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Monitoring urban growth and land use changes using GIS and remote sensing: A case study of Tehsil Burewala

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Abstract

Geospatial data is being extensively used to monitor the changes in an urban environment and assists as a decision-making tool for sustainable urban growth of the towns and cities. Intermediate and small cities of Pakistan are also getting urbanized day by day due to population growth and infrastructure development. The tehsil Burewala is one of the intermediate tehsil of Punjab province with Burewala city as Headquarter. Burewala city is included in medium sized cities of Pakistan presenting a kind of social and economic interaction. Urban growth of the city has extended beyond the municipal limits converting peri-urban vegetation into built up land. This study is aimed to focus on analyzing the urban growth of tehsil Burewala from 1981 to 2011 using Geo-spatial techniques. The land use changes and urban growth of the tehsil were analyzed using Landsat Multispectral Scanner (MSS) and Thematic Mapper (TM) data. The results of land cover classification revealed that built up area of the tehsil increased from 3.3% in 1981 to 4.7% in 2011. Likewise, vegetation cover of the tehsil is also increased from 66% in 1981 to 81% in 2011. The change detection analysis further depicted the conversion of barren land into agriculture in four rural areas of the city, while peri-urban agriculture is converted into built up assisted by residential and commercial development of the tehsil. The urban growth of the city is increased at the rate of 4.2% from 1981 to 2001 and 2% from 2001 to 2011. GIS based analysis of land use maps also revealed an increase in built up from 29% in 1981 to 62% in 2011. Remote sensing and GIS based analysis of urban growth of intermediate cities can be proved as basis of urban planning and management for decision makers.

Keywords: Urban growth, Landsat, Land use changes, Burewala.

1. Introduction

Urban growth is a global phenomenon and one of the most fundamental reforming processes affecting both natural and human environment through many ecological and socio-economic processes (Mandelas et al, 2007). The massive migration of population into cities is becoming a major reason of accelerated urban growth. Other than human population growth and migration to cities, urban areas are also increasing in number and spatial extent due to more infrastructure development (Mohammady and Delavar, 2015). On the one hand, urban growth is an important indicator of socio economic development, but unfortunately it takes place at the expense of loss of agricultural land and results in major land use conversions (Badlani et al, 2017). Increasing trend of urbanization in developing countries cause various kinds of land use conversions within and outside the city centers.

Increasing urban density in cities of less developed countries requires proper monitoring for planning purpose because accelerated urban expansion is posing a serious threat for sustainable urban development (Sivakumar, 2014; Islam et al, 2017) . Although the movement of people from rural to urban areas for residential and commercial purposes has been a reasonable sign of economic vigor as well as the cause of the city expansion and land use change (Sankhala and Singh, 2014), but this type of changes can affect the local and global environmental conditions. Human activities causes changes in land cover and land use patterns through several means (Alves and Skole, 1996). Requirement of shelter, food and other infrastructure has altered the shapes of cities. It is therefore essential to inspect the changes in land use/cover, so that sustainable land use planning can be achieved (Muttitanon

and Tripathi, 2005). In Pakistan, population growth and rural urban migration with unplanned progression has led to urbanization and urban sprawl, which make the shortage of infrastructure facilities. Sprawl is usually referred as the dispersed development along highways, suburbs of the cities and rural areas of a region. (Belal and Moghanm, 2011). The process or phenomenon of remotely observing the state of change in urban patterns at different times is referred as urban growth monitoring and has become a main application of remote sensing data (El-Baz et al, 1979); thus urban growth monitoring is the process of observing or depicting changes in land use land cover attributes using multi-temporal satellite images (Shalaby and Tateishi, 2007). Currently, worldwide city planners require remote sensing data to observe present urban growth and planning for anticipated future change (Goetz et al, 2003; Rawat and Kumar, 2015).

To monitor urban growth and Land use change in remote sensing environment include the examination of two aerial or satellite multi-spectral images with same geographical area at different time periods. Derived observations recognize changes in land use patterns that have taken place in the same geographical land between the two times periods considered (Radke et al, 2005). Hence, monitoring land use change over local or regional levels at different time periods through remote sensing is becoming more effective and lower costs than those used of traditional methods (El-Raey et al, 1995). Satellite data in the form of digital images, are widely used in various studies to monitor the expansion of built up areas and other land use changes (Mukherjee, 1987).

Monitoring LULC modifications, more than one satellite/raster images are needed for comparison, satellite images at distinctive time, obtained for this objective can be used to monitor the temporal differences that have taken place between them (Yuan and Elvidge, 1998). This study aims to analyze the changes in land use of tehsil Burewala and associated urban growth of city Burewala. The accelerated urban growth of Burewala city is analyzed using multi temporal satellite images processed in ERDAS Imagine. This study is focused on analyzing the urban growth of the city from 1981 to 2011 using geospatial techniques. The major objectives include (i) to analyze the land use changes of the Tehsil Burewala using Landsat data from 1981 to 2011 (ii) to analyze the urban growth of the city Burewala through change detection in remote sensing and land use change analysis in GIS.

2. Material and methods

2.1. Study area

Tehsil Burewala is located on 30.16°N 72.67°E in the east of tehsil Vehari. It is surrounded by Pakpattan in the east, Vehari in the west, Sahiwal in the northern side. In the southeastern side of the Tehsil Bahawalnagar district is present, and it form boundary to river Sutlej on its south-eastern side. It is 35 Km east of District Capital Vehari on the main Burewala Multan Road. Total area of the tehsil is 1603.14 Km2 (160314 hectare) and comprises of many small villages and settlements with main urban center known as Burewala. Fig. 1 shows the location of tehsil Burewala in Pakistan. The climate of the tehsil is hot in summers with cold winters. Maximum and minimum temperatures of the tehsil are 35.5°C in June and 12.8°C in January with an average rainfall of 60mm. Burewala is the 31st biggest city of Pakistan in terms of population as well as the second biggest tehsil of Punjab with respect to area.

