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Spatial interrelationships of quality of life with land use/land cover, demography and urbanization

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Abstract

The quality of life (QOL) is a measure of social wellbeing and life satisfaction of individuals in an area. Measuring its spatial dynamics is of great significance as it can assist the policy makers and practitioners in improving the balance between urbanization and living environment. This study proposes an approach to spatially map and examine the relationships between QOL, land use/land cover (LULC) and population density in an urban environment. The city of Lahore, Pakistan was selected as the case study area. The QOL was evaluated through the data related to physical health, psychological, social relationships, environment (natural and built), economic condition and development, and access to facilities and services. The weights/relative importance of each QOL domain was determined through the analytic hierarchy process by processing the data collected from local field experts. Overall QOL was computed by applying the domain weights to the data; spatial mapping of QOL domains and overall QOL was conducted afterwards. The spatial dynamics of QOL were examined, and its interrelationships with LULC and population density were analyzed. The relationship between these three variables turned out to be spatially dynamic. The proposed approach assists the spatial mapping and analyses of QOL, LULC and population, and by examining the spatial dynamics of these variables, contributes to devising appropriate land management and QOL improvement strategies and policies in the metropolitan regions.

Keywords: analytic hierarchy process; correlation; Lahore; land use/land cover; population; urban quality of life

1. Introduction

The quality of life (QOL) is considered important to determine the livability of an area. The concept originated from the West (Gurin et al. 1960; Andrews & Withey 1976; Campbell et al. 1976), and over the decades, the efforts to study the QOL expanded to the developing countries. Researchers and some international organizations have developed a variety of means to measure the QOL of individual country or a region (Liu 1976; Boyer & Savageau 1989; Blomquist et al. 1988; Stover & Leven 1992; Sufian 1993; UNDP 1994; Ballas 2013). Although QOL has been the focus of research in both the developed and developing countries, its universally acceptable definition is not yet established (Das 2008).

The urban areas hold around half of the world's population (United Nations 2012). Usually characterized by high urbanization and industrialization rates, these areas form the basis of economic growth in a region (Ulengin et al. 2001; David et al. 2013). Examining the urban QOL is therefore crucial to understand the livability dynamics. Assessing the QOL, however, is not straightforward as its perception varies from person to person; some may consider happiness as the factor to a better QOL, whereas others may think of the economic status as an appropriate measure. Therefore, the frameworks and results of studies on QOL are variable due to the differences in the selected indicators, weighting schemes, methodologies and geographical locations (Ulengin et al. 2001).

The landmark empirical study on QOL was conducted by Day (1987), which examined the indicators related to 13 broad domains; the individuals' level of satisfaction was assessed using a five-point Likert scale. These domains included family life, material possessions, personal health, health care, social life, working life, self-development, religion/spiritual life, leisure/recreation, life in the country, the federal/national government, state and local government, and shopping/consumption of goods and services. Another study considered 12 domains of life for assessment of QOL though questionnaire survey; the domains comprised spiritual life, family life, life in Singapore, personal health, living environment, material possessions, health care services, acquisition and consumption of goods, social life, self-development, working life, mass media, leisure, and school life (Wang 1993). Although some common indicators could be determined from different studies, the domains for assessment of QOL are quite variable. A few standard schemes, however, have been developed for the QOL questionnaire design such as the ones by Christakopoulou, Dawson, & Gari (2001); Whittington (2000) and WHOQOL Group (1995). These patterns can be used to prepare the questionnaire specific to local context (Das 2008).

The QOL is computed by aggregating the scores of individual indicators/domains. The weights of the domains, however, need to be decided prior to aggregating. The weighting is usually based on the researchers' own judgments (Liu 1976; Boyer & Savageau 1989). However, Ulengin et al. (2001) presented a methodical way that employs the hierarchical information integration and conjoint analysis together with the pairwise comparisons to model the weights of the QOL variables. The analytic hierarchy process (AHP) is a popular and widely used method for decision analysis in which the experts' judgments are compared pairwise to derive the relative weights of the input factors (Saaty 2008; Albayrak & Erensal 2004; Kuo et al. 2002; Lai et al. 2002). The consistency and reliability of the experts' judgments are also tested during this process. Researchers have demonstrated the use of AHP for computing the weights of QOL domains (Rinner 2007; Lotfi & Solaimani 2009), the scores of individual domains are then aggregated by applying the weights to compute the overall QOL (Ulengin et al. 2001).

