Assessment of Urban Sprawl in Sargodha City using Remotely Sense Data

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Received: 31 May 2022 / Accepted 2 July 2022

Abstract. The current study focuses on tracking urban sprawl in one of the rapidly growing cities of Pakistan i.e., Sargodha. The secondary cities have the capacity to persuade people from rural areas to relocate. In this regard, the current study is unique in that it will give a comprehensive analysis of urban sprawl of Sargodha City. The remotely sensed data is used for this purpose. The study is primarily based on the collecting of both primary and secondary data. For the last 30 years, from 1987 to 2017, primary data was gathered from the United States Geological Survey (USGS) and the Global Land Cover Facility (GLCF). ERDAS Imagine 2013 is used to classify land use using remotely sensed data. The Kappa Coefficient was used to compute the accuracy assessment of classified maps. Maps are used to depict a comparative analysis of urban sprawl in the city. In addition, regression analysis and simple statistical computations are also utilised to assess dynamic changes in urban sprawl. From 1987 to 2017, a 10-year interval was used to measure change in built-up land using an equation. According to the findings of the study, Sargodha City has experienced considerable changes in land use patterns. This current study is beneficial for policymakers to design the city in a well-planned manner. The appropriate design of cities can pave the way for higher living standards in rapidly growing cities of Pakistan.

Key words: urban areas, demographic processes, land use change, spatial pattern, rate of urban sprawl, GIS, satellite imagery.

1. Introduction

Urban areas cover around 2-3 percent of the Earth's total surface, according to estimates. This increase in urban population has resulted in leapfrog sprawl, which has a substantial impact on the city's land use pattern. Land usage and land cover refer to two distinct characteristics of urban sprawl that are inextricably intertwined. Satellite remote sensing techniques have become more important in land use monitoring in the modern era. It is rather simple to keep track of past urban sprawl. Remotely sense data provide a wide range of uniform spatial resolution and revisit frequencies of satellite data. It provides an opportunity for future prediction and urban planning. Particularly after 2008 due to the free availability of satellite archives the monitoring of the land use has become more easier as compare to the past (Zhao et al., 2017).

Globally the urban population is increasing day by day. It is estimated that in 2030 about 60% of the world's population will be in urban areas (Seto & Fragkias, 2005). Population sprawl is directly related to urban sprawl and urban sprawl has an impact in regional economic sprawl. Urban sprawl also increases land values, living cost, economic inequalities, and results in social stratification in the city (Rahman, 2016). Urban sprawl has been monitored in many developed and developing countries using statistical techniques along with remotely sense data and using GIS. The use of GIS and database management systems has helped in calculating, observing, modelling, and then predicting the urban sprawl phenomenon (Jat et al., 2008). It is always difficult to define urban area. Day by day the population of the cities are increasing but still there is no definition of urban area in the world. The definition of urban area is always varies with time and area to area (Cohen, 2004). The most dominant developmental pattern observed in United States is Urban sprawl and over the globe. In the 1990s, most of the work on urban growth focused on issues that were formulated and described by Wilson and Chakraborty (2013).

People and the area are primarily affected by the sprawl both in positive and negative manners as well. On the periphery of the city land is purchased from farmers for residential and commercial purposes as result of this purchase agricultural land is invaded for city use. But on the same hand farmers are paid more money which in turn increase their financial positions improves the lifestyle of the farmers. Now farmers are urbanized as their lifestyle is more focused on urbanism (Kassa, 2014). Population explosion is posing severe threats to environmental sustainability of the cities in developing countries (Ojima & Hogan, 2009).

Government bodies and non-profit organizations are focusing on urban sprawl. Various indicators of this process are presented in Table 1. Generally there is very little work on environmental impacts of urban sprawl in the cities (Johnson, 2001). Land use mapping has been improved by the use Geographic Information System (GIS). From last 3 decades the images of Landsat-TM images providing useful and endless archives of the earth's surface (Rawat & Kumar, 2015). The use of remotely sense data in Egypt is as old as the technology of RS. Change detection is another aspect of Land use monitoring in which the Spatio-temporal changes in the land use are monitored between two different eras of time (Hegazy & Kaloop, 2015). Post classification techniques have some difficulties but still this technique is widely uses for the identification LULC predominantly in urban areas. The main disadvantage associated with this approach is the accuracy of the results. However, this post-classification technique is useful to generate the land use maps of 'from–to' (Dewan & Yamaguchi, 2009). It is difficult to develop the land use land cover classification and perhps it will remain mystery to develop land use land cover classifcation that will follow all over the world. There are diverse angles in the classification procedure (Anderson, 1976).

