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Assessment of urban sprawl and land use change dynamics through GIS and remote sensing in Quetta, Balochistan, Pakistan

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ABSTRACT

Background: Urban sprawl is a quite complexed phenomenon with several environmental and social implications. Therefore, its assessment, analysis and, modelling are imperative for effective urban planning.

Objectives: The current study aims at assessing the urban sprawl and spatio-temporal LULC changes in Metropolitan Corporation Quetta – capital of Balochistan and the 10th most populous city of Pakistan through GIS and remote sensing data during the period of 1999 to 2019.

Methods: Landsat 7 ETM+, Landsat 5, and Landsat 8 OLI for the years 1999, 2009, and 2019 along with Shannon's entropy model integration with GIS were used to assess land use land cover (LULC) changes and spatial dispersion and compactness of urban sprawl.

Results: Results show that the built-up area is highly increased (52.33%) from 105.14 km^2 to 160.17 Km^2 and massive loss (59.38%) has occurred in vegetation cover from 74.31 Km^2 (1999) to 30.18 Km^2 (2009). Moreover, built-up area is increased drastically (99.89 Km^2, 95%) and open areas are lost by (52.99 Km^2, 34% from 1999 to 2019. The overall relative Shannon's entropy values for the years 1999, 2009 and 2019 are 0.919, 0.940, and 0.957 respectively, which are closest to the upper limit 1, thus, indicates the spatial dispersion within the study area during the study period.

Conclusions: The use of geospatial technologies for assessing and monitoring the pace of urban sprawl and LULC change dynamics in Quetta city may assist to manage and control the unplanned and haphazard urban growth and sprawl in the city. Moreover, a comprehensive Master Plan of Quetta city is the need of the today. Besides this, effective coordination among the planning and development departments is direly needed. Further research can be done on the use of GIS and remote sensing for future prediction of changes in urban sprawl and LULC.

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Pakistan

1. INTRODUCTION

The rapid population growth is leading to uncontrolled, haphazard growth in the outskirts of city areas. This is commonly termed as urban sprawl - a scattered development along highways, or around the urban area (Theobald, 2001). It can be defined as "an expansion of the peripheral boundary, the spread of development in sensitive green fields and agricultural soils, increase in congestion on highways, increase of new subdivisions of similar and low density, single-family dwellings" (Bourne, 2001). In today's world, both in developed and developing countries, cities are witnessing urban sprawl phenomenon

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(Inostroza et al., 2013). Urban sprawl is a complicated phenomenon, with several environmental and social implications (Barnes et al., 2001). It is considered as a negative type of urban growth that causes adverse effects (Mohammady & Delavar, 2016). The most significant negative impacts of urban sprawl include an increase in automobile reliance on transportation (Torrens & Alberti, 2000), loss of productive agricultural land around the cities (Brabec & Smith, 2002; Zhang, 2000), loss of green areas, and devastation of forest land, increased energy use, need for more infrastructure and related costs (Brueckner et al., 2001). Similarly, it leads to longer travel times and increased car traffic, travel costs and, ultimately, massive environmental pollution, depletion of peri-urban habitat (Johnson, 2001; Y. Li et al., 2006), and disintegration of land use and biodiversity loss (Alberti, 2005), and reducing equal access to urban administration (Burton, 2001). In metropolitan areas, unplanned urban sprawl is a serious concern. Development and implementation of proper land managing practices is the only source to make urban growth viable (Bhatti et al., 2015; Zhao, 2010).

Urban sprawl is imperative to be monitored, modelled, and analysed (Mohammady & Delavar, 2016). As it is defined in diverse ways, thus several methods are available for measuring it. To capture the numerous dimensions of sprawl, various techniques are used. The modern remote sensing techniques, both aerial and satellite-based systems, and their integration with Geographic Information System (GIS) allow us to analyse the data spatially, offering possibilities of the assessment of urban sprawl at a very speedy and repetitive way (Ghosh et al., 2014). From the past few decades, remote sensing and GIS techniques, particularly due to their low cost, massive spatial coverage's repetitive observations and efficient data-processing capabilities, have been extensively used for assessing and monitoring of spatio-temporal land use and land cover (LULC) changes, and spatial patterns of urban growth and sprawl (Corner et al., 2014; Raziq et al., 2016). The use of GIS along with remote sensing data serves to be a powerful tool for land use /land cover changes assessment and urban sprawl modelling studies (Aswal et al., 2018; Tiwari et al., 2018).

Remote sensing technology, a free-to-less expensive data source, provides satellite imageries and their time-series data that impressively enrich the capability for monitoring urban sprawl and growth (Goodchild, 2000; Hayek et al., 2011), land use land cover change dynamics (Herold et al., 2003), landscape pattern analysis (Li & Yeh, 2004), and urbanization (Weng, 2007). Hence, the utilization of geospatial approaches to assess and monitor urban development viz-a-viz population increase. The resulting change in land use/land cover has been started since 1970's when the first Landsat Satellite was launched (Hadeel et al., 2009; Rashed et al., 2005; Shirazi & Kazmi, 2014). Knowledge about land use and land cover has become increasingly important in the planning process, especially, to overcome the problems of haphazard, uncontrolled development, deteriorating environmental quality, loss of major agricultural lands, and loss of fish and wildlife habitat (Anderson, 1976).

Several studies have been conducted to examine LULC changes and urban sprawl in various parts of the world as well as in Pakistan. Aswal et al. (2018) used two satellite imagery of the year 2008 and 2016 to map the urban growth patterns of Kanpur city, India. They used a basic remote sensing built-up index - normalized difference built-up index (NDBI) – a technique to compute the urban built-up area. Further, multi-ring buffer analysis was employed over both year imageries to estimate the changing pattern of urban sprawl from the city center. Malligai and Jegankumar (2018) used eight-year temporal satellite imageries and toposheets from 1932 to 2017. These imageries were then classified into built-up and non-built-up areas and the total area was calculated. The central business district (CBD) was chosen as a central point of the study area. It was then divided into 15 concentric circles and multi-ring buffer analysis was applied. The interval between each buffer was 1 km. For urban sprawl analysis, Shannon's entropy method was computed for the years 1932 and 2017.

Remotely sensed, Landsat's data for the years 1999 and 2016 were used for LULC changes and urban sprawl assessment of Peshawar city. Landsat 7 ETM+ and Landsat 8 OLI cloud-free data from 1999 and 2016 covering the study area were acquired freely from the US Geological Survey (USGS) (Raziq et al., 2016). Ghosh et al. (2017) used Landsat images with a temporal variation for the year 1977 (Landsat-2 (MSS) and for 2017 (Landsat-8 (OLI & TIRS) which were acquired from USGS Earth Explorer site for classifying land use. Supervised Classification Technique - Maximum Likelihood Algorithm was applied for land-use analysis, using signatures from training samples which included all land use types. Accuracy assessment was performed with the help of Kappa Coefficients. Built-up area, airport, low vegetation, forests/tree cover, agricultural land, open space, rivers/streams, and inland water bodies were the classes used for the study. Shannon's Entropy was computed to determine the growth and urban sprawl were divergent or compact (Raziq et al., 2016).

In Pakistan, several studies have been conducted on the assessment of urban sprawl and the monitoring of LULC changes. From Khyber Pakhtunkhwa, Raziq et al. (2016) have analyzed urban sprawl and LULC changes in Peshawar city. Studies from Punjab have also assessed urban sprawl using multi-stage remote sensing data in Lahore (Mahboob & Atif, 2015), urbanization and urban sprawl analysis through remote sensing and GIS in Faisalabad (Safder, 2019), and monitoring urban expansion and land-use change analysis in Lahore and Bahawalnagar (Aziz & Ghaffar, 2017; Bhalli & Ghaffar, 2015). From Sindh, Mahboob et al. (2015) have assessed the urban sprawl in Karachi. Similarly, urban sprawl in Islamabad was studied by Butt et al. (2012) through multi-sensor and multi-temporal data. There is a lack of literature that has explored urban sprawl and land use land cover changes in Balochistan. To the best of authors' knowledge, none of the study is available on assessment of urban sprawl of the Metropolitan Corporation Quetta (MCQ), the provincial capital and 10th most populous city of Pakistan (Pakistan Bureau of Statistics, 2017). To fill the gap in the body of knowledge, this study is first of its kind. The current study aims at assessing the urban sprawl and spatio-temporal LULC changes in MCQ through the integration of Shannon's Entropy model with GIS and remote sensing data for the years 1999, 2009 and, 2019.

2. METHODS

2.1 Study design

This paper follows the case study research design. Quantitative techniques and geospatial technologies such as GIS and remote sensing were used for statistical and geospatial analyses.

2.2 Setting

Metropolitan Corporation Quetta (MCQ) is a basin which is a bowl-like valley surrounded by mountains (Figure 1). It is the capital and biggest city in the province of Balochistan, and 10th populous city in Pakistan (Pakistan Bureau of Statistics, 2017). The city is part of the Pishin Lora Basin, located on the borders of Pakistan and Afghanistan (Khan et al., 2013). Geographically, Quetta city is located at 30.17° North latitude and 66.97° East longitude. It is the most urbanized city of the province and has 2, 037, 637 population (Balochistan Local Government, 2019). The average elevation of Quetta valley above sea level is 1300 meters (5,500 ft.) The watershed area of the valley is 1756 square kilometers, out of which 792 square kilometers have an alluvium cover (Alam, 2010). The elevated valley is bounded in the west and southwest by Koh-i-Chiltan, in the north by Takattu range in the southeast by Koh-i-Lamrdar (Sunny Mountain) and to the north-east by Zarghoon hills. These mountains rise to a height of about 3470 meters above sea level.

