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Spatio-temporal assessment of urban growth using multi-stage satellite imageries in Faisalabad, Pakistan

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Abstract

Today, urban growth is a multidimensional spatial and temporal process. The analysis of urban growth using spatial and attribute data is regarded as one of the basic requirements of urban geographical studies, future planning as well as the establishment of political policies for urban development. The current study is an effort to spatially and temporally assess the urban growth in district Faisalabad from 1991 to 2019. Landsat images, population and registered industries data were utilized carryout spatial analysis. Supervised image classification and linear regression model has been applied to visualize the results. The result inferred from the classified images revealed that the in 1991 the total built-up area of Faisalabad was 1219 km^2 (20.81 percent) while year 2010 classified Landsat image depicts that the total built-up area was 3358 km^2 (57.34 percent) of the district. The total areal change for 28 years research span was 36 per cent in built up land, contrary to this non built-up /open area decreased to 35 percent during the same period. The results of current study can facilitate district government and Faisalabad Development Authority (FDA) in decision making regarding haphazard growth of urban areas.

1. Introduction

Globally, urban areas are expanding. The rapid urban expansion is the resultant of urban population and industrial growth [1]. The environmental, physical, social and economic factors over time influence urban growth [2]. Half of the world's population is urbanized and expected to increase [3]. The urban growth specifies speedy increasing in urban population, economic development and importance of city. Urban areas are experiencing rapid expansion as a result of economic urban population increase, anthropogenic and industrial activities in cities, and migration of individuals from rural to urban regions [4]. The human activities consisted of industrialization and urbanization has transformed the open land into built up areas [5]. Investigating land use and land cover changes is essential in understanding the interactions between anthropogenic activities and environment [6-8]. Human has been transforming one type of land cover to other to sustain his life [9-10]. Various factors join together to justify these transformations like economic, cultural, environmental, political, biophysical and intuitional. Their interactions behind the changes are hard to understand that how these changes function [11].

The urban growth assessment is one of the most significant fields in the science of urban geography and urban planning [12]. Frequent increasing of a built area is a symbol of landscape modifications in rapidly urbanizing regions [13]. The urban growth has not only transformed the form of urban landscapes but also the agricultural landscape and natural landscape of nearby regions [14]. Assessments of the temporal and spatial variations of the urban landscape pattern could support the urban growth analysis worthily [15]. Remote sensing is a low-cost, technically wide-ranging, and progressively popular technique for investigating urban growth and land cover

changes [16]. The cities are growing very rapidly and therefore research on current and future urban growth is the need of time. As suggested by [17] that the results of such studies can contribute in technical assistance in decision-making regarding urban and regional planning.

Faisalabad is the hub of the industrial growth. People around the district prefer to settle here because it provides an attractive opportunity in term of jobs and basic facilities. With the increase in industries and population, the land is continuously transforming into built up land. Spatial variations in land cover changes are caused by the growth in industries and population. Therefore, the purpose of this study is to spatially assess urban growth in terms of built up land changes in temporal extent of 1991 to 2019 in relation to population and industrial growth in District Faisalabad.

2. Study Area

Faisalabad is also known as the Manchester of Pakistan. Relatively, southern side is bordered by Toba Tek Singh and Sahiwal, north by Districts of Hafizabad and Chiniot, east by Nankana Sahib and Jhang is located in west. Geographically it extends 30° 67' to 31° 78' north latitude and 72° 70' to 73° 68' east longitude (Figure 1). It covers an area of 5,856 km^2. Administratively, there are 6 Tehsils in district Faisalabad named as Chak Jhumra, Jarnawala, Tandlianwala, Samundari, Faisalabad Saddar and Faisalabad city. It consists of 289 union councils. Also, the smallest administrative units, Mauzas, are 820 in numbers to regulate the decisions at grass root level. Additionally, the City District Government of Faisalabad divided into eight Town Municipal Administrations (TMAs) [18]. It is one of the developed and mega cities of the country. Also, the third most populated district of the Punjab. Faisalabad is called as the Manchester of Pakistan. It is hub of the activities related to industries. It is contributing to uprising Pakistan's economy. It is developing in a haphazard manner and also growing as a base of an economy of Pakistan [19].