The area in which much of the land is coverd with infrastructure is termed as built-up land or urban area. This is a vast category encompasses the not only the development in cities, towns and villages but it also inlcude development along the roads, highways in the form of strip develoment. These areas are the hub of mills, industrail areas, commercial areas and institutions that are not the partt of urban centers but can categorised under built-up land (Anderson et al., 2001). To model and predict the dynamic urban features various modelling approaches are developed. One of the effective approaches for modelling and prediction of urban growth is Cellular Automata - CA. GIS data with the integration of remotely sense data is an effective basic tool for modelling to identify and analyse spatial land use patterns in urban areas (Araya, 2009). According to population size Pakistan is ranked at 6th position in the world. Almost all capital cities of Pakistan are experiencing period of unprecedented population. The urban areas of Pakistan are expanding rapidly due to natural increase and rural to urban migration (Khan et al., 2014). Asia is the one of the densely populated continents in the world. Some areas of South-East Asia are experiencing sprawl with low-density while in East Asia density tends to be increased with urban sprawl. This urban sprawl is the result conversion of agricultural land into the residential areas on the periphery of the city (United Nations, 2017).

Annual rate of urbanization in Pakistan is 3% that makes the Pakistan rapidly urbanizing country in South Asia. Presently about 1/3 of the population of Pakistan is living in the cities but according to the estimates of The United Nations Population Division at the end of 2025 almost half the Pakistan population will be living in the cities. Pakistan is at the verge of an alarming phase of demographic transition in urban areas (Jabeen & Jadoon, 2017). In Pakistan urban residential development is mainly taking place on the rural urban fringe. Previously Bahawalpur was an agro-based city but now the trend has been changed and city is shifted from agro-based to commercial-based centre. Due to this shift, there is a significant change in the land use and land cover pattern of the rural urban fringe. Most of the newly built housing schemes are on the rural urban fringe hence the direction of urban sprawl is towards the periphery areas of the Bahawalpur city (Mohsin et al., 2015). There is a dire need to understand the driving forces of urban sprawl. These driving forces may differ from region to region and for a different period. This scale can provide a great opportunity to study the driving forces of urban expansion on national and regional scale (Guangjin et al., 2016). Develop and developing countries have different and aims and objectives to study the urban sprawl. Similarly, the driving forces of urban sprawl are different in developing countries as compared to the developed countries (Tendaupenyu et al., 2016).

Table 1. Indicators of Urban Sprawl.

Serial No.	Spatio-Temporal Indicators of Urban Sprawl	
1	Land use Indicators	Change in Built-up land use, Agricultural land use, Barren land use, Commercial land use, change in forest land and change in water bodies
2	Density Indicators	Population density in area, built-up land density, Industrial density, agricultural density, Economic density
3	Landscape Pattern	Isolated, Fragmented and Discontinuity, Distance from the economic corridor, Distance from Metropolitan Cities
4	Social Indicators	Job Opportunities, Health Facilities, Education Facilities, Economic Viability, Better life quality

2. Material and Methods

The current study is primarily based upon the primary and secondary data. The primary source of data were the satellite images of the selected cities. The remotely sense data was downloaded from United State of Geological Survey (USGS), Global Land Cover Facility (GLCF) and European Space Agency (ESA) for the time span of last 30 years from 1987-2017. The images were subjected to Supervised classification in ERDAS Imagine 2013 after layer stacking, image enhancement, geometric and radiometric correction for land use classification. The remotely sense data was obtained for the years of 1987, 1997, 2007 and 2017 of same months to avoid the seasonal variation on the satellite images. Secondary data was obtained from the official sources in the form of published data e.g., Government Reports, Population Census Data and Historical Maps of the cities. The secondary data was helpful to compare the rate of urban sprawl with the increase in population over the last 30 years in Sargodha City. In the current research the accuracy assesment of classified images was calculated by using Kappa Index of Coefficient (Kraemer, 2014):

$$\boldsymbol{K}^{\wedge} = \frac{\boldsymbol{N} \ \sum_{i=1}^{k}(\boldsymbol{xii}) - \sum_{i=1}^{k}(\boldsymbol{xi}+\times\boldsymbol{x}+\boldsymbol{i})}{\boldsymbol{N}^{2} - \sum_{i=1}^{k}(\boldsymbol{xi}+\times\boldsymbol{x}+\boldsymbol{i})} \ .$$

The type and characteristics of acquired remotely sense data is given in the Table 1 and Table 2.

Table 2. Characteristics of Remotely Sense Data.

Sargodha City				
SATELLITE	**Date of Acquisition**	**Row/Path**	**Resolution**	**Source**
LANDSAT	March 1987	150/38	30 m	GLCF/USGS
LANDSAT	March 1997	150/38	30 m	GLCF/USGS
LANDSAT	March 2007	150/38	30 m	GLCF/USGS
SENTINEL-2	March 2017	T43SDR	10 m	ESA

Different combinations of bands were used to measure the urban sprawl. The combination of various bands used to study the urban growth and sprawl is given below (Table 3).

Table 3. Band Combination for Image Classification.

Serial No.	**Satellites**	**Bands Combination**
1	Landsat 5	Band4 , Band 3 , Band 2
2	Landsat 5	Band4 , Band 3 , Band 2
3	Landsat 5	Band4 , Band 3 , Band 2
4	Sentinel-2	Band 7, Band 4, Band 2

Urban Sprawl was monitored by suing simple mathematical equation for the interval of 10 years spaning between 1987-20017. More variation in the rate of dynamic change of built-up land more the pace of urban sprawl in particular time span (Li, 2012; Xie & Fan, 2003):

$$\mathrm{DU} = \frac{\mathrm{DB\ r_2} - \mathrm{DB\ r_1}}{\mathrm{DB\ r_1}} \mathrm{x} \frac{1}{\mathrm{T_2} - \mathrm{T_1}} \mathrm{x100} \quad ,$$

where DU = Dynamic change rate of urban sprawl for specif periods

DB r_1 = It is the total built-up area in T_1

DB r_2 = It is the total built-up area in T_2

T_1 & T_2 = Specific years to monitor the rate of urban sprawl.