The valley is accessible by four pathways. From the north-east it opens into Bostan plain. Sariab connects Quetta with Dasht plain to the South. Whereas, Sharan Tangi gap connects Quetta with Kutch valley through Hanna valley. Lastly, Sur-Range connects Quetta with Oshtakai to the south-east.

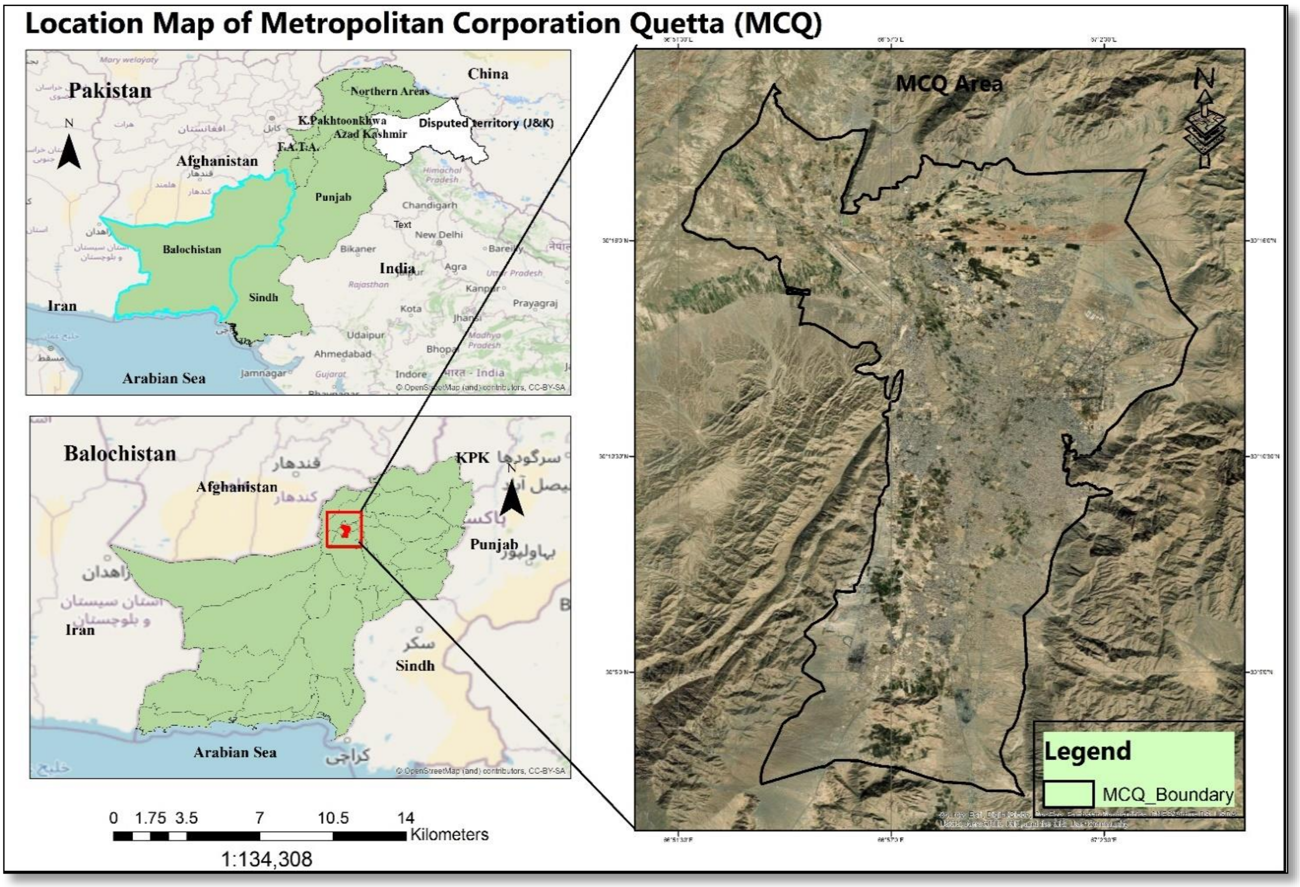

Figure 1 Location map of Metropolitan Corporation Quetta (MCQ)
Source: The boundary of MCQ was obtained from Regional office, Pakistan Bureau of Statistics, Quetta.

2.3 Data sources

The remote sensing data for assessing urban sprawl and LULC changes were obtained from the Earth explorer, United States Geological Surveys (USGS) (USGS Earth Explorer, 2019). For detection of LULC change ArcGIS 10.2.2 software was used. The MCQ boundary of 2019 was used for all three-year data.

2.4 Data analysis methods

Data were collected from various sources to assess urban sprawl and LULC change dynamics. Landsat imageries with temporal variation were acquired free of cost from the United States Geological Survey (USGS), Earth explorer was used for classifying LULC (USGS Earth Explorer, 2019). All imageries were USGS processed and provided with level-one terrain-corrected (L1T) Landsat data in WGS84 geodetic datum, Universal Transverse Mercator map projection (UTM, Zone 42N). These satellite imageries were already radiometrically and geometrically corrected by USGS (Landsat NASA; Rahman, 2016). Ten years interval between two temporal data was used in this study (Boori et al., 2015; Jensen & Im, 2007). Specification of satellite imageries was as follows: Landsat-7 for the year 1999, Landsat-5 for the year 2009 and Landsat-8 for year 2019 (Table 1). The satellite imageries were further processed in ArcGIS software and Google earth pro.

2.4.1 Remotely sensed data pre-processing

Satellite imageries having multi bands are combined into a single raster dataset for all three years 1999, 2009, and 2019, using band composite tool in ArcGIS 10.2.2. False colour composite (FCC) of all imageries were generated. Using "Extract by mask tool" imageries were cropped with the updated boundary of the study area in ArcGIS software. Image enhancement was also done in ArcGIS.

Methodology adopted for current study

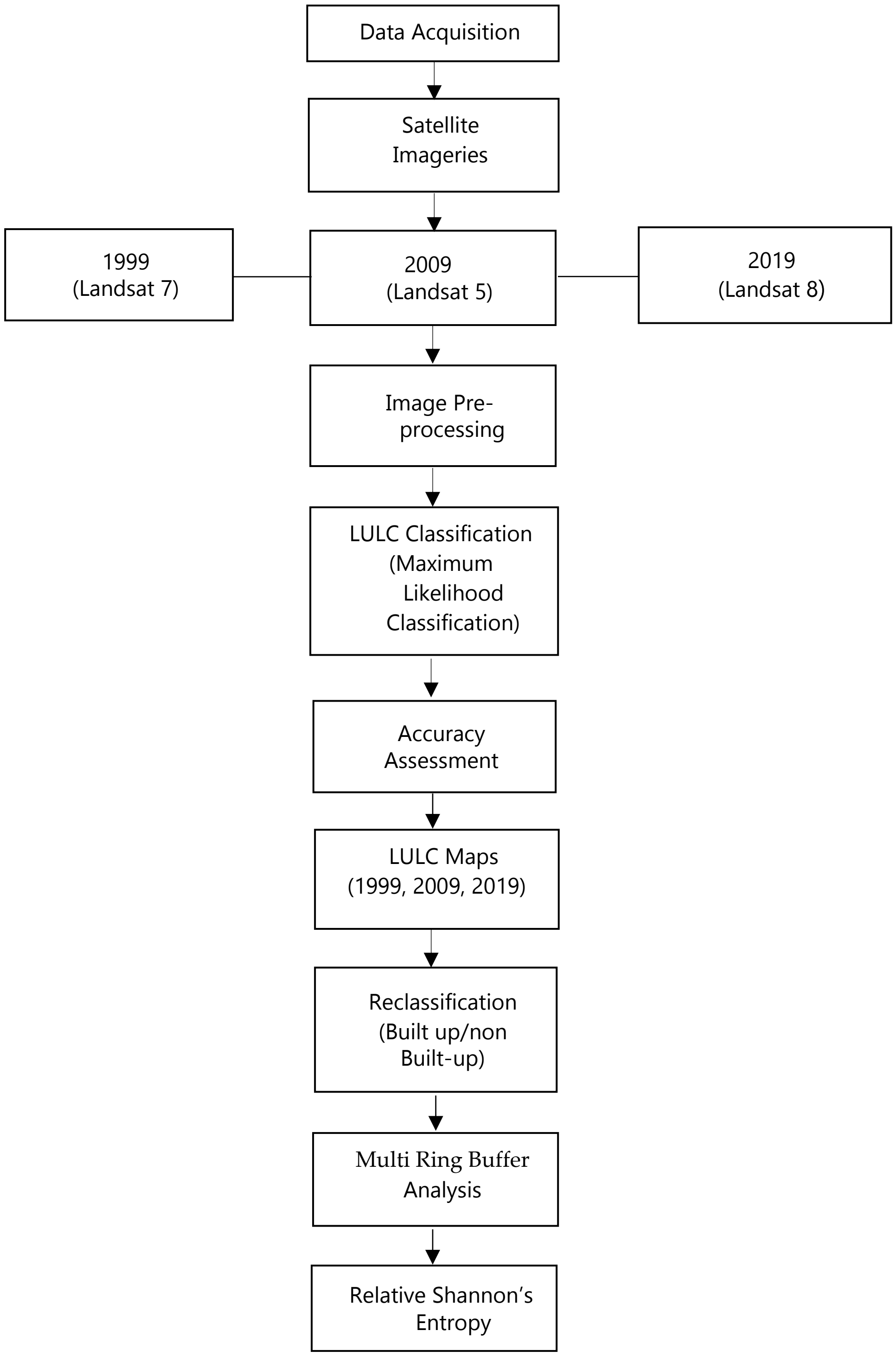

Figure 2 Flow chart showing methodology adopted for the current study

2.4.2 Remotely sensed data pre-processing

Satellite imageries having multi bands are combined into a single raster dataset for all three years i.e., 1999, 2009, and 2019, using band composite tool in ArcGIS 10.2.2. False colour composite (FCC) of all imageries were generated. Using the "Extract by Mask" tool imageries were cropped with the updated boundary of the study area in ArcGIS software. Image enhancement was also done in ArcGIS.