Sutlej River crosses Burewala near the towns Jamlera and Sahuka in the south. Southern side of the tehsil was occupied by the forest and with the passage of time it was humanized by local clan called Langrial. People started to settle in villages due to Pakpattan canal operating in this area, resulting in conversion of forest to agricultural fields.

2.2. Data collection

To analyze the changes in land use pattern and urban growth of the tehsil, satellite data of Landsat 4 MSS (multispectral scanner) and Landsat 5 TM (thematic mapper) are obtained from the online service of USGS (United States Geological Survey). Landsat 1, 2 and 3 operated in near polar orbits from altitude of 920 kms. They completed 14 orbits a day and producing continuous swath imagery of 185km

wide with complete coverage of earth's surface in 18 days. These Satellites carried two sensors namely Return Beam Vidicon (RBV) and Multispectral Scanner (MSS). The spatial resolution of MSS was 80 meters with four band spectral coverage of visible green to near infrared wavelengths. Landsat 4 and 5 carried MSS and another developed sensor namely Thematic Mapper (TM). TM sensor provided seven spectral channels of data as compared to four channels collected by MSS. Like other Landsat sensors, these also had a swath width of 185km (Livermann et al, 1998).

Three multi date satellite images of the years 1981, 2001 and 2011 were used and processed in ERDAS Imagine analyzing the temporal variations of land use in the study area (see Fig. 2). Table 1 provides the detail of acquired multi spectral satellite data.

Other ancillary data used to examine the city expansion and growth in different directions consists of land use base maps of the city Burewala obtained from the city master plan and physical housing and planning department and administrative department of local Government. The land use maps for the three respective years are georeferenced and created in ArcGIS 10 that was also used for image training.

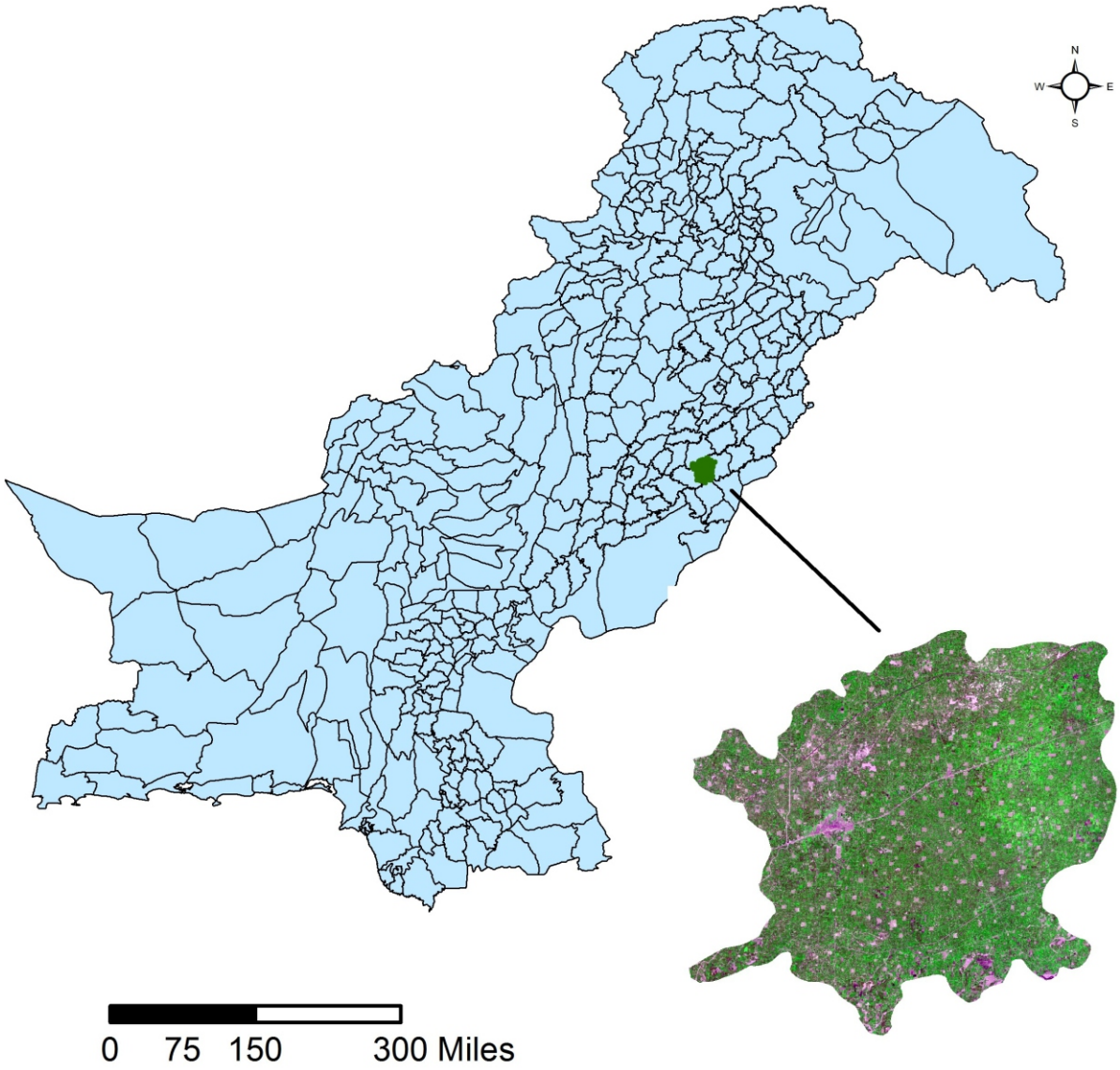

Fig. 1. Location of Study area (Tehsil Burewala) in Pakistan.