The climate of southern and central Punjab owns semi arid and dry characteristics. Faisalabad is situated at an altitude of 184.4m. In the summer months the rays of sun do not slant much. Therefore, in the summer high temperature prevails. The average temperature in summer months prevails between 104.9 °F and 80.4°F. The winter season is cool and dry. And the temperature varies in winter months from 66.9°F and 39.4°F. The average rainfall experiences here are 375 mm. The soil of Faisalabad comprises alluvial deposits mixed with loess having calcareous characteristics, making it very fertile [20]. It is one of the densely populated cities of Pakistan and enjoys third position [21]. The current population is more than 7million whereas in 1998 its population was 5.4 million. The major crops are sugarcane, wheat, maize, rice and citrus in addition with the cultivation of fruits i.e., mangoes and guava [22]. Faisalabad is industrial city and the manufacturing units across the region ranging from foundry, chemical, engineering, ghee, construction material and pharmaceuticals. Being an urban city, the economy of Faisalabad has prospered relatively. It is hailed as the third largest economic state of the country. These economic activities are the main pull factors and people migrate from diverse geographic units to Faisalabad leading to population increase and urban growth [23].

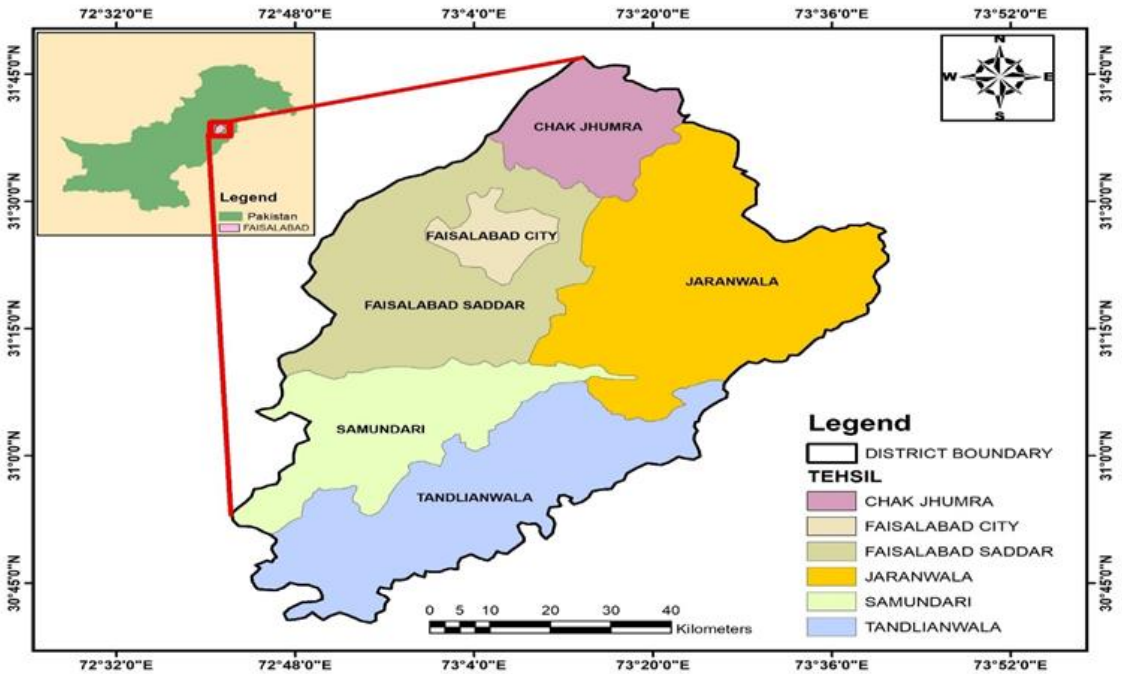

Figure 1. Location of the study area

3. Method

In this study, the designed objectives were achieved by adopting secondary research technique. Land cover change was taken as independent variable whereas Industries and Population growth were dependent variables. Supervised image classification with maximum likelihood algorithm was utilized to classify satellite images and linear regression model was applied to determine the correlation between urban growth, population and industrial growth.