Table 1 Landsat Imageries used in this study

Acquisition Year	Acquisition Date	Sensor	Path/Row	Spatial Resolution of Respective bands	Cloud Cover (%)	Number of Bands	Format
1999	3 July 1999	Landsat-7 ETM+	153/39	30	Less than 10	8	GeoTIFF
2009	22 July 2009	Landsat-5	153/39	30	Less than 10	7	GeoTIFF
2019	18 July 2019	Landsat-8 OLI/TIRS	153/39	30	Less than 10	11	GeoTIFF

Source: (USGS Earth Explorer, 2019).

2.4.3 Image processing and LULC classification

Based on Anderson's classification level I scheme, three LULC classes i.e., built-up land, vegetation cover, and open areas were identified in Landsat images (Anderson, 1976). Ninety (90) training samples, 30 from each class, were chosen for LULC classes and polygons were drawn properly on these training samples' sites for all three year imageries. Then, supervised Maximum Likelihood Classification (MLC) technique was applied to classify imageries. Then statistics regarding growth among these classes were acquired and LULC maps were generated for the years 1999, 2009 and 2019 (Figure 3 and 4). The classification scheme for LULC is shown in Table 2.

Table 2 Land cover classification scheme used in this study.

Land Cover Type	Description
Built-up land	All types of manufactured structures: residential, industrial, agricultural commercial and Services; transportation and utilities; mixed urban or built-up.
Vegetation	Trees, natural vegetation, gardens, recreational areas and playgrounds, grassland, vegetated
Open areas	Areas with no vegetation cover, sand, open space, bare soils, and uncultivated Agricultural lands.

Source: (Rahman, 2016; Tewolde & Cabral, 2011)

2.4.4 Accuracy assessment

Accuracy assessment is a method to evaluate the validity of classification. Kappa coefficients was done for this. Overall accuracy of the classification was performed for all imageries using kappa coefficient.

2.4.5 Urban sprawl measurement

In the current study, for measurement of urban sprawl, the geospatial analysis techniques such as Reclassification Approach, Multi Ring Buffer Analysis, Intersection tool, and Relative Shannon's Entropy (RSE) were used.

(1) Reclassification

To assess the density and expansion of built-up areas in the study area during the three time periods, imageries were reclassified into built-up and non-built-up land areas and maps were generated. This method was followed for all the selected imageries (1999, 2009 and 2019). Then the built-up and non-built-up areas were calculated in ArcGIS. These calculations were then used in Multi Ring Buffer Analysis for calculating Shannon's Entropy values to find out the compactness or dispersion of built-up area.

(2) Multi Ring Buffer Analysis

Multi Ring Buffer Analysis technique was applied for creating buffers (zones) with 2 km interval around the city's centre i.e., central business district (CBD). Masjid at the city centre used to be very old, thus, is considered to be the original centre of the city. Following previous studies, Grand Kandahari Jamia Masjid at Bacha Khan Chowk has been selected subjectively as the centre of City in this study (Aswal et al., 2018; Boori et al., 2015; Malligai & Jegankumar, 2018; Rahman, 2016). Rahman (2016) selected Mosque Al-khobar as a city centre. Likewise, Boori et al. (2015) and Aswal et al. (2018) also drawn rings around the central point. In the current study, nine concentric ring buffers were drawn around the city centre with an interval of 2 km to cover the entire study area. All rings buffers were clipped and fixed to the size of study area boundary using clipping tool in geo-processing tab in ArcGIS 10.2.2. The classified imagery and buffer layers were then intersected in ArcGIS, and built-up land of every ring with an interval of 2 km was calculated to analyse the urban growth in the study area. This method was applied for all years' data.

(3) Relative Shannon's Entropy

In studies on urban sprawl, the most proficient and generally used approach is to integrate Shannon's Entropy (En) with GIS tools (Sun et al., 2007; Tewolde & Cabral, 2011). Shannon's Entropy calculates the density of urban development to measure the degree of concentration or dispersion among n zones (Rahman, 2016; Tewolde & Cabral, 2011). Therefore, the Relative Shannon Entropy (RSE) value for each and overall ring buffers for each year i-e. 1999, 2009 and 2019 has been calculated (Table 8) to assess the urban Sprawl in the study area suing this formula:

$$En = \sum^{n}_{\mathrm{i}} \; \mathrm{Pi} \log(1/\mathrm{Pi}) / \mathrm{Log}(n)$$

Where,

En=is the relative entropy
Pi=probability or proportion of built-up in the zone
N=Number of zone

$$Pi = Xi / \sum^{n}_{\mathrm{i}} \; Xi$$

Where,

Xi=is the density of developed land, which equals to the amount of built-up land divided by the total amount of land in the i^{th} zone in n total zones

The value of Shannon entropy ranges from 0 to log n. Value of 0 indicates that the distribution is a very compact and high-density urban development that makes city vulnerable while value nearer to 1 indicates low-density urban development and high degree of urban sprawl causing disarray in providing transportation and other utility services (Malligai & Jegankumar, 2018).

3. RESULTS

3.1 Land use and land cover (LULC) classification and change detection analysis

The results of land use and land cover classification using the Maximum Likelihood Classification technique for three time periods (1999, 2009, and 2019) within the study area are given in Table 3. Three classes were selected for all year imageries for the classification of Landsat-7 ETM+, Landsat-5, and Landsat-8 OLI/TIRS to obtain appropriate results (Table 2). The statistics of each land use and land cover class for all three years are shown in Table 3. The result shows that the built-up land area was 105.14 km^2 (31.70 %), open areas 152.19 Km^2 (45.90%), and vegetation area was 74.31 Km^2 (22.40%) in 1999. While in 2009, the built-up land was 160.17 Km^2 (48.29 %), open areas 141.32 km^2 (42.60 %) and vegetation area was 30.18 Km^2 (9.09%). According to the LULC classification results, the built-up area in 2019 was 205.03

Km^2 (61.82%), open areas 99.20 Km^2 (29.91 %), while vegetation area 27.42 Km^2 (8.26%). The result indicates that the overall increase (99.89 Km^{2,} 95%) in built-up area, decrease (52.99 km^2, 34%) in open areas and loss (46.89 km^2, 63.10%) in vegetation land cover from 1999 to 2019. The maps showing land use and land cover classification of the year 1999, 2009, and 2019 are shown in Figure 3 and Figure 4.

3.2 LULC change detection from 1999 to 2009

According to statistics calculated from the land use land cover maps of 1999 and 2009, the built-up area is highly increased from 105.14 km^2 (31.70 %) in 1999 to 160.17 Km^2 (48.29 %) in 2009. The 55.03 Km^2 (52.33 % +v) Change in built-up land has been detected from 1999 to 2009 period of time. Whereas, decrease in vegetation cover from 74.31 Km^2 (22.40%) in 1999 to 30.18 Km^2 (9.09%) in 2009, with a difference of 44.13 Km^2 (59.38 % -v) has also been observed in this period. It can be inferred from the results that in first-decade massive changes occurred in the study area in terms of built-up area (55.03 Km^2 +v change) and in vegetation (44.13 Km^2 -v Change), (Table 4).

3.3 LULC change detection from 2009 to 2019

LULC change in the study area has continuously occurred. A significant change of 44.86 km^2 (28 % +v) has been detected from the year 2009 to 2019 in built-up areas. Whereas, a very little change is observed in vegetation during this period compared to the period (1999 to 2009) where enormous negative change has occurred in vegetation cover. Open areas of 42.12 Km^2 (29.80 % -v change) has been converted into a built-up area during the period 2009 and 2019. Table 4 and Figure 5 show the statistics about LULC changes during three time periods.