3. Results and Discussion

Land use is most dynamic phenomena on the face of the earth. History of human dwellings and related land use change is as old as human being. In the early ages, man was not as civilized as today. The difference of civilization gives birth to urbanization and ultimately to urban sprawl in the urban centres of the developed and developing countries.

3.1. Demographic Profile of Sargodha City

The census data is evident that Sargodha city has shown a constant increase in terms of total population. At the time of partition majority of the migrants were shifted to Sargodha. This increase is the result of the creation of a Divisional Headquarters at Sargodha, because of this the town got more momentousness. People starts to migrate for employment in Government offices and in other tertiary activities. Establishment of Cantonment and the expansion of Airbase are also contributed to the expansion of the city with the increase in population during this decade.

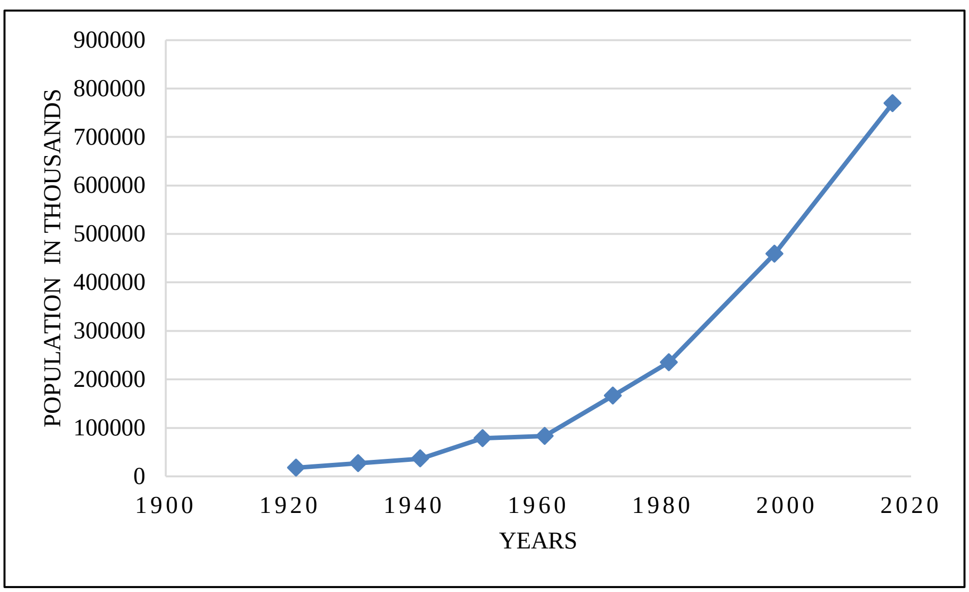

Figure 1. Historical Growth of Population of Sargodha City.

3.2 Annual Growth Rate of Sargodha City

Annual growth rate of population in selected cities is shown in the Figure 2. The annual growth rate of Sargodha is shows significant increase in the annual growth rate of population. This increase was due to the establishment of Sargodha as "Divisional Headquarter". This attracts the population from the nearby areas to migrate towards Sargodha. Census report of 1981 has shown significant decrease in the annual growth rate of population. Overall fertility was decreased in this era. In 1998 again the annual growth rate of Sargodha was increased around 5.5% but again the city has seen the decline in the annual growth rate of population as annual growth rate was dropped down to 3.9% from 5.5%.