3.1. Data collection

The data was acquired from secondary sources. Data regarding industries and population was acquired from Pakistan Bureau of Statistics, Government of Pakistan. Satellite imageries of different temporal extent having 30m spatial resolution were downloaded from United States Geological Survey (USGS) open-source geo-database details are presented in Table 1.

Table 1. Landsat Meta Data

Sr. No	Images	Bands	Year	Resolution
1	LANDSAT-4	8	1991, Oct	30 meters
2	LANDSAT-4	8	2001, Oct	30 meters
3	LANDSAT-8	12	2011, Oct	30 meters
4	LANDSAT-8	12	2019, Oct	30 meters

3.2 Satellite processing and classification

Maximum likelihood algorithm is one of the proficient classification techniques for extraction of different land cover classes [24]. Therefore, we utilized the supervised image classification with maximum likelihood algorithm for extraction of Built-up land, vegetation cover, barren land and water body in order to assess urban growth. Training samples were chosen for each of the present land cover classes. The pixels contained by these polygons were used to record the spectral signatures for the various land cover types that were obtained from the satellite data using the following steps.

ERDAS IMAGINE software was used for Landsat image processing. The images downloaded from USGS geo-database were in multiple titles and bands. The spatial extent of study area falls in four scenes. By running the Mosaic Pro function four tiles were combined into single image. Then multiple bands were combined by running the layer stacking tool and single image was generated. Then resultant images for all years were clipped using study area boundary. After extracting the study area, images were classified by applying supervised image classification with maximum likelihood algorithm and built-up land, vegetation cover, barren land and water body classes were extracted. The resultant images were added in ArcGIS and area covered by each land cover class was calculated in km^2.

3.3 Accuracy assessment

Global Position System (GPS) survey was conducted for accuracy assessment. Similarly, Google Earth was also used for accuracy assessment. For this purpose, polygons were drawn and overlapped on the satellite images of the year used in the classification. Google Earth Pro, historical view allowed us to get the required image of the past year. So, saving these KML file for different period of time by overlapping of these polygons on the classified image, the accuracy of the images can be confirmed. The accuracy of the processed images was more than 82%. Results were exported in the form of map. The layouts were saved in 1000 dpi.

4. Results

The assessment of urban growth has been a key issue in urban geography, which emphasizes on the location, development and spatial arrangements of towns and urban center. The study of urban growth is significant area of concern for analysis and sustainable management of the cities. The urban growth of Faisalabad has been spatially assessed using geo-spatial technique. In order to assess the pattern and trend of urban growth by geo-visualizing the physical expansion by utilizing Landsat images of the past three decades. Furthermore, population and industries data have also been used to supplement the results extracted from satellite data.

4.1 Population and industrial growth

The administrative unit under study is one of the populous cities of Pakistan. In the year 1991, population was 4.1million and the numbers have grown to over 8million in 2019. The population boom was triggered by the increase in natural growth and migration. In the last 10 years, increase of more than 2million has been occurred (Table 2). Similarly, the registered industries have reached to 2360 (2019) which were 612 (1991). The data showed the industrial growth led by the establishment of various industrial estates (Figure 2).

Table 2. Comparison of registered industries and population [34]

No	Years	Registered Industries	Population (Millions)
1	1991	612	4.131
2	2001	819	5.839
3	2011	1650	6.24
4	2019	2360	8.493