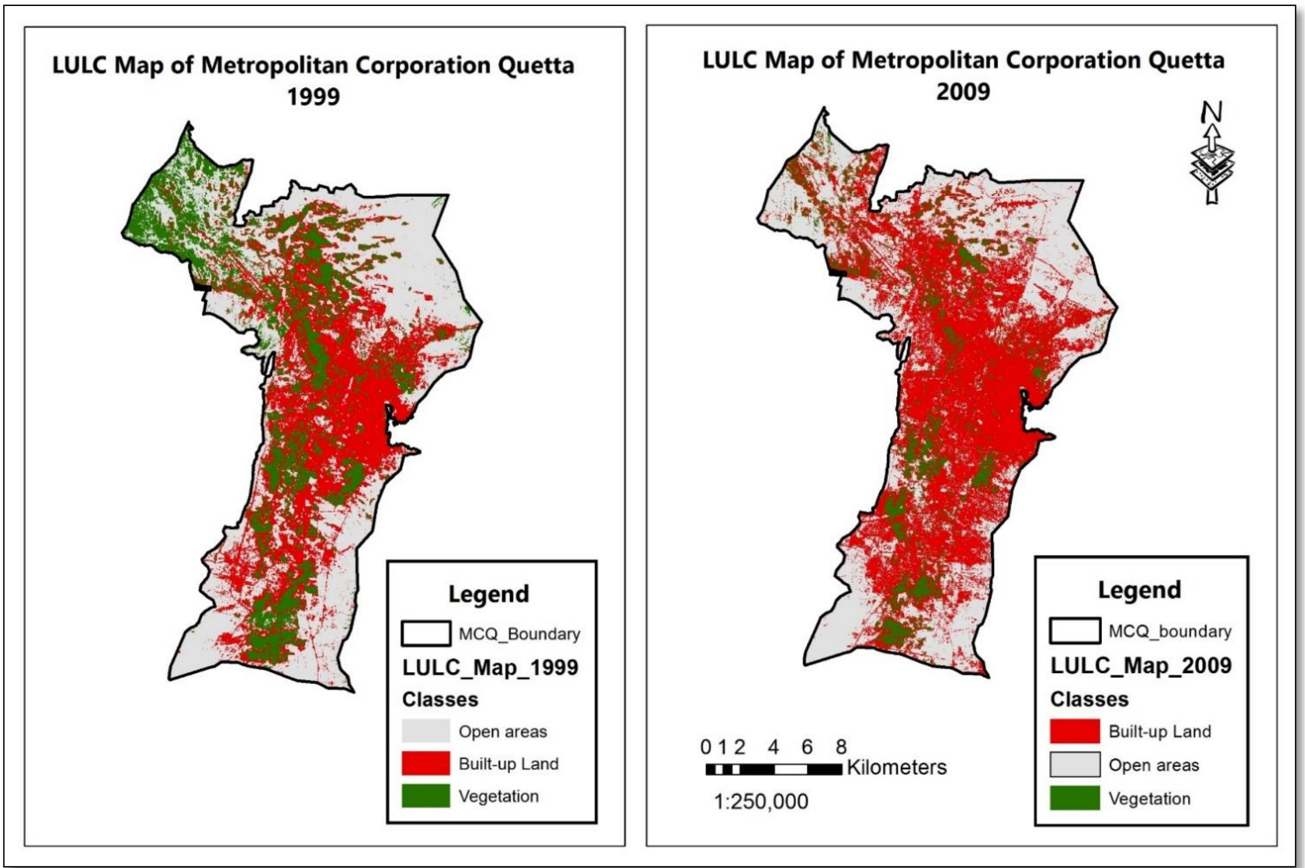

Figure 3 LULC Maps of Metropolitan Corporation Quetta (MCQ), showing various classes that are classified for the year 1999 and 2009.
Source: Generated by authors

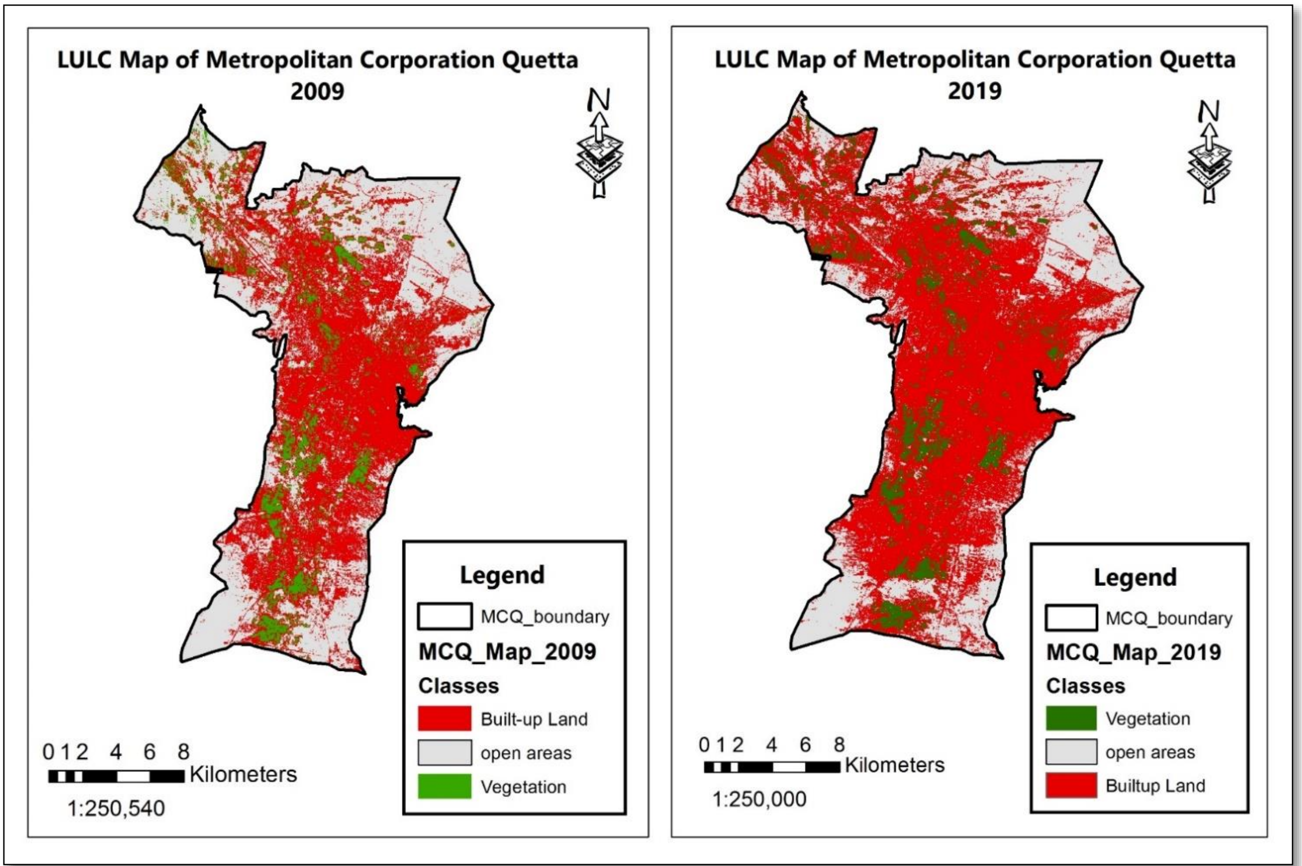

Figure 4 LULC Maps of Metropolitan Corporation Quetta (MCQ) showing various classes that are classified for the year 2009 and 2019.
Source: Generated by authors

Table 3 LULC classification for the years 1999, 2009, and 2019

Sr no.	Land Classes	1999		2009		2019	
		Area (Km^2)	Area (%)	Area (Km^2)	Area (%)	Area (Km^2)	Area (%)
1	Built-up Land	105.14	31.70	160.17	48.29	205.03	61.82
2	Open areas	152.19	45.90	141.32	42.60	99.20	29.91
3	Vegetation	74.31	22.40	30.18	9.09	27.42	8.26
4	Total Area	331.6		331.6		331.6	

Source: Authors' calculations

Table 4 LULC change detection analysis for the years 1999, 2009, and 2019

Sr. no	Land Classes	Change detection b/w 1999 to 2009		Change detection b/w 2009 to 2019		Change detection b/w 1999 to 2019	
		Area (Km^2)	Area (%)	Area (Km^2)	Area (%)	Area (Km^2)	Area (%)
1	Built-up Land	55.03 (+v)	52.33(+v)	44.86 (+v)	28 (+v)	99.89	95 (+)
2	Barren Land	10.87(-v)	7.14(-v)	42.12(-v)	29.80(-v)	52.99(-v)	34(-v)
3	Vegetation	44.13(-v)	59.38(-)	2.76(-v)	9.145(-v)	46.89(-v)	63.10(-v)

Source: Authors' calculations

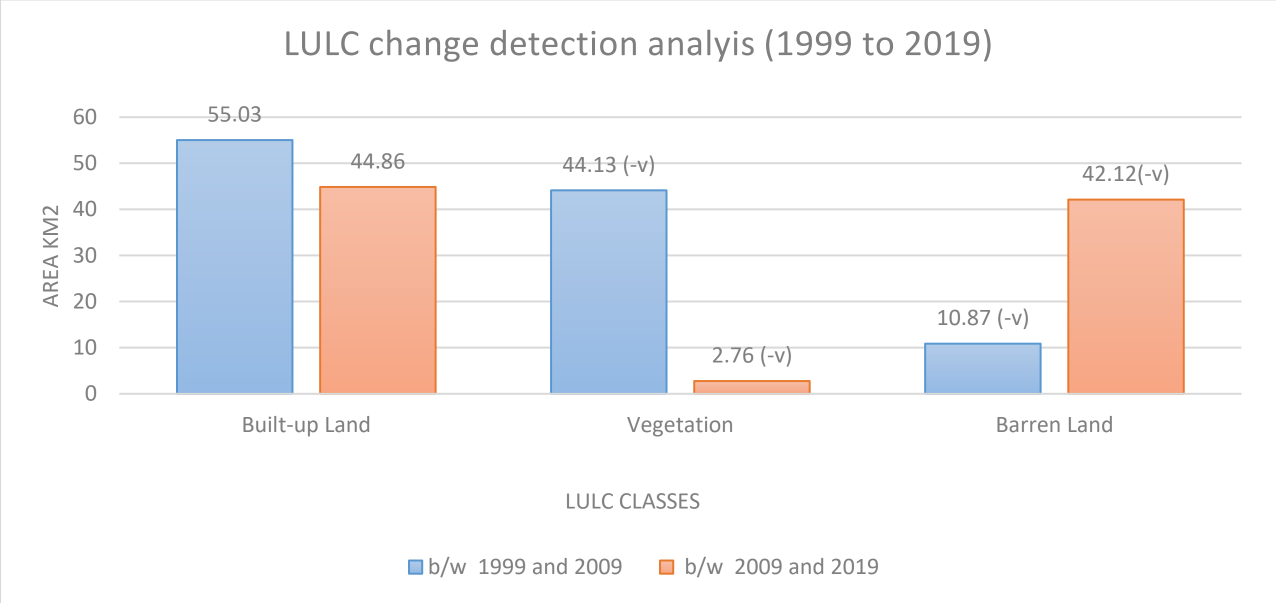

Figure 5 Change detection analysis between 1999, 2009 and 2019

3.4 Accuracy assessment

Accuracy assessment (Producer's accuracy, user's accuracy, and kappa coefficient) was calculated from the error matrix for each classified dataset (Table 5). The overall accuracy of LULC classification was 0.82, 0.91, and 0.91 respectively for the years 1990, 2009, and 2019. The level of accuracy was more than the Anderson's standard 0.85 or 85% accepted overall accuracy level for LULC classification (Anderson, 1976; Rahman, 2016).