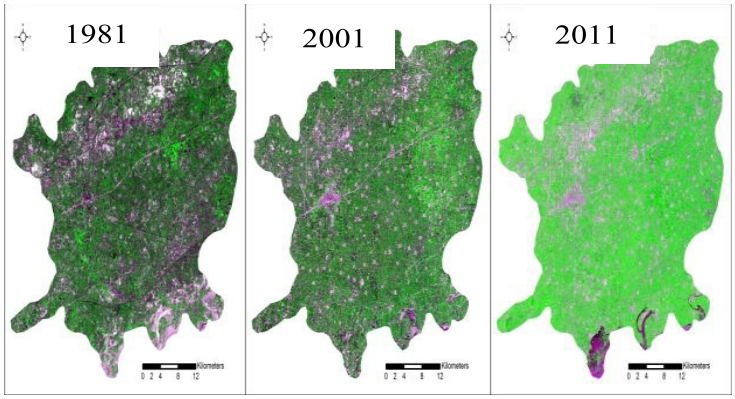

Fig. 2. False color composite of study area.

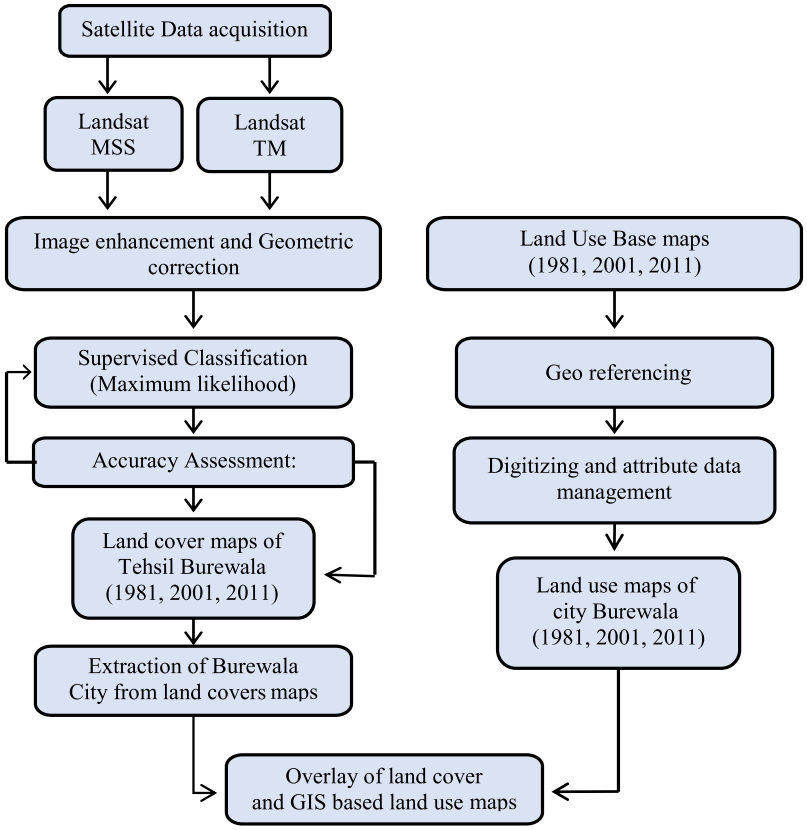

Fig. 3. Methodology framework.

Table 1: Acquisition and characteristics of data used in research.

Reference Year	Sensor Data/ Land use data	Resolution	Path/Row	Date of Acquisition	Source
1981	Landsat MSS	60 m	161/039	20-10-1981	---
2001	Landsat TM	30 m	150/039	06-04-2001	---
2011	Landsat TM	30 m	150/039	25-09-2011	---
1981	Land use plan	---	---	---	Housing & physical planning Department Burewala
2001	Land use plan	---	---	---	Housing & physical planning Department Burewala
2011	Land use plan	---	---	---	Punjab Municipal Development Fund Company

2.3. Image pre-processing and classification

After data acquisition, it is employed to pre -processing procedures of geo referencing and geometric corrections. Geo-referencing of land use base maps of Burewala city is performed in ArcGIS 10.4.1 by applying UTM projection of WGS 1984 datum using identifiable ground control points. Afterwards, land use maps of Burewala city for respective years are digitized separately and area is calculated in hectares for each land use layer separately. Similarly, Geometric corrections of satellite images are performed in Erdas Imagine using 50 ground control points with RMS error less than 1 pixel. After geometric corrections, a subset of the Tehsil Burewala is prepared by masking operation in Erdas. After preparation of the study area, spatial and spectral image enhancement techniques are applied for better visual interpretation of different land use classes in the images. Before starting any change detection procedure, it is very important to identify and divide the land use into reasonable classes as per objectives. Four land use classes are made in this study for analysis, namely (1) built-up land (2) vegetation cover (3) open/barren land and (4) water bodies.