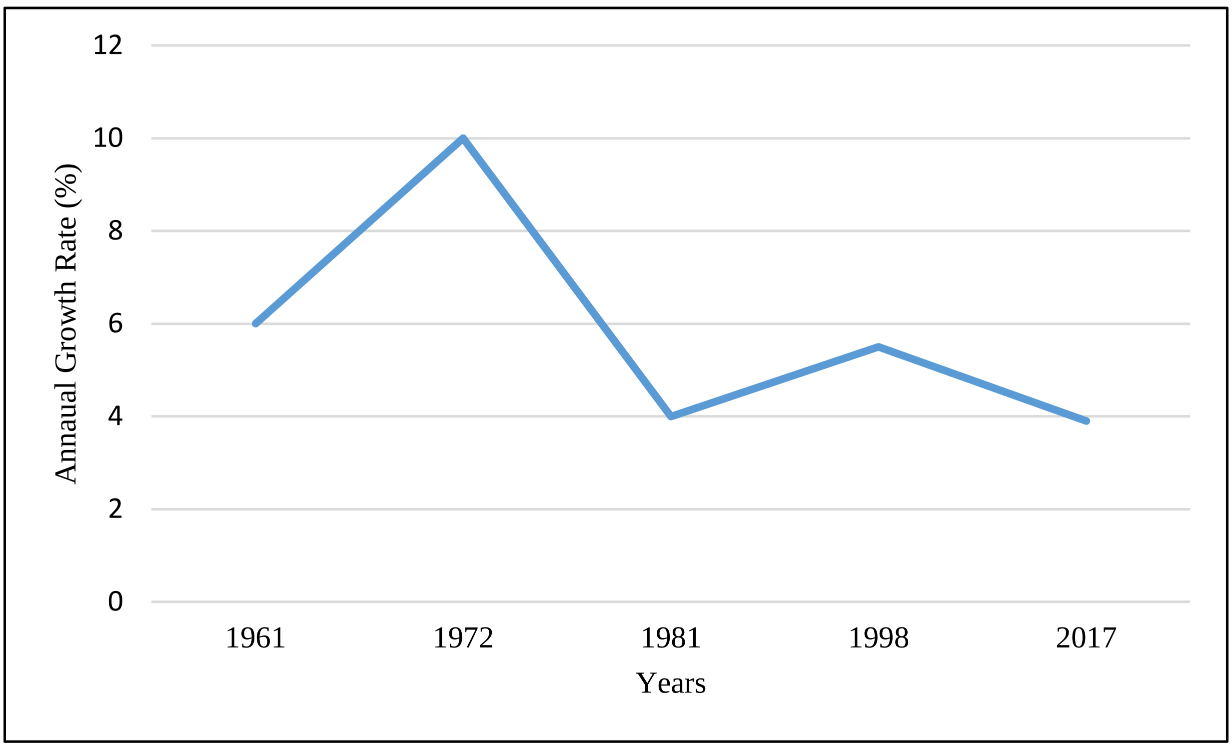

Figure 2. Annual Growth Rate of population of Sargodha City.

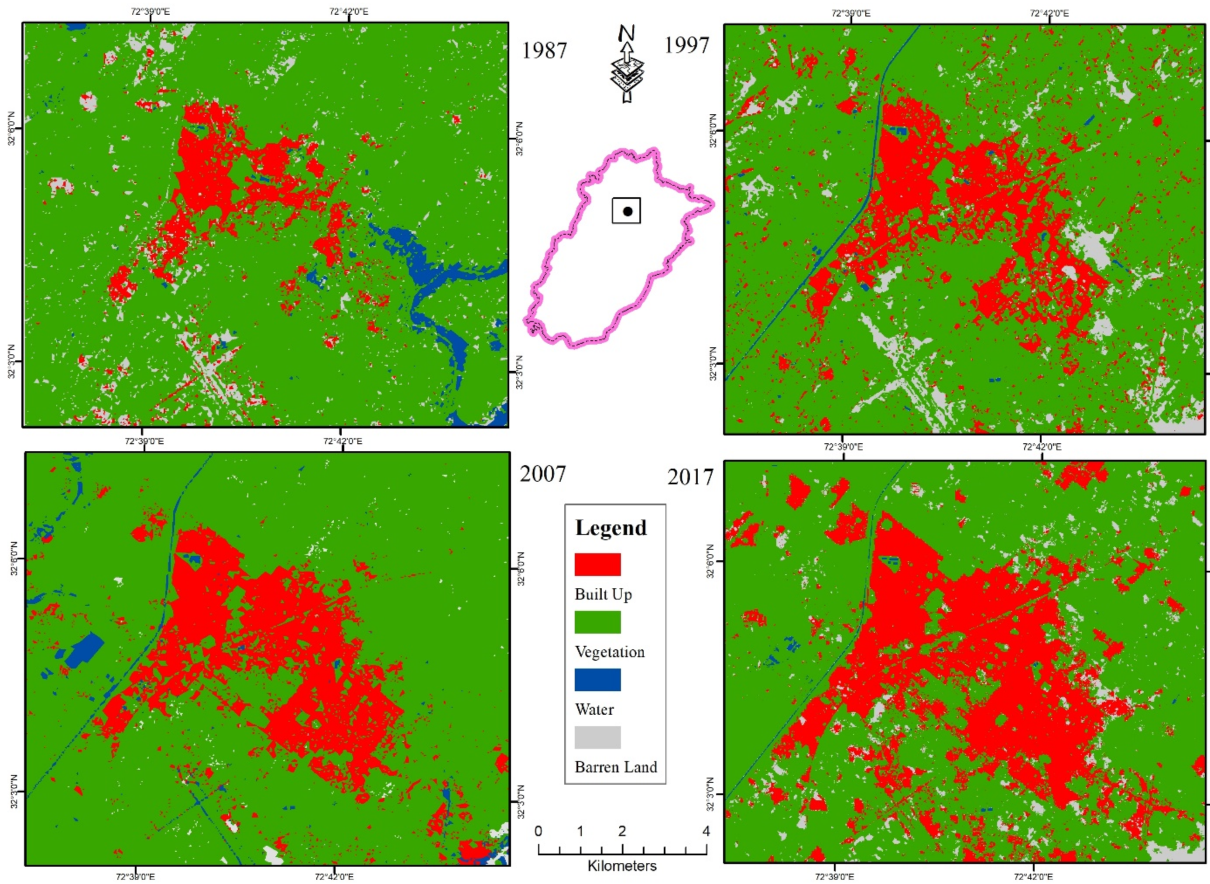

Figure 3. Spatio-Temporal variation in the Land use of Sargodha City (1987-2017).