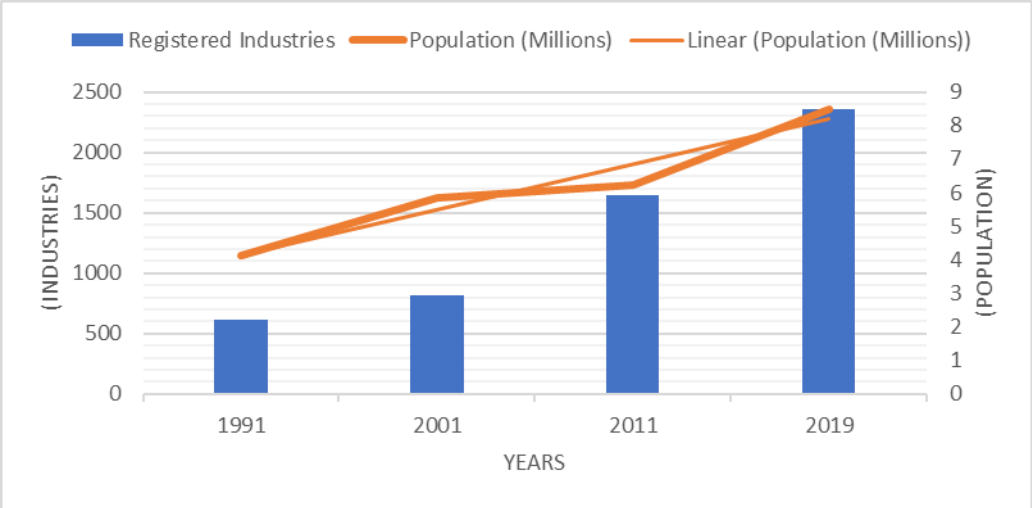

Figure 2. Population and registered industries growth (1991-2019)

4.2 Spatial analysis of urban growth

It is evident from the spatial distribution of the different land cover classes that open spaces and green cover has been transformed into built-up land. The land area covered by built up environment, vegetation cover, barren land and water body varies across the selected temporal extent (Table 3). In Figure 3a, the maximum land area is covered by vegetation cover and built-up area was less than vegetation cover. After a decade (2001), the green cover and barren land has been decreased (Figure 3b). Most of the green spaces and barren land has been transformed into built up land. This has resulted increase in built-up land.

The Figure 3c depicts that the built-up area has further expanded in the year 2011 in all directions. Small patches of barren land were abridged in some part of the area in addition with the transformation of the vegetation land into barren land. The water body as Ravi River is also appeared because of the 2010-flood. Then in the year of 2019, most of the land has transformed into built up (Figure 3d). The built-up area has extended more densely. Waterbody and barren land were scarce to see. But vegetation cover was still available for agricultural activities (Figure 4-5).

Table 3. Temporal variation in land cover (1991-2019)

Land Cover	(1991) Area km²	(2001) Area km²	(2011) Area km²	(2019) Area km²
Built Up Land	1219	2269	2748	3358
Vegetation Cover	3822	3275	2986	2426
Barren Land	807	302	89	57
Waterbody	8	10	33	15
Total	**5856**	**5856**	**5856**	**5856**