Image classification is the next step of monitoring land use changes in this study. The classification of satellite images falls in two types, i.e. supervised and unsupervised. The technique selected in the current study is supervised classification that is done in four major steps of image training, image classification, Accuracy assessment and image output analysis. Before classifying the image, the image is trained through visual interpretation. Historical aerial imageries of the three years obtained from Google earth and ground truthing through GPS survey were also used to identify confused land use pattern. Although trainings of historical satellite imageries for 1981 and 2001 were more difficult, but in personal interviews from the elder population of the area and aerial imageries helped for the identification of various land use classes. Image trainings lead to the development of a signature file, which was evaluated through statistical and histogram analysis. The process is then followed by maximum likelihood supervised classification algorithm technique, creating the final thematic map of land use for three respective years, those pixels that couldn't be identified in any class were manually recoded over the images (see Fig. 3).

2.4. Accuracy assessment

Classified image mostly contains some sort of errors that occurs due to several factors and should be assessed by preforming the accuracy assessment method. Accuracy assessment of the current classified images is performed using 170 stratified random sampling GCPs (Ground control points) as reference data imported into Erdas imagine 9.2. After measuring the accuracy, an error matrix table is drawn from which producer's and user's accuracy for each class is calculated. The detail of accuracy assessment for each class is shown in Table 2. To examine the urban growth in city Built up land area expansion ratio is employed in the study that is proved to be a suitable indicator for analyzing the rate of urban growth and expansion using the formula derived from (Xiaoa et al, 2006; Xu and Min, 2013; Boori et al, 2015).

$$\frac{BuA\ (i+n)-BuA(i)}{n \times BuA(i)} * 100$$

Fig 3 also shows the flow chart of methodology adopted for the study.

Table 2. Accuracy Assessment of Classified images.

Land use / Years	Built		Vegetation		Water		Barren		Overall
	P%	U%	P%	U%	P%	U%	P%	U%	Accuracy
1981	91	82	89	94	77	87	83	82	88.3%
2001	91	96	96	100	86	100	96	90	94.4%
2011	94	90	86	98	84	80	91	82	88.8%

3. Results & discussion

3.1. Land use change detection and Urban growth of tehsil Burewala

Land use change of Burewala is analyzed after supervised classification. Figure 4 shows the land cover/ land use of tehsil Burewala derived after supervised classification. Table 3 shows the area covered by each land use category in the tehsil. Built up area of the Burewala in 1981 was 5421 ha including Burewala city and all rural villages comprising 3.3 % of total land area of the tehsil. In 2001 built up area of tehsil reached to 6714 ha making 4.2% of the total land area and in 2011 it reached to 7586 ha making 4.7% of the total area. The increased built up of the tehsil is majorly accompanied by the urban growth and development of Burewala city (Mohammady and Delavar, 2015). Migration of human population from rural villages towards city became the main reason of urban growth in the region (Badlani et al., 2017). Satterthwaite (2010) also supported the view that urban growth in most of the cases is the result of rural population attraction towards the urban centers and Poverty pressure in nearby rural villages causes migration flow towards cities (Kiani MF and Siyal HB, 1991; Jedwab et al, 2015; Jiang and O'Neill, 2018). Afterwards, area occupied by vegetation in the tehsil was 106436 ha in 1981 and comprised 66.3% of total area, 129696 ha in 2001 making 80% of total tehsil area and in 2011 it is computed as 130153 ha making 81% of total land area. Furthermore, barren land area of the tehsil was 42020 ha in 1981 comprising 26.2% of total land area, 18550 ha in 2001 making 11.5% of total tehsil area and 18022 ha in 2011 making 11.2% of total land area. Fertile soil structure of the tehsil supports the vast agricultural production in the tehsil with spotted settlement in the form villages as shown in classified image in Figure 4. Loamy and clayey soil structure of the tehsil contributes the formation of old and young flood plain supporting major crop production of wheat, cotton and rice. As most of the agriculture in Pakistan is depending upon irrigation more than groundwater therefore improvements in canal irrigation and installation of tube wells from 1990s to 2000s supported the expansion of agricultural area from 1981 to 2001 (Randhawa, 2012; Raza et al, 2012). Sindhu (2010) also reported the 5.5% increase in the installation of electric and 129% increase in diesel powered tube wells in the region supported the agriculture activity. Moreover, increase of labor force in agriculture sector, replacement of mechanization or use of tractors over farm animals for land preparation also helped in the extension of agriculture in the district. Change detection analysis of satellite images shows the expansion of agriculture and reduction of barren land. This rapid expansion of agriculture would take place at the expense of land that was previously saline or nonproductive or being used as rough grazing land (Sindhu, 2010; Islam et al., 2017).

Like other land use, area covered by water bodies also shows dynamic characteristics as it was 4% of total land area in 1981, 3.3% in 2001 and 2.8 % in 2011.

Table 1. Area coverage of land use in respective years for tehsil Burewala.

Land Use Category	1981		2001		2011	
	Area (ha)	Area %	Area (ha)	Area %	Area (ha)	Area %
Built-up	5421	3.3	6714	4.2	7586	4.73
Vegetation	106436	66.3	129696	80.90	130153	81.19
Barren	42020	26.2	18550	11.57	18022	11.24
Water	6437	4.02	5354	3.34	4553	2.84
Total	160314	100	160314	100	160314	100

Table 1. Change Detection of classified images of Burewala city (subset) in respective years.