Spatio-temporal variation in the land use pattern of Sargodha City is shown in the Figure 3. This variation in the built-up land use is associated with the changes in the population structure of the city. In 1987 most of the urban population was in clustered form in the centre of the city which means that built-up area was in the city centre. But with the passage of time as the population grew the demand of more land for residential area was also increased and city was started to expand its boundaries. From the land use classification of 1987, it is obvious that it there are many clustered and scattered built-up land in almost in the city but most of the built-up land is in the centre of the city. In 1997 the built-up land further increased and there is a significant decline in water body and vegetal cover of the city. In 1997-1998 the total population of the city was more than 400,000 it means more land is required to accommodate the needs of growing population. Another important variation was observed in the imagery of 1997 was the increase in the barren land. This seems to be quite strange as the city was expanding its urban boundaries but on the same time barren land was also increasing. This increase was due to the waterlogged soil. From 1997-2007 the built-up land of the city almost doubled following the previous trends of urban expansion. In this period both i.e., vegetal cover and barren land of the city was engulfed by the built-up land. Most of the area was converted into the built-up land in the north-eastern and south-eastern side of the city. The built-up area was expanding in these directions invading the fertile vegetal cover and converting barren land into the built-up area. For the land use classification of year 2017 the satellite image of Sentinel-2 of 10-meter resolution was used. This gives a clear picture of urban expansion in the city. Although the image shows that the barren land of the city is also increased but this is due to the increase in waterlogged soil in the city. Land use classification of 2017 image gives a better direction to the urban sprawl in Sargodha City. In 2017 most of the urban expansion is in the direction of north-western, north-eastern, and southern part of the city. The city has shown significant variation in its land use patterns in the past 30 years. It is obvious form the land use classification of the satellite imagery of last three decades that the built-up land has been increased due to the change in the demographic structure of the city.

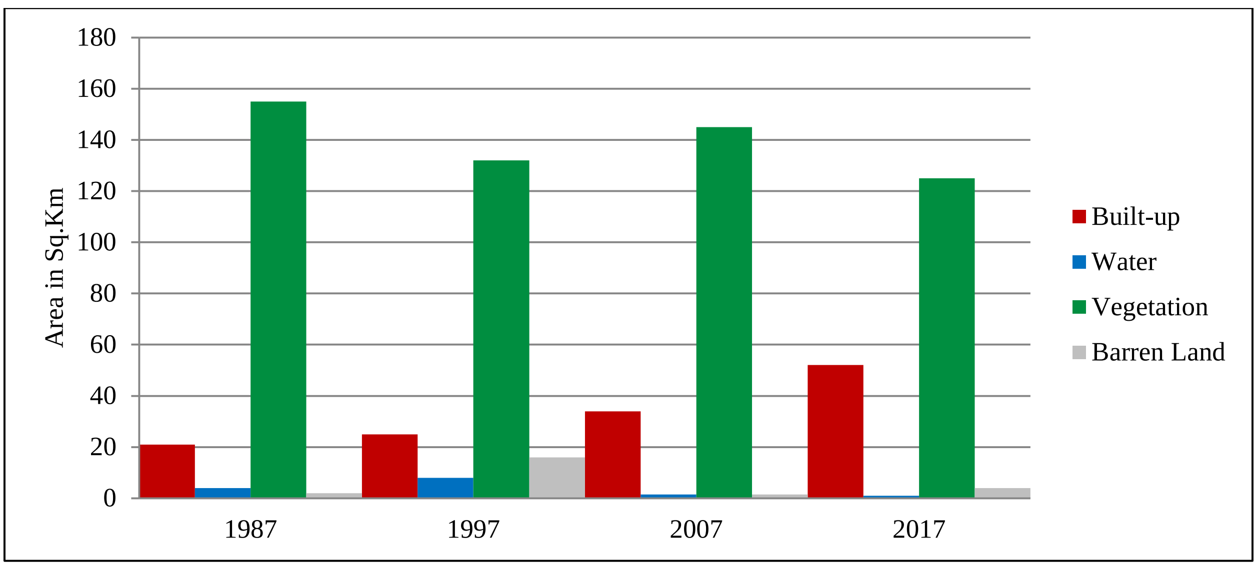

Figure 4. Variation in Land use Pattern of Sargodha City.

Spatio-temporal variation in the land use pattern of Sargodha City is also shown in the Figure 4. In 1987 the most dominant land use was the vegetal cover it accounts for almost 114 km^2 of the area in and around the city. Second dominant land use was the built-up land which was around 9 km^2 in 1987. Barren land and water bodies account for 7 km^2 and 4 km^2 respectively. Between the time span of 1987-1997 built-up land of the city was almost doubled showing the 100% increase in the built-up land because of this there was a change in the area covered by vegetation and in the area covered with water body. Both these land uses were reduced in response to increase in built-up land. The expansion of city continues in terms of urbanization and built-up land reaches to 24 km^2 in 2007 from 18 km^2 1997. During this decade barren land and vegetal cover were decreased due to urban expansion of the city. Land use classification of 2017 image also indicating the expansion of built-up land on continuous bases. Satellite image of Sentinel-2 gives clear picture of built-up land than Landsat-5 images. In 2017 the total built-up land in the city was around 31 km^2 because of this increase vegetal cover was also reduced to 95 km^2 in 2017.