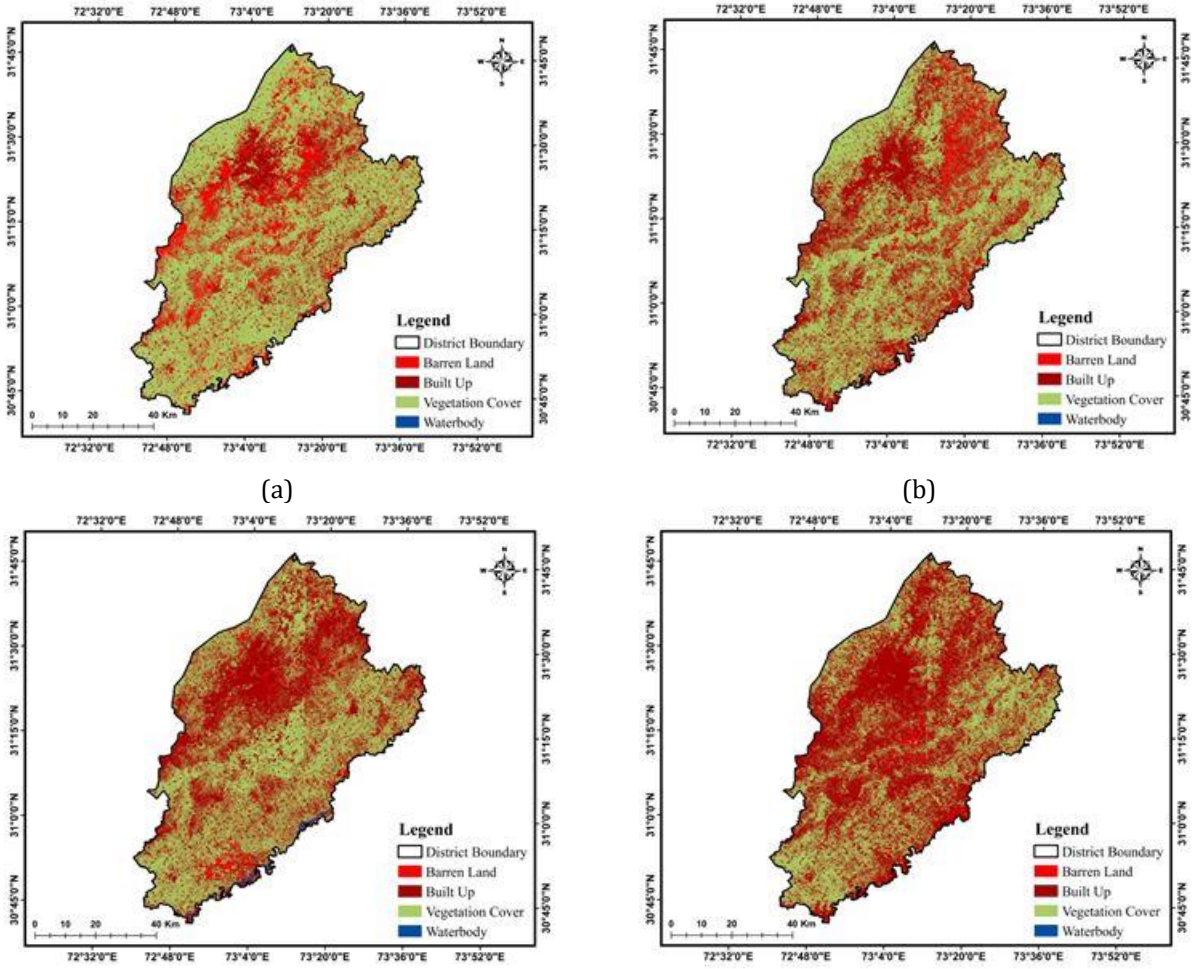

Figure 3. Land cover condition a)1991 b)2001 c) 2011 d) 2019

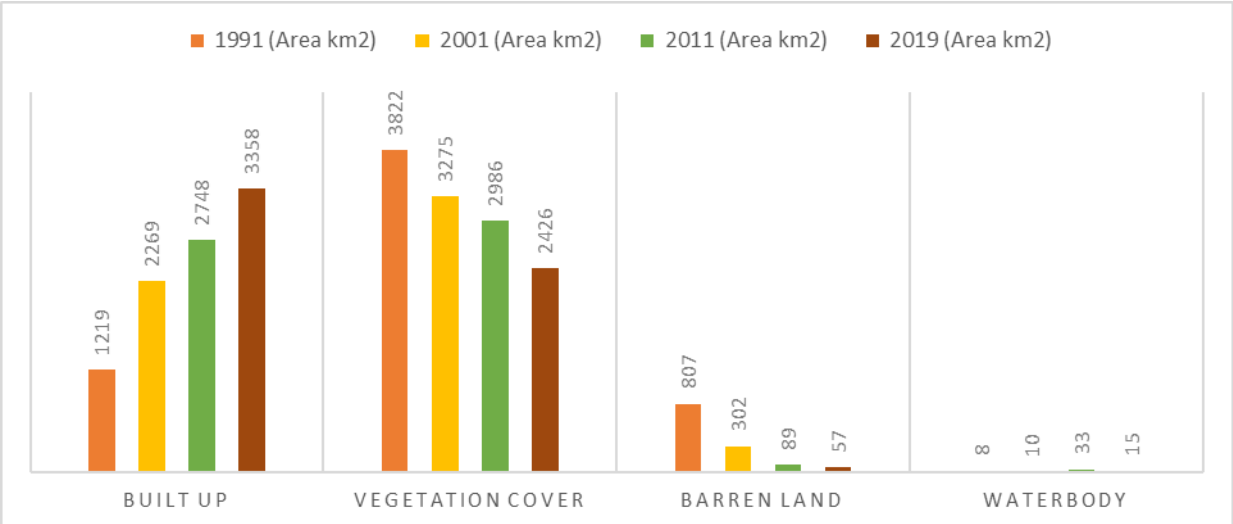

Figure 4. Comparative distribution of Land Cover (1991-2019)

