many environmental problems. An increase in agricultural production would improve the economy of the people, as well as our country, and will progress quite rapidly. Therefore, the government should make policies to provide enough land management at the district level by managing land resources and some other suitable measures. This study will also help improve the ability of the government in the study area to implement local strategies for improving agricultural production, water management, and planned urbanization at a local scale. Proper LULC policy is necessary; otherwise, we may lose our ecological resources. This study should also be used to investigate different LULC classes using other satellites, such as Sentinel and the platform of Google Earth Engine (GEE) in the future. In the future, we can also study the impact of climate change on LULC changes in the whole of Pakistan, which can be easily implemented using the proposed methodology.

Author Contributions: Conceptualization, S.H. and W.N.; methodology, S.H., A.T. and W.N. software, M.M. and S.H.; validation, S.H., A.T., B.G.M., F.M. and L.L.; formal analysis, S.H., W.N., A.T., B.G.M. and M.A.; investigation, S.H., W.N., L.L., A.T., S.K., S.F., B.G.M. and M.A.; resources, S.H., W.N., B.G.M. and A.T.; data curation, S.H., W.N., A.T. and S.K.; writing—original draft preparation, S.H., W.N., A.T. and M.M.; writing—review and editing, S.H., W.N., L.L., A.T., S.K., S.F., B.G.M. and M.A.; visualization, S.H., W.N., L.L., A.T., S.K., S.F. and M.A.; supervision, L.L. and A.T.; project administration, L.L.; funding acquisition, L.L. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by the Strategic Priority Research Program of the Chinese Academy of Sciences (grant numbers XDA19090130) and the National Natural Science Foundation of China (grant number 42071321).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The datasets used and/or analyzed during the current study are available in the article/from the corresponding author on request.

Conflicts of Interest: The authors declare no competing interest.

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