3.3 Monitoring of Urban Sprawl in Sargodha City

Sargodha city also followed the phenomena of sprawl. There was only 3.3% increase in the built-up land from 1997-2007 and from 2007-2007 only 2.9% of built-up land was increased in city. It is to be noted here that trend of decline in built-up does not mean that built-up land has reduced. The word decline in built-up land is used by comparing the past trends for the periods of 10 years from 1987 to 2017.

The urban sprawl in Sargodha City in 1987-2017, determined according to the DU formula in Chapter 2, Materials and Methods, is shown in Table 4.

Table 4. Rate of urban sprawl in Sargodha City (1987-2017).

Built-up (SGD)	**1987**	**1997**	**2007**	**2017**
Built-up area(km^2)	9	18	24	31
Net Area (km^2)		9	6	7
The dynamic rate (%)		10	3.3	2.9

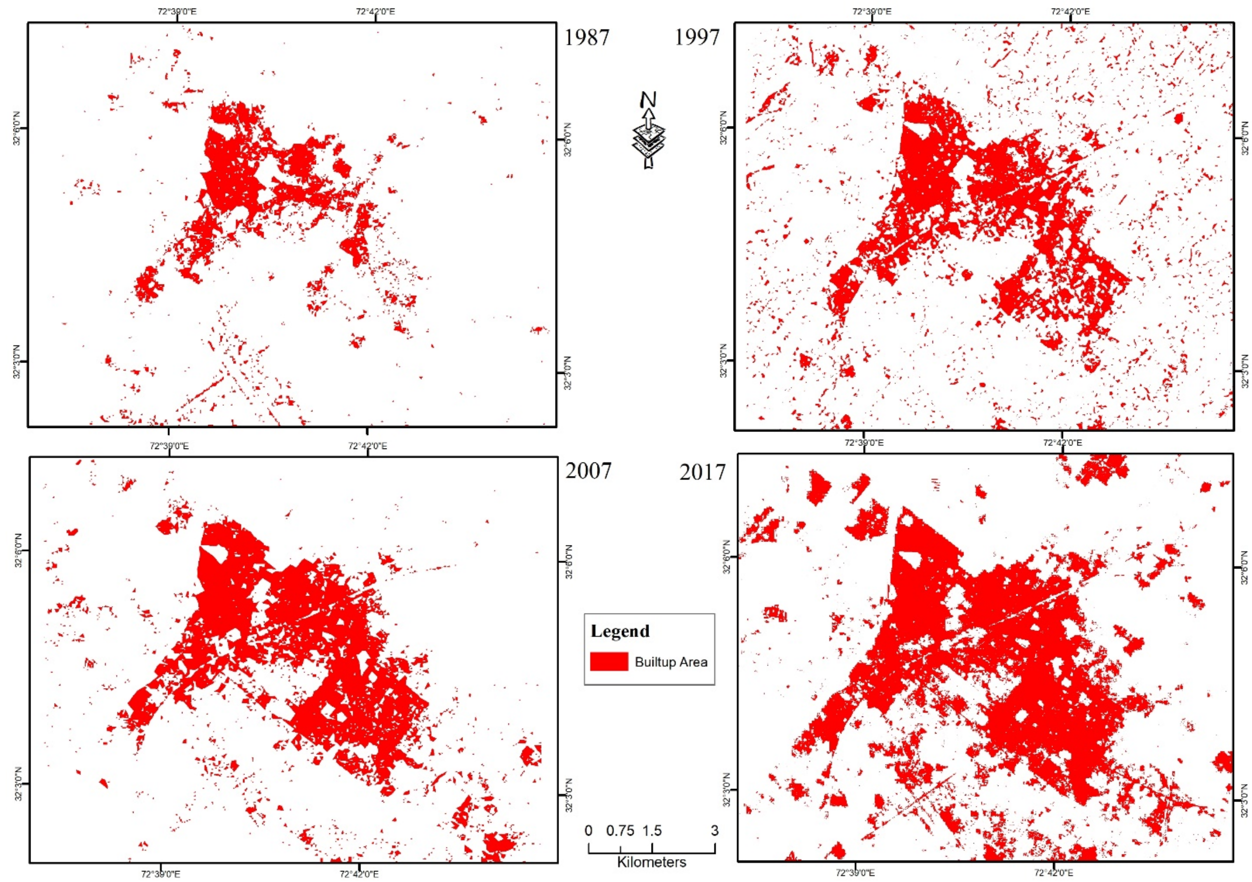

Figure 5. Variation in Built-up Area in Sargodha City (1987-2017).