The Geographical Information System (GIS) and remote sensing methods have also been used to estimate the overall QOL and to examine its spatial distribution (Porter & Tarrant 2001; Harner et al. 2002; Mennis 2002; Lotfi & Koohsari 2009). In a study conducted by Jensen, Gatrell, Boulton, & Harper (2004), the relationship between leaf area index (observed through remote sensing) and the standard socioeconomic factors was observed to assess the QOL. A positive correlation between leaf area, population density, and their interaction with income and housing value demonstrated that these variables could be related to, and used to examine the QOL. In another study, the impact of environmental factors on urban QOL was examined, where the QOL was observed through GIS using household survey data (Keul & Prinz 2011). The spatial variations and relationship of QOL with different factors such as social and biophysical (Lo & Faber 1997), economic, environmental and crowdedness (Li & Weng 2007), population density (Cramer et al. 2004), household density (Carnahan et al. 1974), and amenities and economic performance (Deller et al. 2001) have also been examined. Another study demonstrated the use of GIS-based methods to understand the contribution of five factors, education, health, employment, industry and transportation, and communication, towards overall QOL (Abdullah et al. 2013).

These studies indicate that GIS and remote sensing methods, together with the ground-based data, can be employed to examine the QOL. However, since the perception of QOL varies significantly across regions, countries and even within cities (Rogerson 1999; Godfrey & Zhou 1999; Mccrea et al. 2005; Sirgy & Cornwell 2002), its estimation remains a challenge that should be addressed at a local rather than a regional scale. Majority of the previous work in this regard has been conducted at a broader scale (regional or city level), and the QOL variability at a detailed scale (within city or towns) has not been examined (Godfrey & Zhou 1999; Hagerty et al. 2001; Rogerson 1999). However, from the planning point of view, it would be interesting to examine the QOL and its relationships with other pertinent variables at a scale considered suitable by the policy makers for efficient resource management (Megone 1990; Steinberg 2000). Another basic characteristic of QOL is the variability in relative importance of the indicators used for its assessment. The same set of indicators for assessing QOL in one region would have different weights (importance) compared to that in another region (Ulengin et al. 2001). Therefore, it is important to understand the 'local perspective' on QOL, which in some studies has been accomplished through the survey of local experts (Lotfi & Solaimani 2009; Ulengin et al. 2001).

In addition, an overlooked dimension of QOL is its relationship with the land use/land cover (LULC) from the lens of urban planning. Since the LULC can serve as an indirect indicator to several variables, such as population, infrastructure and environment (Li & Weng 2007; Lo & Faber 1997; Jensen et al. 2004; Carnahan et al. 1974), examining its relationship with the QOL could be interesting. However, the LULC mapping could be challenging. There are several approaches for mapping the LULC through satellite images that can be grouped into two general categories: (1) classification-based approaches, such as supervised, unsupervised and object-based methods (Guindon et al. 2004; Cleve et al. 2008; Gao 2008); and (2) indices-based approaches that involves direct segmentation of the imagery through manipulation of spectral bands (Zha et al. 2003; Zhang et al. 2005; Knight et al. 2006). The selection of the classification method depends on several factors, such as the input data, objective of classification, skill of interpreter, and mapping speed. In terms of image interpretation skills and time required to generate the maps, the indices-based methods have a certain advantage over the classification-based approaches; the former are comparatively easy to comprehend (Zha et al. 2003; Zhang et al. 2005). A variety of indices such as normalized difference vegetation index (NDVI), normalized difference snow index, normalized difference water index, modified normalized difference water index (MNDWI), normalized difference built-up index and built-up area extraction method (BAEM) have been developed to map different LULC features, the outputs of which can be combined to generate the LULC maps (Huete & Jackson 1987; Hall et al. 1995; McFeeters 1996; Zha et al. 2003; Xu 2005; Bhatti & Tripathi 2014). This study digs into the aforementioned research areas of QOL, LULC and urbanization through spatial mapping and analyses of urban QOL, LULC and population in a developing city of Lahore, Pakistan.