Table 5 Accuracy assessment of LULC classification

Land cover classes	Producer's accuracy			User's accuracy		
	1999	2009	2019	1999	2009	2019
Built-up land	77.5	100	100	91.17	85.7	85.71
Vegetation	100	100	100	90.90	100	100
Open areas	90	83.33	83.33	83.72	100	100
Overall accuracy	1999		2009		2019	
	0.82		0.91		0.91	

Source: Authors' calculations

3.5 Urban sprawl measurement

3.5.1 Built-up change analysis

In order to assess city expansion and further analysis for the measurement of urban sprawl in the study area, imageries were reclassified into built-up and non built-up areas. Figures 5, 6, 7 and Table 6 show the total built-up and Non- built-up land area of Quetta city and results acquired from the analysis of urban built-up maps. The built-up area of Quetta city was 105.14 (Km^2) in the year 1999,160.17 (Km^2) in 2009, and 205.03 (Km^2) in 2019. The total built-up area of Quetta city has been increased from 105.14 (Km^2) to 205.03 (Km^2) which constitute a 45.45% increase from 1999 to 2019. This specifies that the built-up land is rapidly increasing from the year 1999 to 2019 in general, and massive growth in the built-up area detected from 1999 to 2009 in particular. This increase was due to the war condition in neighboring Afghanistan, after the invasion of the United States and its allies. This further aggravated the situation in an already urbanized and unplanned city in terms of housing, traffic congestion, water and sanitation problems, and solid waste management, etc. due to this massive changes from 1999 to 2019, where the planning for the city was already lacking, urban sprawl occurred in the surroundings of CBD, which further created more problems for the residents of the city as well as government departments and planners.

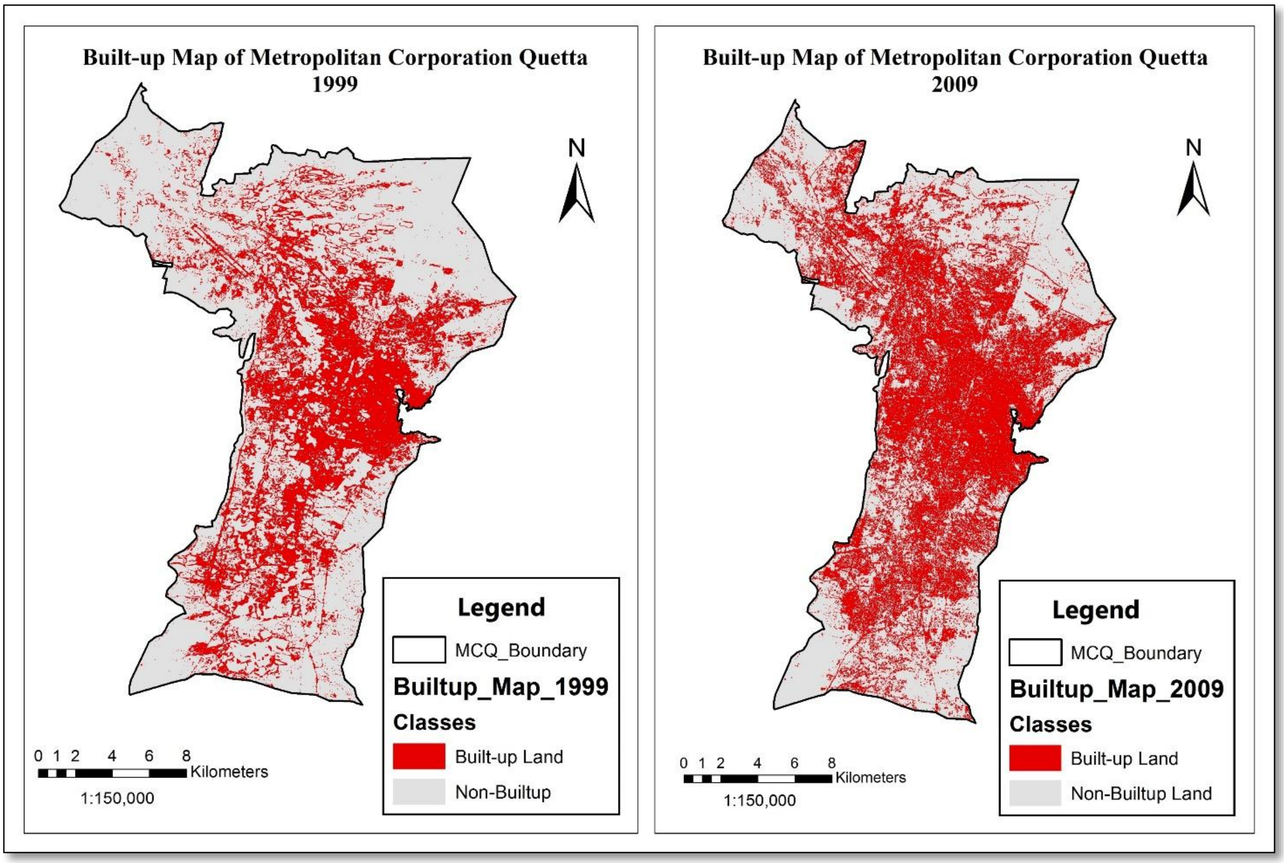

Figure 6 Built-up maps showing built-up and non-built-up areas of Metropolitan Corporation Quetta (MCQ), for the year 1999 and 2009.
Source: Generated by authors

Table 6 Built-up land and non-built-up land of study area

Sr no.	Classes	1999 (area in Km^2)	2009 (area in Km^2)	2019 (area in Km^2)	Change from 1999 to 2009 (%)	Change from 2009 to 2019 (%)	Change from 1999 to 2019 (%)
1	Built-up land	105.14	160.17	205.03	52.33 (+v)	28 (+v)	95 (+v)
2	Non-built-up land	226.50	226.50	126.62	-24.29 (-v)	-26.15(-v)	-44 (-v)

Source: Authors' calculations

3.5.2 Multi ring buffer analysis

For a further in-depth assessment of the study area, multi-ring buffer analysis technique has been applied. Multi ring buffer technique allows researcher(s) to investigate in detail the urban growth through creating buffers on the map and acquire statistics for each zone/circle within the study area. To evaluate the built-up growth of each ring buffer (zone) and further analysis of the data for Shannon's entropy, a multi-ring buffer technique in ArcGIS was used. While doing so, 18 ring buffers with an interval of 2 km around the city center (*Grand Kandahari Jamia Masjid, Bacha khan Chowk*) were created until the entire study area is covered. The result shows that within the 0-2 km zone, the area is almost urbanized and densest among all other zones with 75.44%, 87.94% and 89.38% of built-up land in 1999, 2009 and 2019 respectively. The zone is a central business district (CBD) area of the city, where most of the commercial activities take place. Whereas, the built-up area in the zone between 4-6 km is higher among all other zones with 23.26 Km^2, 32.53 Km^2, and 37.64 Km^2 in 1999, 2009 and 2019 respectively. Further detailed result is shown in Table 7 and Figure 11. Multi ring buffer analysis for the year 1999, 2009, and 2019 are shown in Figure 9 and 10.