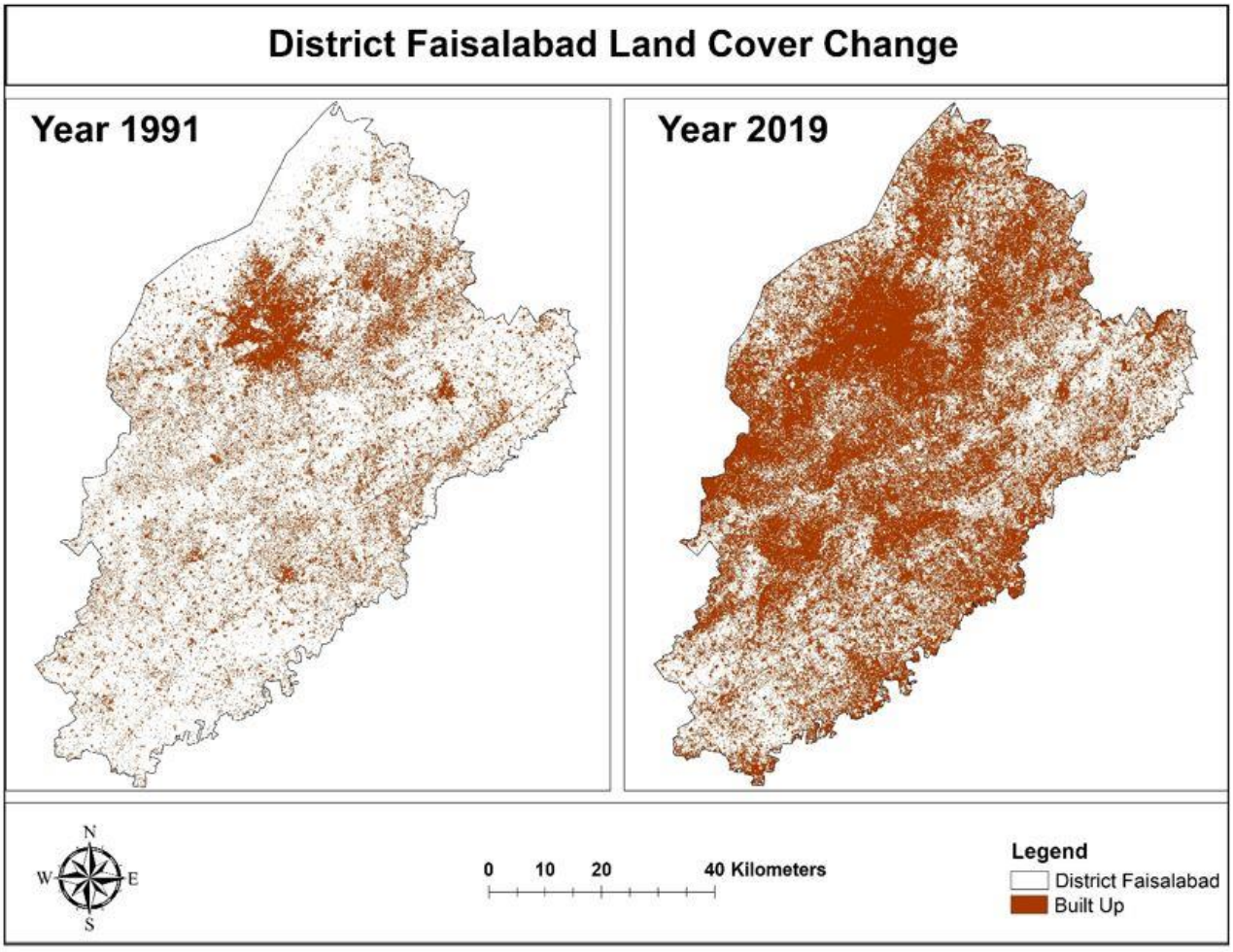

Figure 5. District Faisalabad built up change (1991-2019)