2. Study area

The city of Lahore, which is the capital of the Punjab province of Pakistan, was selected as the study area. The city is stressed in terms of urbanization; census reports and current estimates indicate that the population increased from 1.13 million in 1951 to 9.16 million in 2013, around 82% of which now resides in the urban and the rest in peri-urban and rural areas (Population Census Organization 1998; Bureau of Statistics 2013) (Figure 1(A)). The population density (including both urban and peri-urban/rural areas) was 35.66 persons/ha in 1998, which increased to 51.69 persons/ha by 2013 (Population Census Organization 1998; Bureau of Statistics 2013); the density is even higher in urban areas. Although the population increased manyfold during the past decades, especially in the urban areas, no comprehensive study has been conducted to examine the QOL in the city.

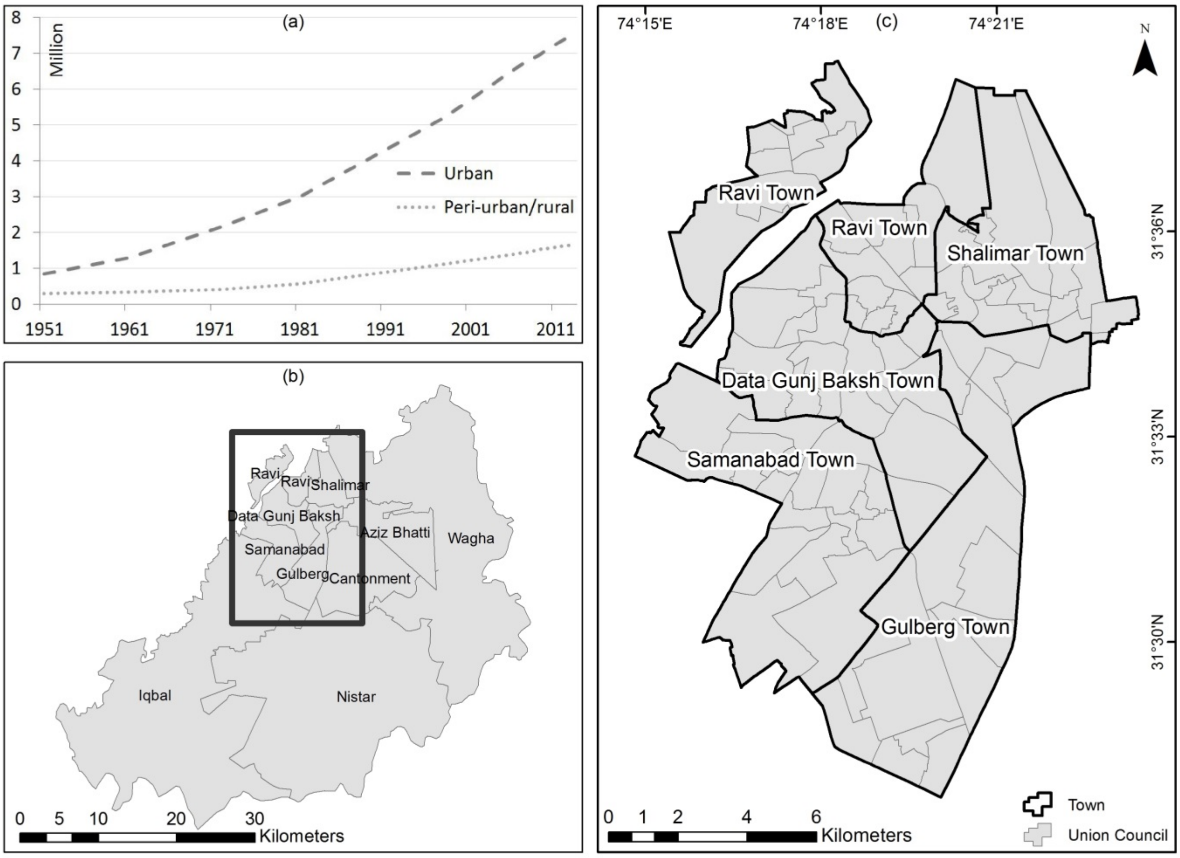

Fig. 1 (a) Population growth in urban and peri-urban/rural areas of the city of Lahore, Pakistan from 1951 to 2013, (b) towns in the city and (c) urban towns and union councils selected for this study