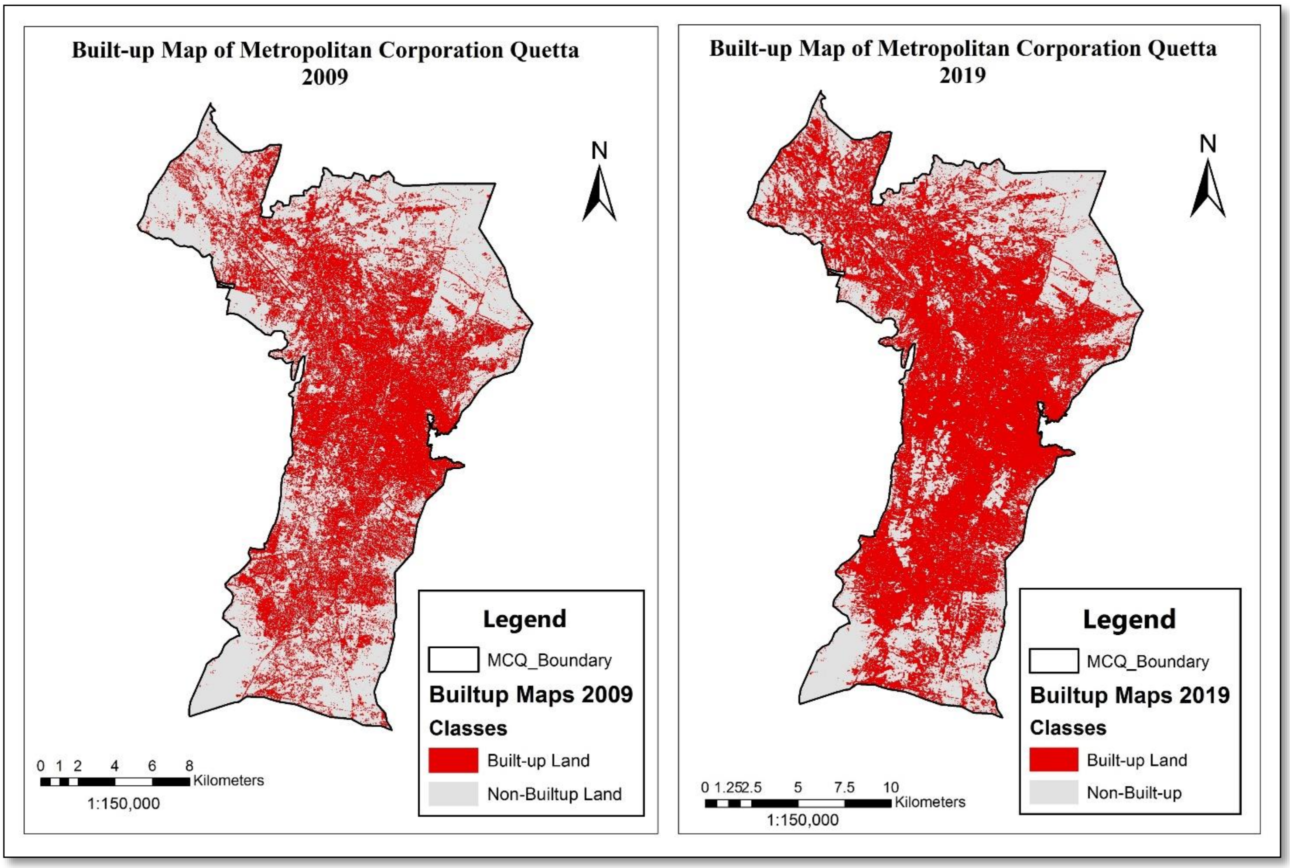

Figure 7 Built-up maps showing built-up and non-built-up areas of Metropolitan Corporation Quetta (MCQ) for the year 2009 and 2019; Source: Generated by authors

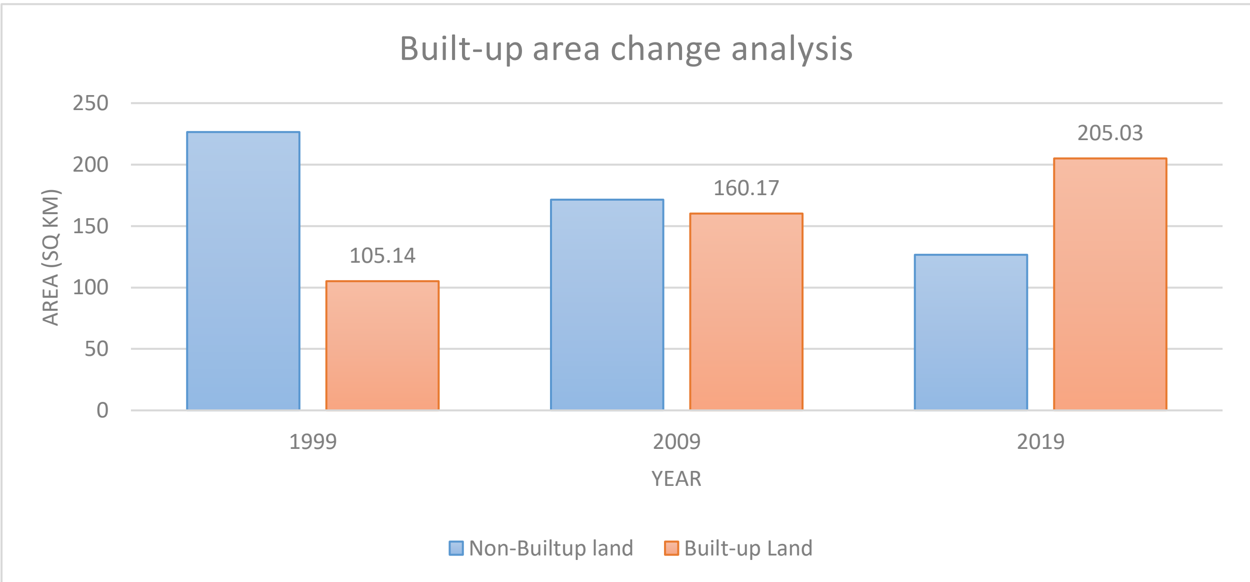

Figure 8 Built-up and non- built up land of Quetta city

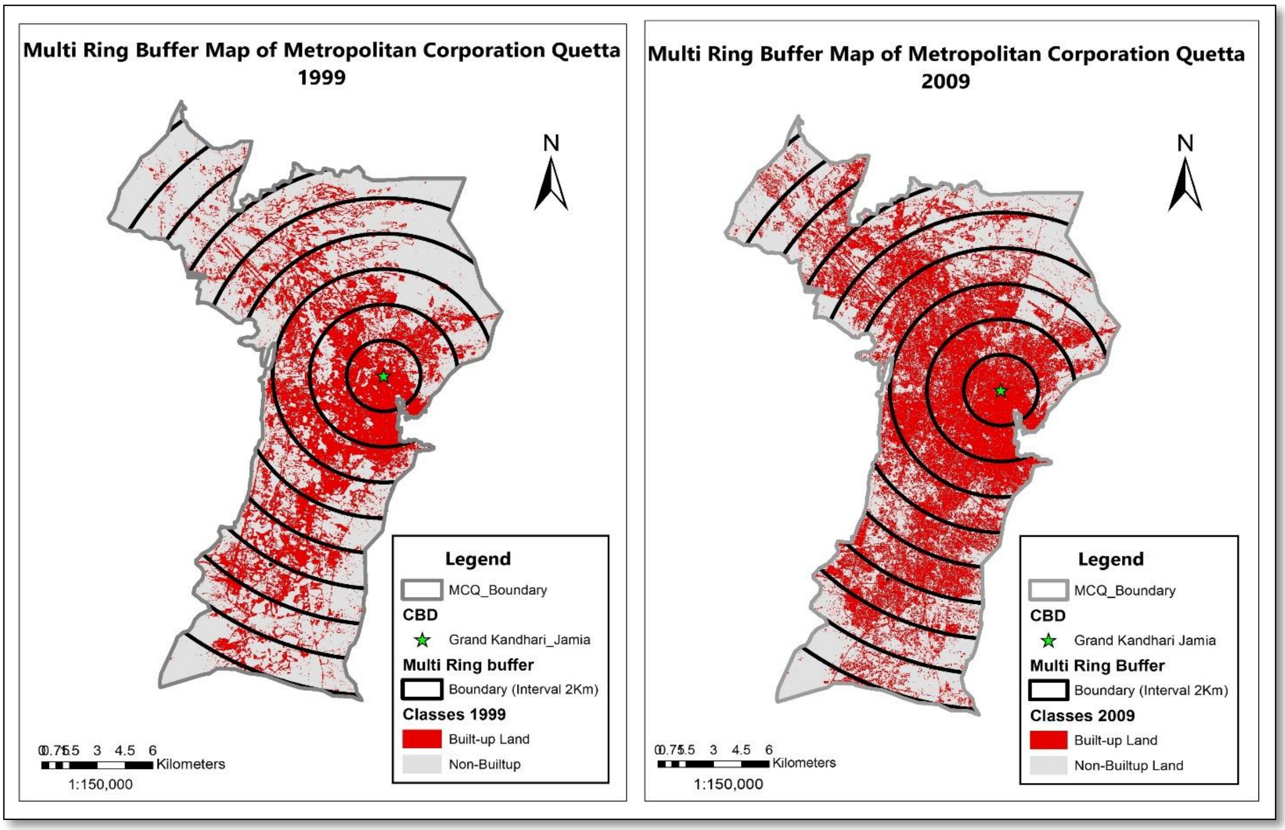

Figure 9. Shows the Multi Ring Buffer analysis of Metropolitan Corporation Quetta, 1999 and 2009.
Source: Generated by authors