4.3 Assessment of urban growth

The industrial and population growth has attracted huge number of people from across the country which has increased the population by almost 100% in the last three decades. Alongside, infrastructures have developed to fulfill the needs of the residents of the city (Table 4). The growth in road network, industrial growth and residential area growth has expanded the city and caused urban growth. Furthermore, with the increase in the establishments of industries and population of the area has led to the conversion of the vegetation cover and barren land into built up land which is presented in Table 5 and Figure 6.

Table 4. Comparison of registered industries, population and built up

No	Years	Built Up (km^2)	Registered Industries	Population (Millions)
1	1991	1219	612	4.131
2	2001	2269	819	5.839
3	2011	2748	1650	6.24
4	2019	3358	2360	8.493

Table 5. Changes in built-up land (1991-2019)

Land Cover	1991 (%)	2019 (%)	Change (%)
Built up Land	20.81	57.34	+36.53
Other Land Cover	79.176	42.649	-36.52

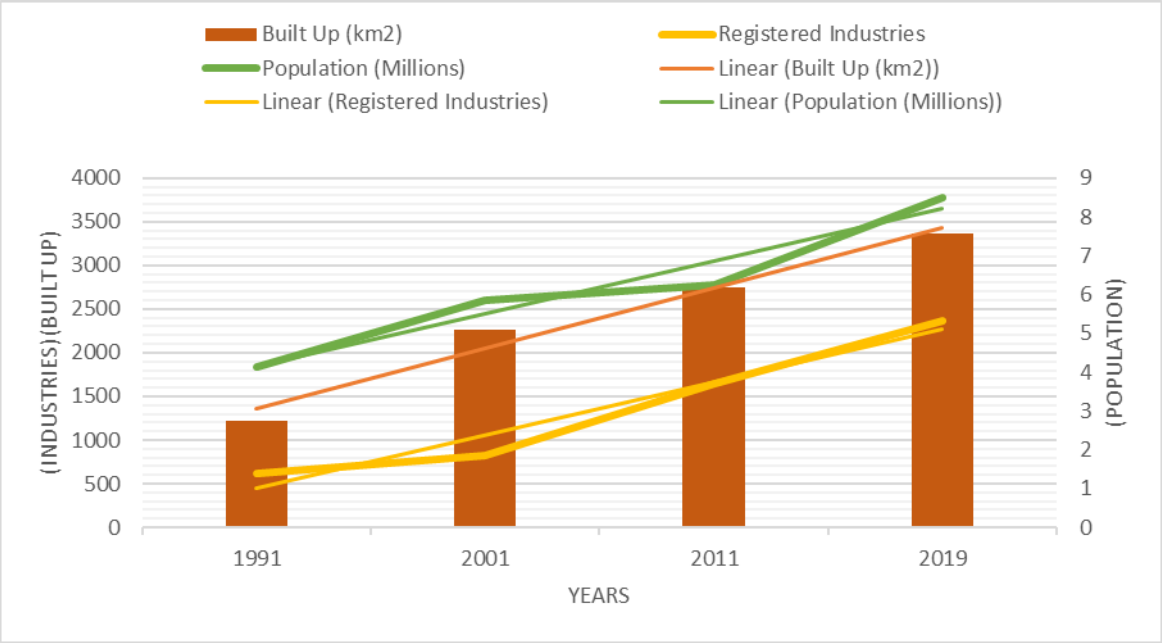

Figure 6. Comparison of Trends of Built Up, Industries and Population

5. Discussion

The assessment of urban growth has been a key issue in urban geography, which emphasizes on the location, development and spatial arrangements of towns and urban center. The study of urban growth is significant area of concern for analysis and sustainable management of the cities. The urban growth of Faisalabad has been spatially assessed using geo-spatial technique. In order to assess the pattern and trend of urban growth by geo-visualizing the physical expansion by utilizing landsat images of the past three decades. Furthermore, population and industries data have also been used to supplement the results extracted from satellite data.