3.4 Change Detection of Urban Land Use in Sargodha City (1987-2017)

Change detection of major four land use classes of Sargodha City is shown in the Figure 5. Overall, about 16.42% built-up land was increased in Sargodha City but on other hand this increase brings degradation in the vegetal cover and water bodies of the city as well. Vegetal cover was reduced to –14.18% while water bodies reduce to –2.24% while there was 4% increase in barren land as compared to the past.

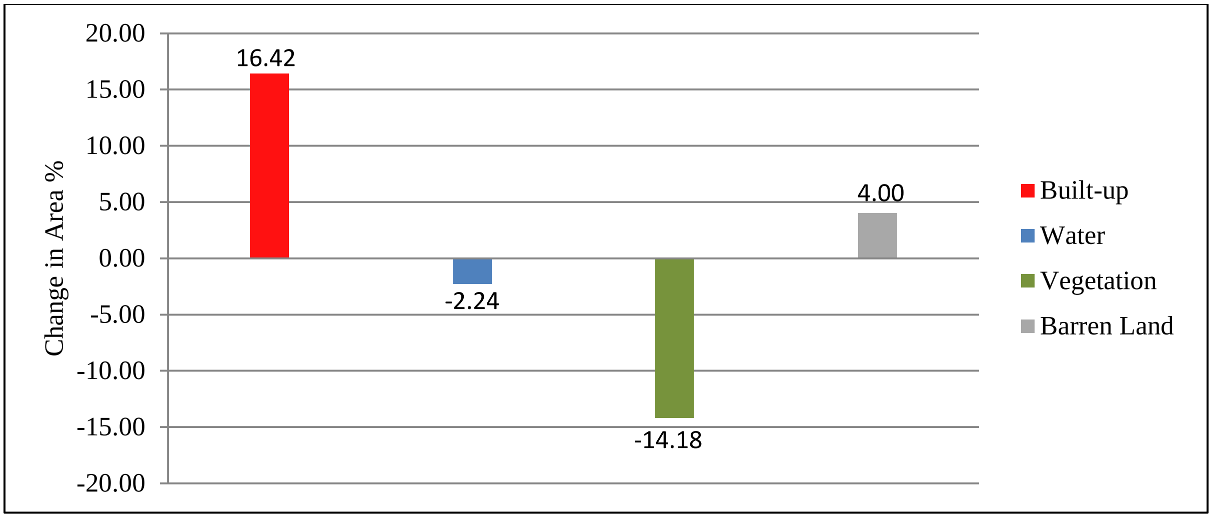

Figure 5. Variation in Urban Land Use of Sargodha City.

3.5 Spatio-temporal variation in Population and Urban Sprawl of SGD City

Spatio-temporal variation in the population and urban sprawl of Sargodha City is shown in the Figure 7. As the population increases built-up land also increases with the passage of time. In 1987, population of 235,000 was occupying 9 km^2 built-up land while in 2017 total built-up land in Sargodha City was around 31 km^2 to support the population of 769,000.

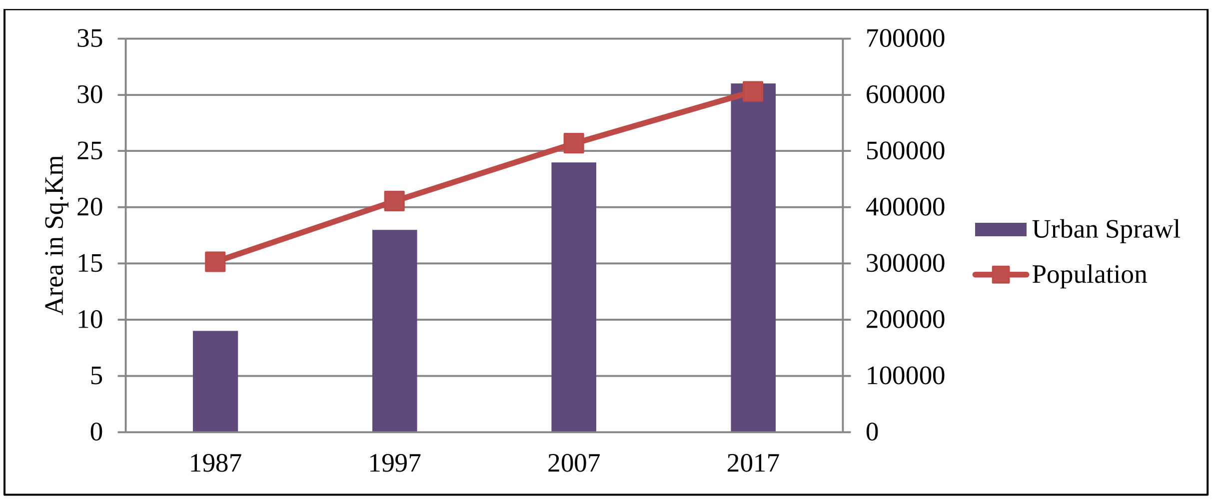

Figure 6. Urban Sprawl and Population Variation in SGD City.