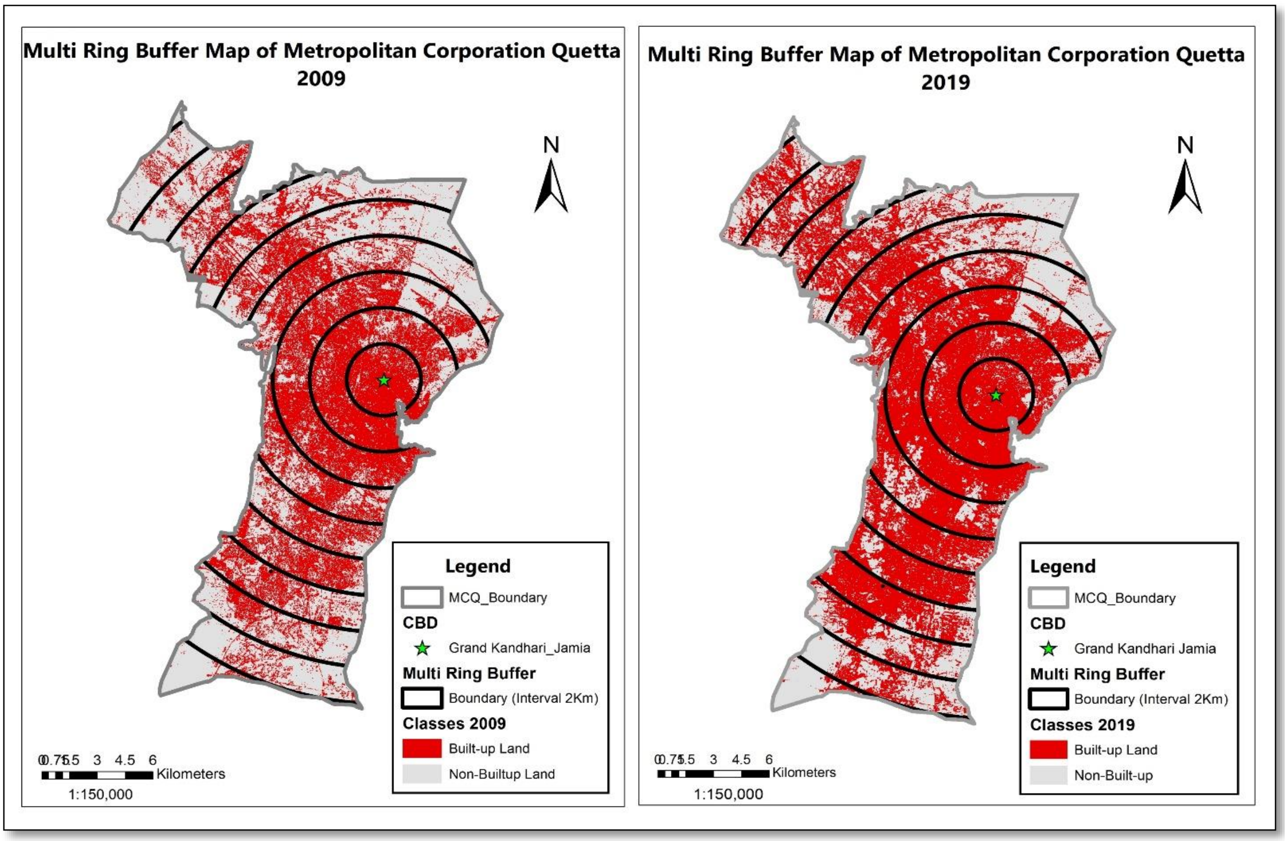

Figure 10 Shows the Multi Ring Buffer analysis maps of Metropolitan Corporation Quetta (2009 and 2019).

Table 7 Multi Ring Buffer Analysis for built-up land

Buffer distance	1999			2009			2019		
	Total area (km^2)	Built-up area (km^2)	Built-up area (%)	Total area (km^2)	Built-up area (km^2)	Built-up area (%)	Total area (km^2)	Built-up area (km^2)	Built-up area (%)
0-2 Km	12.44	9.388	75.44	12.44	10.94	87.94	12.44	11.12	89.38
2-4 km	32.63	20.59	63.10	32.63	25.35	77.68	32.63	27.94	85.62
4-6 km	48.59	23.26	47.86	48.59	32.53	66.94	48.59	37.64	77.46
6-8 km	50.48	12.93	25.61	50.48	22.72	45.00	50.48	29.92	59.27
8-10 km	45.58	11.82	25.93	45.58	17.61	38.65	45.58	26.41	57.94
10-12 km	43.75	10.37	23.70	43.75	18.1	41.37	43.75	23.58	53.89
12-14 km	28.46	7.28	25.57	28.46	12.33	43.32	28.46	19.61	68.90
14-16 km	32.47	5.06	15.58	32.47	8.71	26.82	32.47	16.87	50.41
16-18 km	29.59	3.64	12.30	29.59	4.73	15.98	29.59	13.87	46.87

Source: Authors' calculations

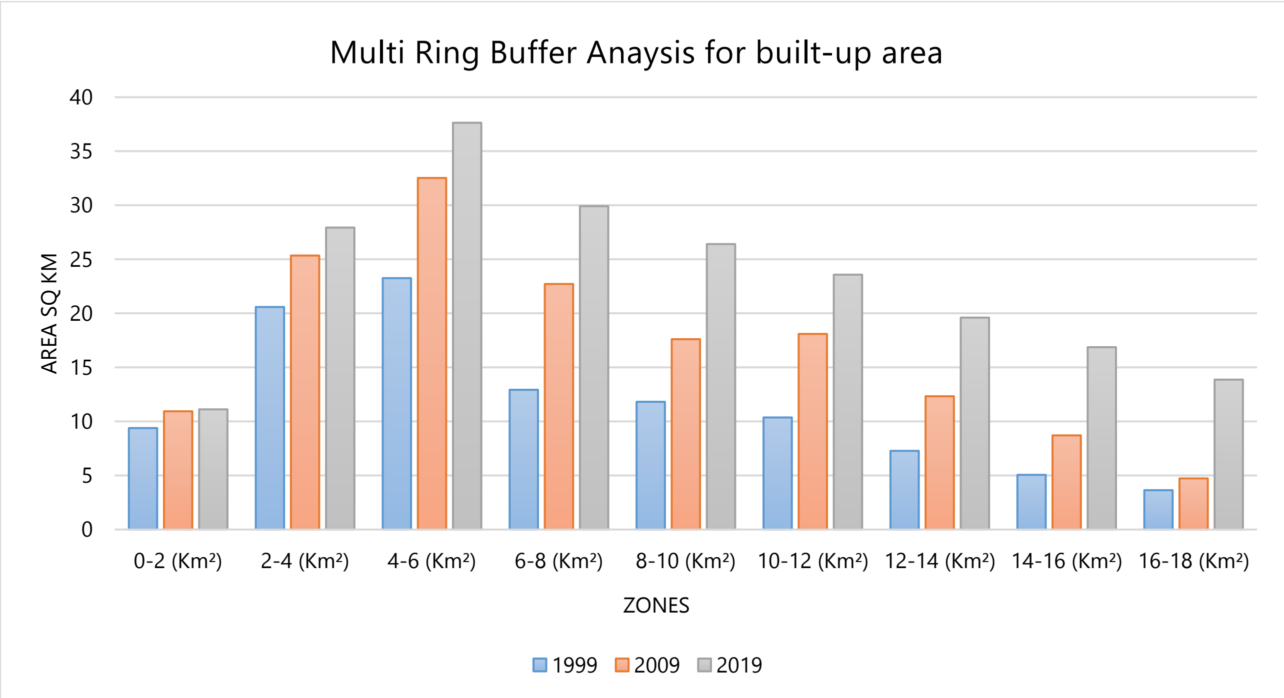

Figure 11. Multi-ring buffer of built-up area (Zone wise)

3.5.3 Results of Shannon's Entropy

Shannon entropy is a measure to determine the compactness or distribution of built-up land growth in the urban areas (Rahman, 2016; Tewolde & Cabral, 2011). The relative Shannon Entropy value of each individual buffer ring and overall entropy value of each year i-e., 1999, 2009, and 2019 have been calculated to assess the urban sprawl in the study area. Table 7 shows the detail of Shannon's entropy value of the built-up land of study area. The overall entropy values acquired were 0.919 in 1999, 0.940 in 2009 and 0.957 in 2019 which are closest to the upper limit of entropy value i.e., 1. This indicates that the urban sprawl in Quetta city is observed in all three selected years. The result of the overall entropy value indicates the degree of dispersion of built-up development in the city. The growth of built-up land is decreased with an increase in distance from the city center.

Table 8 Relative Shannon's entropy values

Sr. No	Year	Built-up Area (Km^2)	Relative Shannon's Entropy (RSE) Value
1	1999	105.14	0.919
2	2009	160.17	0.940
3	2019	205.03	0.957

Source: Authors' calculations
Note. The limits of Relative Shannon's Entropy (1=upper; 0=lower) (Ozturk, 2017).

Table 9 Multi Ring Buffer Analysis for Relative Shannon's Entropy values

Buffer Distance	1999			2009			2019		
	Total area (km^2)	Built-up area (km^2)	RSE	Total area (km^2)	Built-up area (km^2)	RSE	Total area (km^2)	Built-up area (km^2)	RSE
0-2 Km	12.44	9.388	0.095	12.44	10.94	0.050	12.44	11.12	0.045
2-4 km	32.63	20.59	0.131	32.63	25.35	0.089	32.63	27.94	0.057
4-6 km	48.59	23.26	0.145	48.59	32.53	0.121	48.59	37.64	0.090
6-8 km	50.48	12.93	0.144	50.48	22.72	0.162	50.48	29.92	0.139
8-10 km	45.58	11.82	0.159	45.58	17.61	0.166	45.58	26.41	0.143
10-12 km	43.75	10.37	0.141	43.75	18.1	0.165	43.75	23.58	0.150
12-14 km	28.46	7.28	0.144	28.46	12.33	0.164	28.46	19.61	0.120
14-16 km	32.47	5.06	0.131	32.47	8.71	0.160	32.47	16.87	0.154
16-18 km	29.59	3.64	0.117	29.59	4.73	0.133	29.59	13.87	0.160