Land Use Category	1981		2001		2011		change detection (%age)			Rate of urban growth	
	Area (ha)	Area %	Area (ha)	Area %	Area (ha)	Area %	1981-2001	2001-2011	198-2011	1981-2001	2001-2011
Built-up	649	16.14	1206	30	1444	36	13.86	6	19.86		
Vegetation	2699	67.14	2286	57	1884	47	-10.1	-10	-20.1		
Barren	652	16.22	489	12.16	651	16.19	-4.06	4.03	-0.03	4.2%	2.0%
Water	20	0.50	39	0.97	41	1.02	0.47	-0.5	0		
Total	4020	100	4020	100	4020	100					

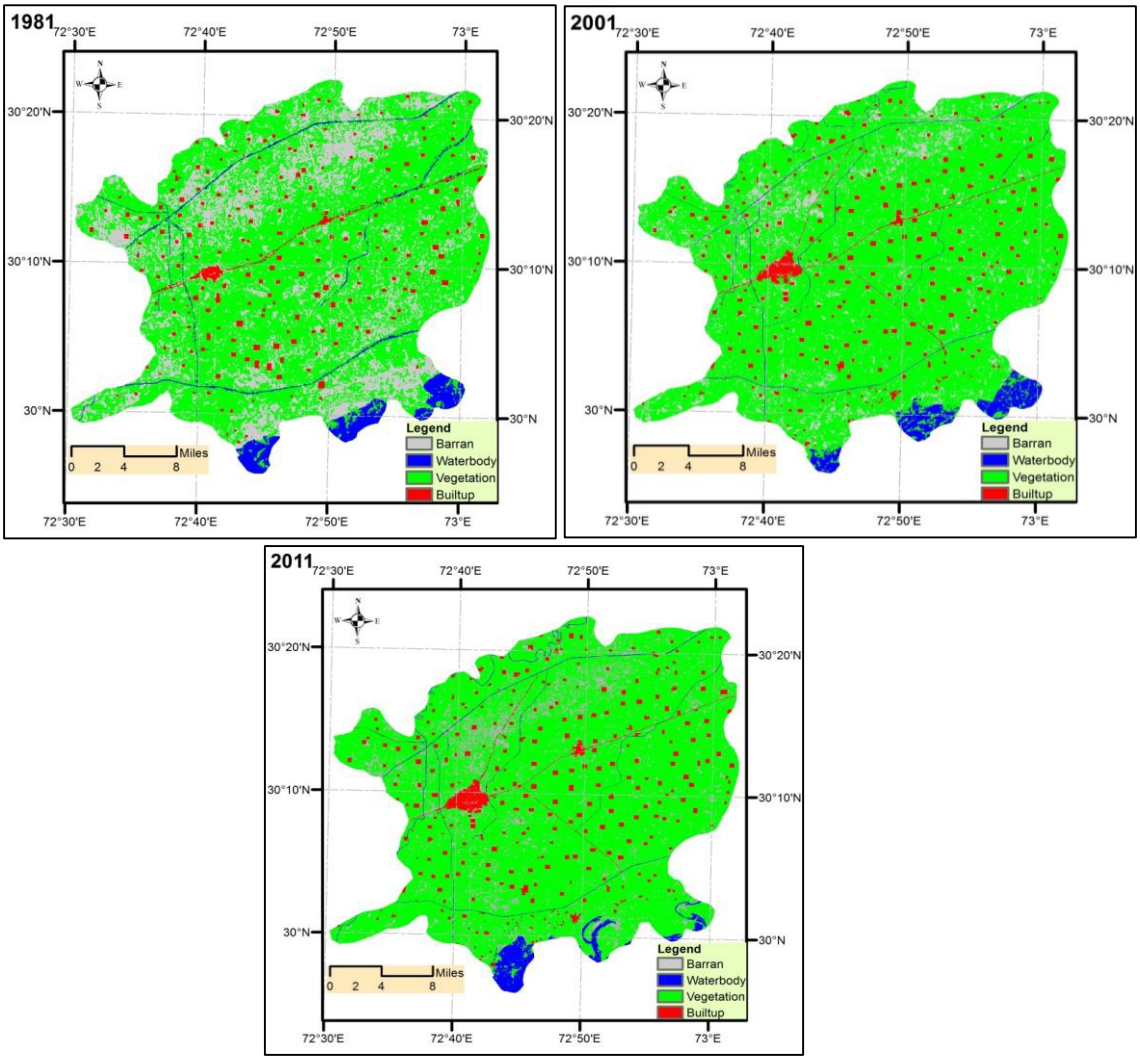

Fig. 1. Classified land use of Tehsil Burewala in three respective years.

In order to analyze the urban growth of the tehsil, a subset of the city Municipal boundary is created for three respective years to monitor the expansion of the city. The results shown in Table 4 indicates the expansion of built up area from 649 ha i.e. 16% in 1981 to 1206 ha making 30% in 2001 and 1444 ha i.e. 36% in 2011. Figure 6 shows the classified land use of city Burewala derived from the tehsil. In contrast to the expansion of built up in the city, vegetative land within the municipal limits decreased from 2699 ha or 67% in 1981 to 2286 ha or 57% in 2001 and 1884 ha or 47% in 2011. Barren land within the city was 26% in 1981 and 11% in 2001 and 2011. Change detection after classification shows that 13.8% increase in built up area of the city from 1981 to 2001 occurred at the expense of 10 % decrease in vegetation and -4% decrease of barren land. From 2001 to 2011, 6% increase in built up area took place with 10% decrease in vegetation area within the municipal limits. Barren land in this time period increased to 4% which might be open or vacant plots in the city. Change detection analysis of whole-time span of 30 years shows a total 19.8% increase in built up area at the expense of the 20% decrease in vegetation.