Population data source: (Population Census Organization 1998; Bureau of Statistics 2013)

Ten towns comprise the city (Figure 1(B)), of which five urban towns, Data Gunj Baksh, Gulberg, Ravi, Samanabad and Shalimar, were selected for this study (Figure 1(C)). A total 88 union councils (UCs) constitute these towns with an area of around 16700 hectare.

3. Materials and methods

The database used in this study comprised QOL data collected through questionnaire survey, LULC data generated through Landsat satellite image and demographic data collected through census reports. The overall approach included: (1) computing weights of QOL domains through AHP; (2) computing and mapping QOL with respect to administrative boundaries; (3) LULC and population mapping; and (4) analyses of QOL with LULC and population. The data collection and processing methods are explained in the later sections.

3.1. Database

The pre-survey activities for collecting urban QOL data involved preparing the questionnaire, determining the sample size distribution, developing a surveying plan and determining the relative importance/weight of each QOL domain through experts' (town/urban planners) survey. Six domains were considered for assessment of urban QOL which included physical health, psychological, social relationships, environment (natural and built), economic condition and development, and access to facilities and services. The selection of domains and preparation of questionnaire was carried out by the help of data from the World Health Organization and National University of Ireland (WHOQOL Group 1995; THE WHOQOL GROUP 1998; Fahy 2009). The questionnaire was finalized in consultation with field experts from the Urban Unit, Planning and Development Department, Government of Punjab, Lahore, Metropolitan Wing, Lahore Development Authority (LDA), Lahore and Department of City and Regional Planning (CRP), University of Engineering & Technology (UET), Lahore. All the questions were developed at a Likert scale of 1 to 5 (Appendix) (Gliem & Gliem 2003; Seik 2000; Das 2008).

The Union council (UC) was considered as the basic administrative unit for collection of data. The QOL survey was conducted in January 2014 involving 208 respondents, where the sample size for each town and UC was decided through multi-stage sampling based on the proportion of population in each administrative unit. An online survey of 20 field experts (local town/urban planners) was also conducted to obtain their opinion regarding relative importance/weight of each QOL domain. The LULC of the study area was obtained through processing the Landsat operational land imager (OLI) satellite image of May 2013 downloaded from Earth Resources Observation and Science Center, United States Geological Survey, whereas the demographic data were extracted from the District Census Report of Lahore and the report on Punjab Development Statistics (PDS).

3.2. QOL data preparation

The total score of each QOL domain was computed for every response (total 208 respondents) by summing up the score of questions addressing a particular domain. However, since the number of questions pertinent to each QOL domain were different, the total domain score was normalized, and rescaled to a range of 1 to 20 through linear rescaling by Equation 1 (Cross Validated 2012).

$$NewValue = \frac{(MaxNew - MinNew)}{(Max - Min)} \times (Value - Min) + MinNew \qquad (1)$$

Where *NewValue* is the new rescaled value, *MaxNew* is the new rescaled maximum value (*MaxNew*=20), *MinNew* is the new rescaled minimum value (*MinNew*=1), *Max* and *Min* are the previous maximum and minimum values, respectively, and *Value* is the previous value in a particular domain. The higher rescaled value (close to 20) indicated higher quality and vice versa. The QOL domain values of each UC (total 88 UCs) were computed by taking the average of the total domain score of the responses in a particular UC. For instance, if three responses were recorded in a UC and the rescaled values of the domain “Physical Health” for these responses were 10.50, 15.25 and 13.67, the average of these values (13.14) was assigned to the Physical Health domain of that UC.