Source: Authors' calculations

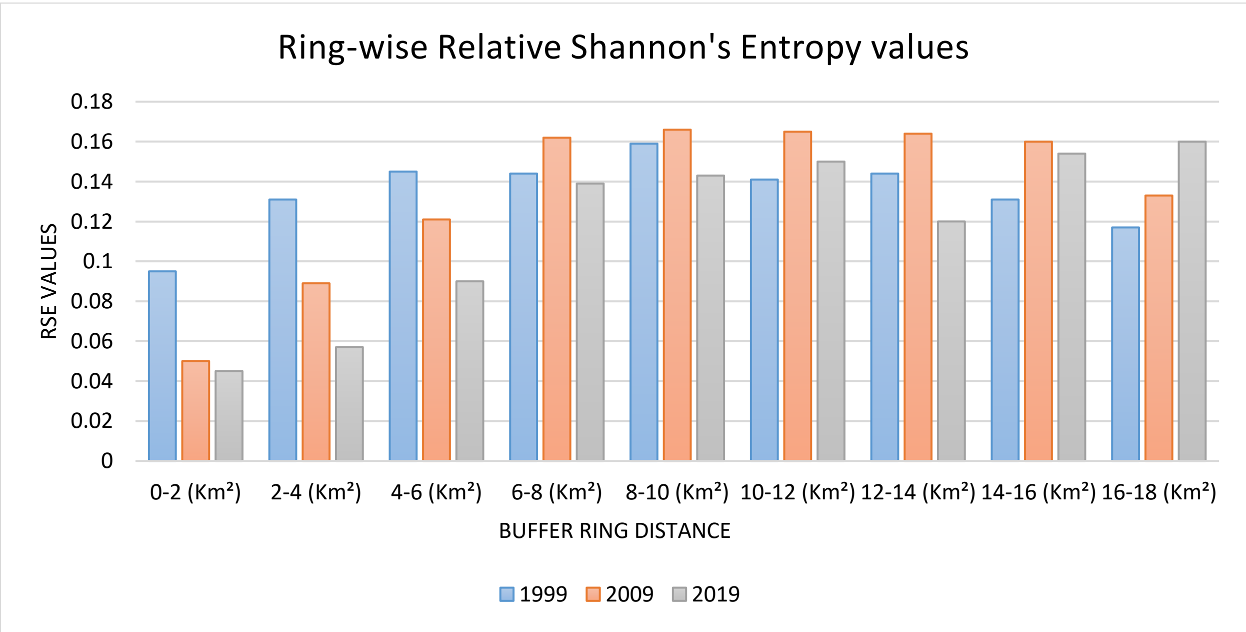

Figure 12 Ring-wise values of Relative Shannon's Entropy from 1999 to 2019

4. DISCUSSION

GIS-based mapping provides a clear depiction of where growth is occurring, it also helps to identify the problems created by such growth, and recommends the possible future directions and patterns of growth (Muiruri & Odera, 2018; Sarvestani et al., 2011). For urban sprawl assessment in Quetta city, the current study used Landsat satellite imageries for the years 1999, 2009, and 2019 and identified three major LULC classes i-e., built-up land, vegetation, and open areas, and the integrated application of Shannon's Entropy with GIS for measurement of urban sprawl. In the current study, it has been witnessed through LULC classification that major part of vegetation cover and open areas in Quetta city has been converted into built-up areas within the study duration.

Our findings show that a significant increase (95%) in the built-up area, a massive loss in vegetation cover, and a decrease in open areas have occurred from 1999 to 2019 in Quetta city, Balochistan (Table 4). An increase in the built-up area puts pressure on the resources of the city. Likewise, loss in vegetation cover has caused health and environmental issues in Quetta city (Ilyas et al., 2010). The findings of this study revealed significant changes in built-up areas of Quetta city, Balochistan, that are in accordance with the earlier studies (Aziz & Ghaffar, 2017; Boori et al., 2015; Butt et al., 2012; Ghosh et al., 2017; Mahboob & Atif, 2015; Mahboob et al., 2015; Raziq et al., 2016). Similarly, our study findings also confirmed a massive loss occurred in vegetation cover in the study area. These findings are similar with the results of previous studies, conducted on urban sprawl and LULC changes in various cities of Pakistan (Aziz & Ghaffar, 2017; Boori et al., 2015; Butt et al., 2012; Ghosh et al., 2017; Mahboob & Atif, 2015; Raziq et al., 2016). Moreover, we also found one-third (34%) decrease in open areas in Quetta city from 1999 to 2019. These findings also endorse those of previous studies in major cities of Pakistan such as Karachi and Peshawar (Mahboob & Atif, 2015; Raziq et al., 2016).

The results of the overall relative Shannon's Entropy values from 1999 to 2019 are closest to the upper limit 1, which indicates the spatial dispersion within the study area (Table 8) and thus, confirmed that urban sprawl has occurred. The results of this study demonstrates the substantial changes that have been occurred in the study area in all three classes during the last 20 years. These findings clearly showed the occurrence of urbanization and urban sprawl. Several factors are behind the sprawl of Quetta city. Since Quetta city is a center and a business hub of the province therefore, it provides opportunities for employment, business, education, health and others services. These set of services attract the people from various districts of the province. Beside this, the seasonal migration from hot climatic regions of other provinces such as Sindh and Punjab due to favourable weather conditions in Quetta, also trigger the pace of sprawl in Quetta city. Moreover, migration of Afghan refugees, after the US invasion in 2001, also accelerated the pace of urbanization and sprawl in Quetta city (Kakar et al., 2020; Khan et al., 2013). The unregulated urbanization and urban sprawl of the city has caused numerous problems such as traffic congestion and associated environmental issues (Ali et al., 2020; Ilyas et al., 2010; Laghari et al., 2013), water depletion and land subsidence (Kakar et al., 2020; Khan et al., 2013), managing liquid waste, sanitation, municipal solid waste (Laghari et al., 2013), and poor housing structure including development of slums in the (Mahar & Attia, 2018). The findings of this study about the occurrence of urban sprawl also endorses the findings of earlier studies who reported the occurrence of urban sprawl in Pakistani cities such as Peshawar (Raziq et al., 2016), Lahore (Bhalli & Ghaffar, 2015; Mahboob & Atif, 2015) Faisalabad (Bhalli et al., 2012; Safder, 2019), Bahawalnagar (Aziz & Ghaffar, 2017), Sheikhupura (Raza et al., 2016), Karachi (Mahboob & Atif, 2015), Islamabad (Butt et al., 2012). Analysis of the above findings confirm the fact that Pakistani cities are urbanizing rapidly and thus, causing urban sprawl. To regulate the expansion of cities, the role of planning and development departments and local government is crucial. In addition to that, the existence of master development plans and their implementation can certainly regulate the haphazard expansion of cities.

Implications

Urban sprawl occurs due to poor land use planning, poor urban governance and non-existence of plans, regulations and implementation. The findings of current study shows significant increase in haphazard development and existence of urban sprawl in the Quetta city. The analysis indicate that, there are many shortcomings in the urban planning and management processes. It can be inferred from the findings that, there is very less or no coordination among the planning and development departments and local government. Seemingly, the above mentioned departments are failed to monitor urbanization and managing urban sprawl. It also seems that planning and development departments and the local government have not well-defined powers and responsibilities.

Limitation of the study

Despite significant findings, the results of this study should be viewed in the light of the study's limitation. This study has not used the high resolution satellite imageries due to the non- accessibility to the free sources. The same analysis, if done on high resolution imageries, may produce better results.

5. CONCLUSION

Geospatial technologies such as GIS and remote sensing proved to be much effective and efficient in assessing and monitoring the pace of LULC change dynamics, urbanization and urban sprawl in Quetta city. This study has assessed LULC change dynamics and measured the extent of urban sprawl through remote sensing data, Geographic information system and Shannon's Entropy model in Metropolitan Corporation Quetta (MCQ) over 20 years (1999, 2009, and 2019). Our study concluded that there is a massive loss in vegetation cover, reduction in open areas, and a drastic increase in built-up areas in Quetta City. Furthermore, the relative Shannon's entropy values are significantly high (Table 8), which indicate the occurrence of urban sprawl over the last two decades. The spread of urban area is compacted in the centre of the city within 6 km buffer ring, whereas the urban spread becomes scattered with increase in distance from the city centre of MCQ. Compared to all zones in the MCQ area, the built-up area was highest in the zone from 4 to 6 km.

From the analysis of the findings it can be concluded that urbanization and urban sprawl have been occurring in Quetta city since 2001. The city is facing severe challenges due to unplanned, unregulated and accelerated urbanization. If it is not managed properly, the situation can further be aggravated. The findings of the study revealed weaknesses in the urban planning and management processes. Policymakers, key stakeholders and planners of various planning and development departments are suggested to take serious the unregulated urban growth and sprawl of Quetta city and take steps for enhancing the capacity of responsible departments in regulating and managing the expansion of city. All development projects and schemes, whether housing or others, either private or government in the MCQ area, should be properly designed and well managed. The construction of private housing schemes should not be allowed without the approval of concerned department such as Quetta Development Authority (QDA) in order to stop the haphazard and unplanned urban growth of Quetta city. Beside this, effective coordination among the planning and development departments is direly needed. The use of geospatial technologies such as GIS and remote sensing for assessing and monitoring the pace of urban sprawl and LULC change dynamics in Quetta city may assist to manage and control the unplanned and haphazard urban growth and sprawl of the city. Moreover, a comprehensive Master Plan of Quetta city is the need of the day. Further research can be done to predict the LULC change dynamics and urban sprawl through GIS and remote sensing technologies.

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Conflicts of interest: The co-author is the editor-in-chief of the journal and research supervisor of the principal author. To support the newly launched journal, he advised his supervisee to submit the article. However, he ensured transparency in the peer review process.
Ethical considerations: This study was based on the secondary data, particularly satellite imageries. Therefore, no ethical approval was required.

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