Figure 7 represents the overlay of built up for three respective years, which clearly explain the urban growth of Burewala city. PMDFC (2008) in their city planning and development report of Burewala also revealed that Burewala city is majorly growing in the north and South East direction. Natural increase and rural Urban migration has a mjor contribution towards the expansion of cities in particular direction (Siddiqi, 1993). The historical Population growth of the city is shown in Table 5 and Figure 5. The results revealed that the population in 1951 was 15 thousand persons and reached to more than 231 thousand persons in 2017. It exerted pressure on agriculture productive land of the city and development of new housing societies and road network facilitated the city urban growth (GOP, 1980; PCO, 1981; Sindhu, 2010).

3.2. Urban growth from 1980 to 2001

Detailed land use maps of the city are obtained from housing and planning department. Figure 8 shows the land use pattern of the city categorized into residential, commercial, educational, public buildings, graveyards, parks and green spaces, disposal lands, open and vacant plots of the city prepared in GIS environment for three respective years. Table 6 shows the area coverage and percentage share of each land use of the city. It is clear from the table that total area of the city increased from 798 ha in 1981 to 1249 ha in 2001. Residential area of the city increased from 29% in 1981 to 53% in 2001. In the year 1980 Burewala city was extended in-between main Burewala-Multan road and the railway line. City was small having low population of about 86000 persons. Main residential areas of the city was located in south-eastern direction in the form of blocks and some housing colonies. Other residential colonies were in north and north-western sides of the city named as yaqub-abad, azeem-abad and fazal-abad colony. In western sides an old housing pattern name mazipura and noor-pur (GOP, 1980). Commercial area was also very limited and located in center of the city comprising 1.4% in 1981 and 1.5% in 2001. No significant commercial development is observed in the city during this time period Major commercial activities are located in the central part of the city and along the linear road network (PMDFC, 2008) . Public buildings of the city also remained confined in the city center comprising an area of 4.6% in 1981 and 2011. One of the major land use characteristics of the city is the industrial Sector. Although many small scale industries developed in the city during the time span of 1981 to 2001 but major land use of industrial sector is occupied by Burewala Textile Mill that is one of the biggest textile industry of Pakistan (PMDFC, 2008). Industrial land use of the city occupied 4.8% in 1981 which increased to 6.9% in 2001. Industrial sectors of the city also became a main factor of population migration from nearby villages for employment opportunities. Another important land use found in the master plan of 1980 and occupying more than 50% of the total land is the presence of vacant or open plots that were neither under cultivation or construction. However, by 2001 more than half of it had been converted into built infrastructure sharing residential and commercial development of the city and decreased to 29%.

Analysis reveals that the overall land use area of the city increased from 798 ha in 1981 to 1251 ha in 2001. Change detection analysis of satellite images as shown in table 4 also reflects that built up area of the city increased to 13.8% in this time span with 4.2% rate of urban growth.

Table 4. Historical population growth of Burewala.

Year	Population
1951	15,383
1961	34,237
1972	57,741
1981	86,311
1998	152,097
2019	231,797

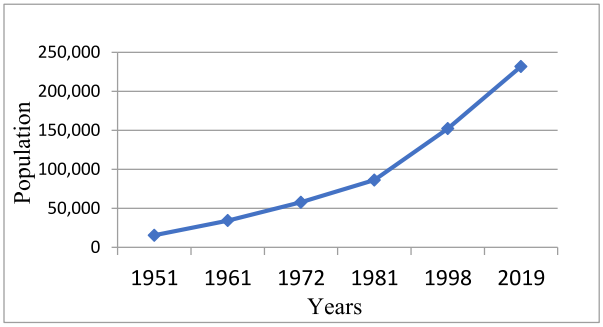

Fig. 2. Historical Population growth of Burewala city as per census.

3.3. Urban growth from 2001 to 2011

Progressive developments are also observed in the time span of 2001 to 2011 reflecting urban growth with 9% further increase in residential areas due to the development of new housing societies like Model town, Faiz abad, Lala zar canal view, Rahmat abad in the North eastern side of the city. The commercial area is increased 2.1% , which facilitated the mentioned residential growth. Area occupied by public buildings also experienced an increase of 1.9% in the form of high-way office, public rest house, civil courts, Burewala club, and cinema etc. Along with other developments, educational institutes also increased in number and area occupied by educational institutes may reached to 4% of total land. In this time span, industrial variation also became a prominent factor of land use change. Many small industries started developing in the periphery areas of the city and industrial area increased to 86 ha making 6% of total land use.

By 2011, land use of the city became more diversified in pattern and shape. Natural increase and rural urban migration became predominant reason for the development of new housing schemes in the north and south of the city. Expansion of city took place in all directions. Conversion of agricultural land into residential schemes lowered the green proportion of the city (PMDFC, 2008). Another significant land use change is observed in the vacant plots which were rapidly filled by the residential, commercial and educational land use and the total land area of the city increased from 1251 hectares in 2001 to 1365 hectares in 2011.

Table 1. Land use classification of Burewala city from Outline development plans in three respective years.