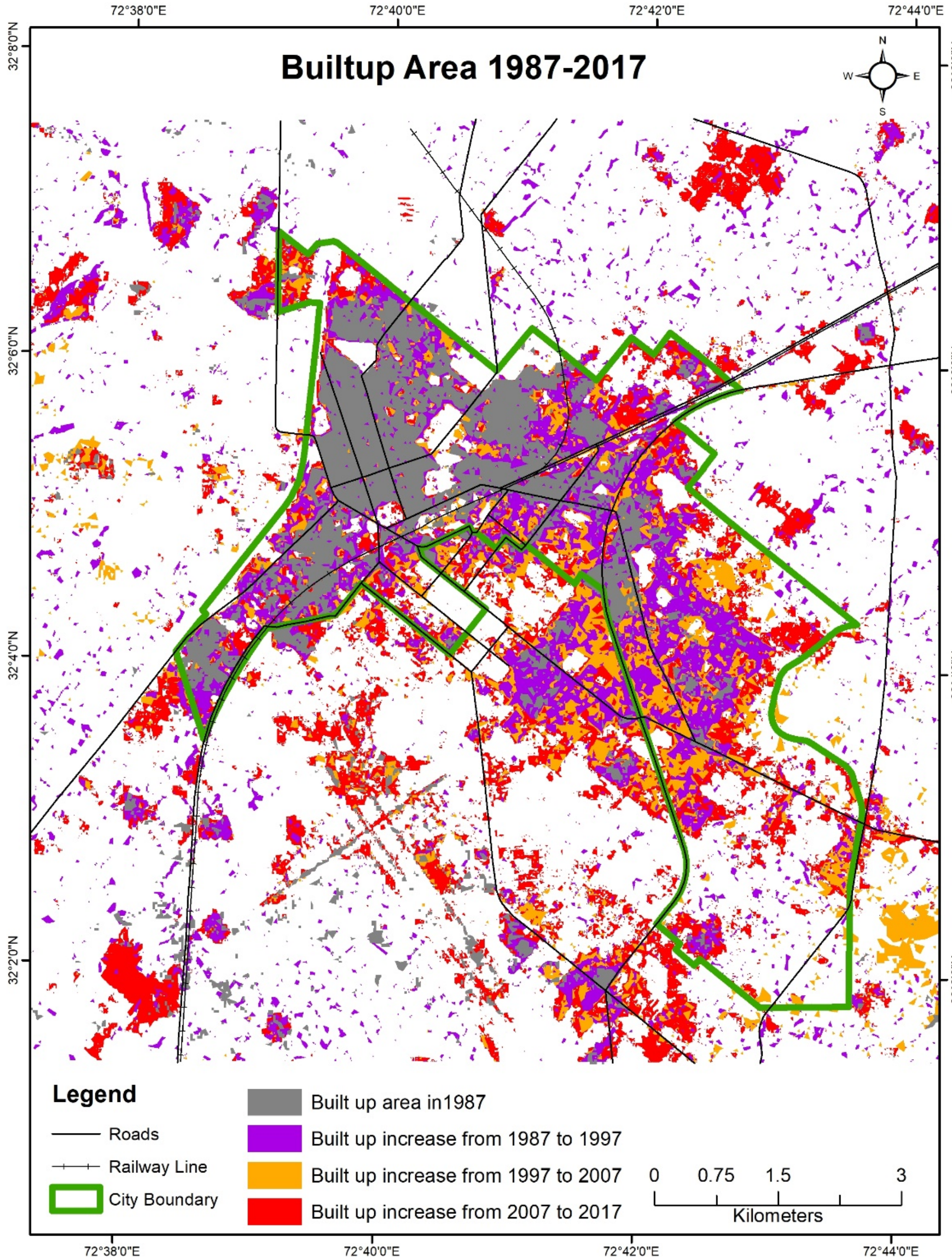

Figure 7. Built-up Area Pattern in Sargodha City (1987-2017).

4.Conclusion

The use of remotely sense data is becoming a vital tool to analyze the spatio-temporal variation in the LULC of any area. The use of satellite imageries provide a wide range of data which is used to analyze the urban sprawl in rapidly growing cities in the developing world. In the present research, use of high-resolution spatial data offers accurate information for the identification of LULC classification more effectively. Sargodha is one of the rapidly growing cities of Pakistan. It is evident from the present study that city has seen the different phases of urban sprawl. The overall area under built-up land has been increased from 9 km^2 to 31 km^2 since 1987 to 2017. Leapfrog and scattered settlement were observed in remotely sense data as shown in the Figure 8. This figure represents the clear picture of urban sprawl. The main cause of urban sprawl is the increase in population in the city. The overall population of the city also increased because of rural urban migration over the years. Regression analysis over population with years also showed the significant increase in the population as shown in the Figure 1. The town planners must plan the city in an effective manner. This will help to control the unplanned conversion of fallow land to built-up land. Unplanned conversion not only destroyed the aesthetic sense of the city but also become the root cause of many environmental problems. There is dire need to give a proper direction to the sprawl of city, so the overall quality of life and environment remain intact from the unplanned urban sprawl. Mostly population of the area depends upon agriculture activities; agriculture land will be shortening in future which will be the risk factor for food security. Sustainable effort is required to cop the issue.

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