The reliability of the QOL data was tested domain-wise separately for each town through the Cronbach’s α (alpha) statistics. It is a coefficient of internal consistency and determines the suitability of data for further statistical analysis (Pallant 2010). Its value is computed by Equation 2.

$$\alpha = \frac{N\bar{c}}{\bar{v} + (N-1)\bar{c}} \quad (2)$$

Where *N* is the number of items being evaluated, $\bar{c}$ is the average inter-item covariance among the items and $\bar{v}$ is the average variance. The value of α generally ranges from 0 to 1, where a value greater than 0.7 indicates that the data is consistent (George & Mallery 2003). The descriptive statistics of respondents encompassing their age, period of living in current

UC (living since), marital status, education, and average monthly income were computed for data examination. The descriptive statistics of QOL domains were also calculated, which included the minimum, maximum and mean values of all QOL domains in each of the five urban towns.

The opinion of field experts about relative importance of each QOL domain was compiled to determine the domain weights; the Saaty's scale of relative importance was used to prepare the pairwise comparison matrix (Table 1) (Saaty 1980).

Table 1. Pairwise comparison matrix to determine the weights of QOL domains.

	Physical Health	Psychological	Social Relationships	Environment	Economic Condition and Development	Access to Facilities and Services
Physical Health	1	3	5	1	1	1/5
Psychological	1/3	1	3	1/5	1/3	1/3
Social Relationships	1/5	1/3	1	1/3	1/5	1/7
Environment	1	5	3	1	3	1/3
Economic Condition and Development	1	3	5	1/3	1	1/7
Access to Facilities and Services	5	3	7	3	7	1

The weight of each QOL domain was computed by applying the AHP to the matrix. The consistency of the experts' judgments was first checked by the consistency ratio (CR) through the consistency index (CI) and random index (RI) using Equation 3 (Saaty 1980).

$$CR = \frac{CI}{RI} \qquad (3)$$

The CI is computed by Equation 4, where λ is the average value of the consistency vector computed through the pairwise comparison matrix and n is the number of factors being evaluated. The value of RI is constant which depends on the number of domains involved in the decision making; for six QOL domains, its value was 1.24 as determined by the RI table (Saaty 1980).

$$CI = \frac{\lambda - n}{n - 1} \quad (4)$$

The computations on the pairwise comparison matrix resulted in the values of 0.1251 and 0.100 for CI and CR, respectively. The CR value significantly higher than 0.1 indicates inconsistent judgments (Saaty 1980), however, the CR value computed (0.100) signifies that the judgments were consistent and can be used for computing the weights of QOL domains.

The domain weights were used to compute the overall QOL (for each response and each UC) by applying weighted sum method to the domain scores. An equal-interval range was applied to categorize the overall QOL into four classes; low, moderate, high and very high.

3.3. Mapping the QOL, LULC and population

The maps of QOL domains and overall QOL were prepared by spatially linking the computed scores to the respective UCs. These maps presented the spatial variation of each domain as well as the overall QOL in the study area.

An indices-based approach was applied to the OLI data to generate the LULC map; the built-up, vegetation and water areas were mapped using the BAEM, NDVI and MNDWI, respectively (Bhatti & Tripathi 2014; Huete & Jackson 1987; Xu 2005). The bare areas were mapped through arithmetic computation of BAEM, NDVI and MNDWI. The outputs were combined to obtain the map representing four LULC classes; bare, built-up, vegetation and water. The LULC area statistics and class densities were computed for each town and UC of the study area. The population data extracted from the district census and PDS reports of Lahore was geographically linked to prepare the UC level population density map.

3.4. Analyses of QOL, LULC and population

To establish an understanding of the impact of LULC class densities on QOL, a correlation analysis was conducted on the two variables. The data from 88 UCs was used which revealed the spatial variations in this relationship at town level. Likewise, the relationship between QOL and population density was also assessed. These analyses assisted in inferring the future implications of rising built-up areas and population on QOL in urban towns of Lahore. In addition to the town level analyses, the correlations between QOL, population density and built-up density were also examined at study area level (urban Lahore) to understand the overall dynamics of these variables.