Land use Categories	1981		2001		2011	
	Area (ha)	Area %	Area (ha)	Area %	Area (ha)	Area %
Residential	230.3	29%	658.4	53%	847	62%
Commercial	11.2	1.4%	19.3	1.5%	50	3.6%
Public Building	37.3	4.6%	57.5	4.6%	90	6.5%
Education	12.9	1.6%	13.7	1.1%	52	4%
Parks	7	0.8%	19.4	1.5%	17.6	1.2%
Graveyard	17.5	2.1%	26.7	2.1%	28	2.1%
Industrial	39	5%	86.9	7%	86	6.3%
Disposal	0.47	.06%	0.2	.02%	3.4	0.25%
Open land	442.3	55.4%	369.6	29.5%	191.2	14%
Total land area	798	100	1251	100	1365	100

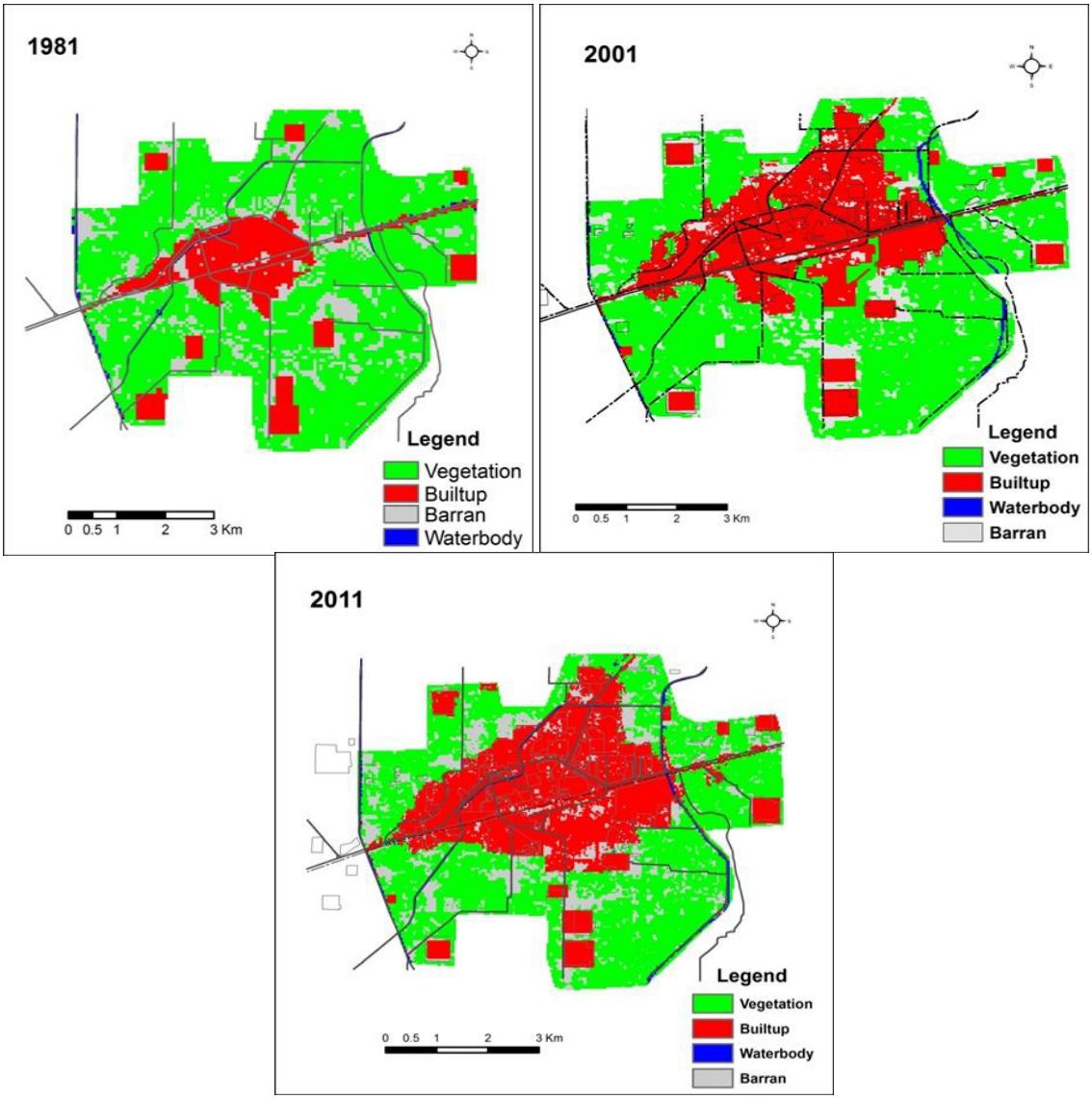

Fig. 3. Land use change of Burewala city derived from supervised classification.

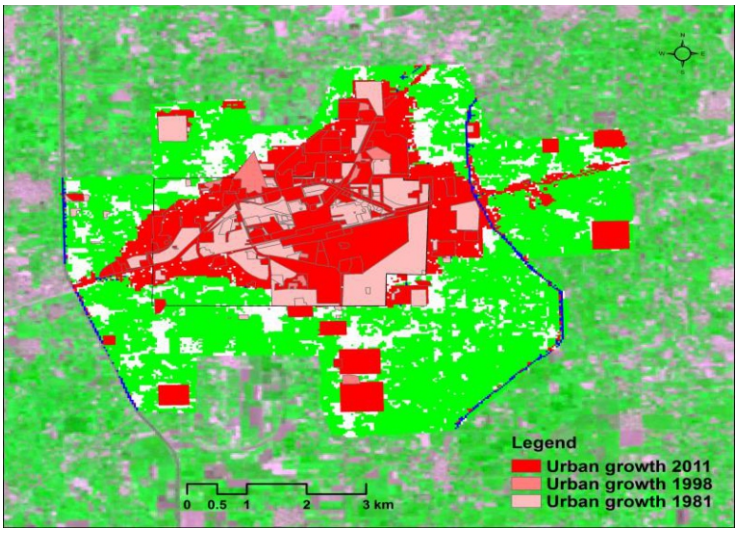

Fig. 4. Urban Growth of Burewala city from 1981 to 2011.