The analysis reveals that the built up area in the year of 1991 was confined to the central and eastern region of the district. The barren land was present in the central and western side of the district. And the waterbody bounded to the south eastern part of the district. In 2001, the growth of the built up land was seen in central, northern and western side of the district. Some developments were also seen in the southern part of the district. In 2011, the built up was extensively expanded in the central and northern side of the district. A considerable area of the barren land was seen in the south western side of the district. In 2019, the growth of the built up expanded out of the central region of the Faisalabad city toward its norther, western and southern sides. Small patches of the barren land were spotted in the middle of the district. These results can be compared with the other research papers and causes of changes in Land Cover. Population and industrial growth is the main factor responsible for the urban growth in Faisalabad. [24-25] also found that Faisalabad being recognized as the industrial hub and the root cause of urban growth is population growth and industrialization.

Additionally, the implications of unintended and uncontrolled urban growth have given rise in severe damaging belongings on the urban inhabitants and their surroundings. It's also connected to health concerns including air pollution, traffic injuries, and work hazards, as well as dangers from social and nutritional differences. The population density in a given region usually accelerates and drives urban growth. The shift in urban land cover configuration is determined by the level of urban growth [26]. In order to conduct an urban spatial analysis research current and historical data is required [27].

Furthermore, the number of registered industries has increased from 612 to 2360 in the past three decades. Pacifici [28] found that the industrial growth in district Dhanbad, India has transformed the other type of land cover into built-up land and led to urban expansion.

Moreover, the pull factors increased the population from 4.1million to 8.4million with 3.4million people in Faisalabad city. The research conducted by [29] has justified the conversion of the land cover by the growth in the population. Similarly, in Upper Benue region Adamawa State, Nigeria changes in the patterns of land cover from 1975 to 2005 due to the rapid population [29].

Finally, it was found from the analysis that change detection has also problems. a) A massive amount of data required to detect only the limited changes in an area. In an image our desired area of interest is very small than the tile we have to acquire for processing. b) As we know that a number of satellites are revolving around the earth to get the data on continuous intervals. All the artificial satellites are equipped with spectral sensors of different kinds and types having range of resolutions. Their spectral band width and wavelength are not the same. c) In

order to study two images of same date with different years, we witness noise to the atmospheric conditions, bad light, calibration of the sensor and moisture on the surface of the ground. These conditions if prevails will lead to visible changes. d) Image distortion, alignment problem and geometrical error is introduced with the acquisition of the satellite imagery for evaluating the change detection [30]. Jensen et al. [31] implemented a method of comparing two independently classified maps of land use land cover of different dates. They found it an accurate procedure to detect the change with the help of GIS and RS techniques [32]. The results of this can contribute in decision-making regarding urban and regional planning, Land use planning and management and Urban Resilience.

6. Conclusion

The study concludes that built up area of the district Faisalabad has altered. The built-up area had been continuously increased from the years 1991 to 2019. Vegetation cover also has altered with the passage of the years. The vegetation cover transformed to barren land. The barren land was then altered to built-up area. The proportions of the waterbody also altered in the respective years. The growth of the population was caused by various factors. It included international migration, internal migration and an increase in the natural growth rate. The migration was initiated just because of the charming financial opportunities and service facilities provided by the district. Additionally, the number of the registered industries had been expanded by many folds. Some other reasons for the transformation of the land cover include the central location of Furthermore the research concludes that with the increase in the number of the industrial establishments in the district attracted the population from the nearby regions to reside near the industrial zones to get economic opportunities and facilities. As the number of the industries increases the number of populations also augmented. This led to the transformation of the vegetation cover to barren lands and the conversion of these barren lands to the built-up areas resultantly conversion of the land cover. So, from the outcomes, its obtained that the spatial changes of the land use land cover in district Faisalabad is caused by the growth in the industries and population.

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Author contributions

Arsalan Saleem: Conceptualization, analysis, geo-visualization and preparation of manuscript. **Shakeel Mahmood:** Conceptualization, analysis, geo-visualization and preparation of manuscript, reviewing and editing.

Conflicts of interest

The authors declare no conflicts of interest.

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