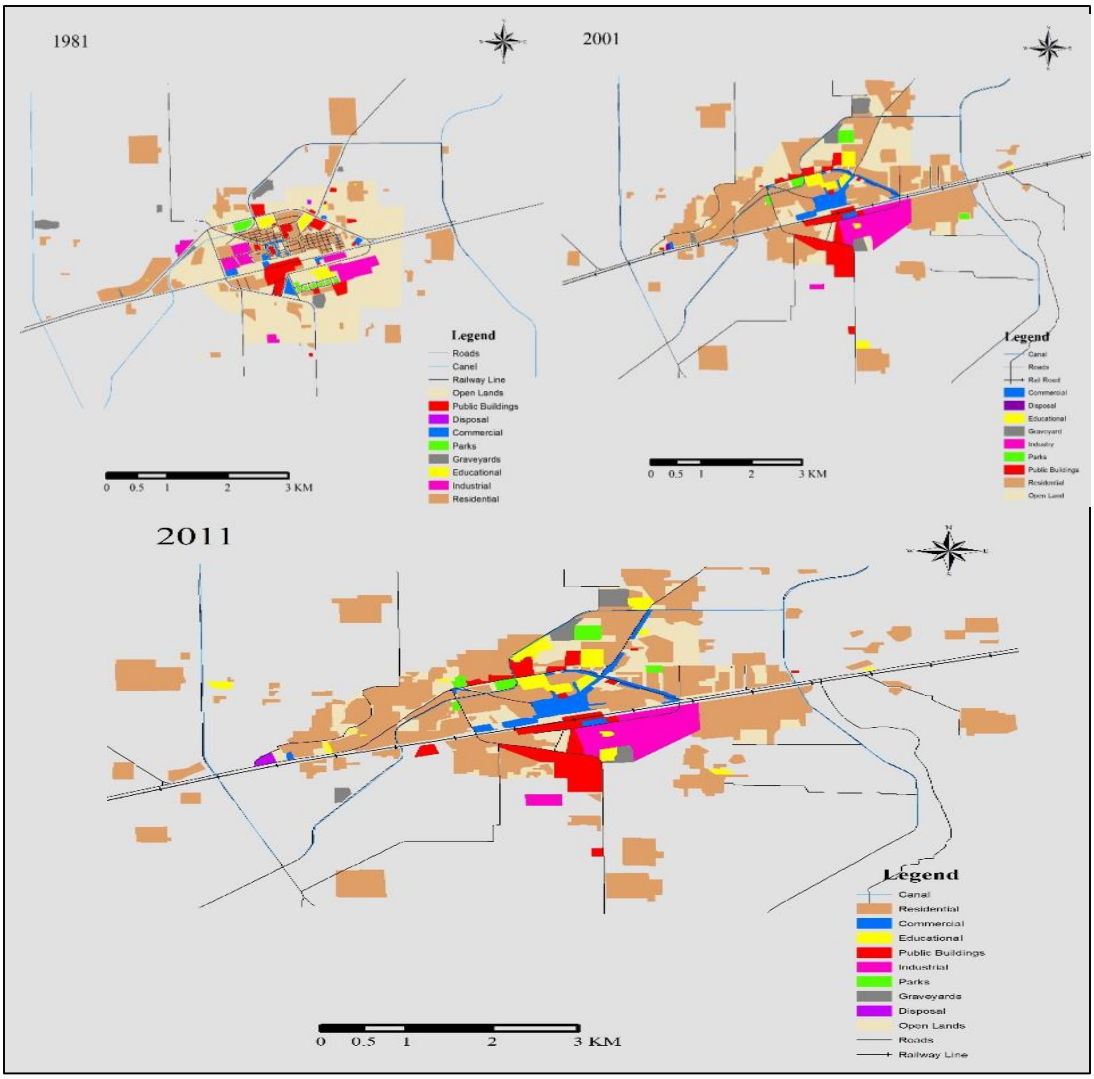

Fig. 5. Land use pattern of Burewala city from 1981 to 2011

4. Conclusion

This study is conducted in one of the small tehsils of Punjab that supports the fact that urban growth is not only taking place in big cities of Pakistan, but small cities and towns are also growing in their spatial extent due to increasing population pressure and infrastructure development. Small towns are converting into cities and small cities are converting into metropolitans. Burewala is also included in the list of medium sized cities that are being developed day by day due to population pressure and infrastructure development. Remote sensing analysis provides a robust computation of change in land cover and rate of urban growth of the city. The analysis shows that the city is expanding in all directions specifically in the north and south-eastern side. The development of road infrastructure, educational institutes and commercialization played a major role for the urban expansion of the city. GIS based analysis of land use plan supported the built-up expansion through residential expansion of the city in the form of new housing societies. Furthermore, Development of small-scale industries also increased the employment opportunities for the permanent settlement of migrant. Remote sensing and GIS used analysis provides empirical evidences of urban growth of the city and this uncontrolled expansion of city in all directions clearly explains the conversion of peri-urban agriculture into built up land. Therefore, it is essential for local Government to play a vital role for the urban planning and management of natural resources like vegetation and agricultural land specifically within the municipal limits. Migration of population in search of employment and better life opportunities sounds good, but improved living standards and

provision of basic services in rural areas can be beneficial for rural landscape of the region.

Authors' Contribution

Sher Muhammad Malik proposed the main concept and involved in write up. Sana Arshad assisted in establishing sequence stratigraphy of the section. Owais Bilal collected field data. Khan Alam did provision of relevant literature review, scientific discussion and proof read of the manuscript.

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