4. Results and discussion

4.1. The dynamics of QOL data

The results of Cronbach's α (alpha) statistics, which was used to test the internal consistency and reliability of the QOL data, are shown in Table 2. The data was tested town wise for each QOL domain. The α value greater than 0.7 for all the towns indicated that the data was internally consistent and suitable for further analyses.

Table 2. Cronbach's alpha statistics of QOL data.

Town	Cronbach's Alpha (α)	No. of Items*
Data Gunj Baksh	0.835	6
Gulberg	0.859	6
Ravi	0.842	6
Samanabad	0.759	6
Shalimar	0.795	6

* Number of QOL domains (six)

The descriptive statistics of 208 respondents (age, living period, marital status, education and average monthly income) were examined comprising 42, 36, 44, 45 and 41 samples, respectively, from Data Gunj Baksh, Gulberg, Ravi, Samanabad and Shalimar towns. The majority of the respondents in all the towns were from the 25-44 years old age group; 64% in Data Gunj Baksh, 56% in Gulberg, 71% in Ravi, 51% in Samanabad and 44% in Shalimar towns of the total samples in each of these towns. Smallest proportion was of the respondents aged 65 or more years. The remaining respondents comprised less than or equal to 24 years and 45-64 years old age groups. So, most of the respondents were from a mature age group indicating that the responses were reasonably thoughtful. The majority of the respondents reported to be living since 20 or more years in their respective UCs; 47% in Data Gunj Baksh, 42% in Gulberg, 57% in Ravi, 42% in Samanabad and 46% in Shalimar towns of the total samples in each of these towns. The respondents living since less than 20 years in their respective UCs were somewhat distributed in all the towns. This implies that most of the respondents were local residents since 20 years or more, thus they had a fairly good idea of the life quality in their area. Of the total respondents in Data Gunj Baksh, Gulberg, Ravi, Samanabad and Shalimar towns, 64%, 75%, 80%, 58% and 61%, respectively, were reported as married and the rest as single. Education wise, the respondents were somewhat distributed; however, majority of the respondents from all the towns reported to have primary-intermediate level qualifications. The majority of the respondents in Data Gunj Baksh (60%) and Ravi (50%) towns reported earning Rs[1]. 20,000-50,000 per month on average. The majority of the respondents in Gulberg (42%), Samanabad (64%) and Shalimar (61%) towns reported earning less than Rs. 20,000 per month. The remaining proportion of the respondents in each town reported earning Rs. 50,000-80,000 per month, whereas a few in Gulberg, Samanabad and Shalimar towns also reported earning more than Rs. 80,000 per month. These statistics indicate that the respondents were quite diverse in different aspects, thus implying that the sample was a fairly reasonable representation of the overall population.

The variability in QOL data was also examined domain wise at town level though descriptive statistics (minimum, maximum and mean values) (Figure 2). The average values of the physical health and social relationships domains were almost similar in all the towns, indicating a thin spatial variation of these domains. However, the mean values of rest of the QOL domains were different in each town indicating their spatial variability in the study area. In Data Gunj Baksh town, the lowest mean value of 7.64 was observed for the access to facilities and services domain (on a scale of 1-20) (Figure 2(A)). However, the values of this domain ranged from 1 to 20 indicating its high variability within this town. All other domains exhibited mean values in the range from 11.52 to 13.80, indicating slightly above average condition of the rest of the QOL domains in Data Gunj Baksh town. Gulberg town exhibited mean values in the range from 10.19 to 13.62 for all the QOL domains (Figure 2(B)). The lowest mean value (10.19) was observed for the access to facilities and services domain. However, this value was the highest when compared to the same in other urban towns, indicating that the Gulberg town had better access to facilities and services compared to the other four towns in the study area. Mean values for all the domains were above 10, giving a feel of an above average overall QOL in this town.

[1] 1 Pakistani Rupee = 0.00981462 USD (Exchange rate on 9 April 2015).

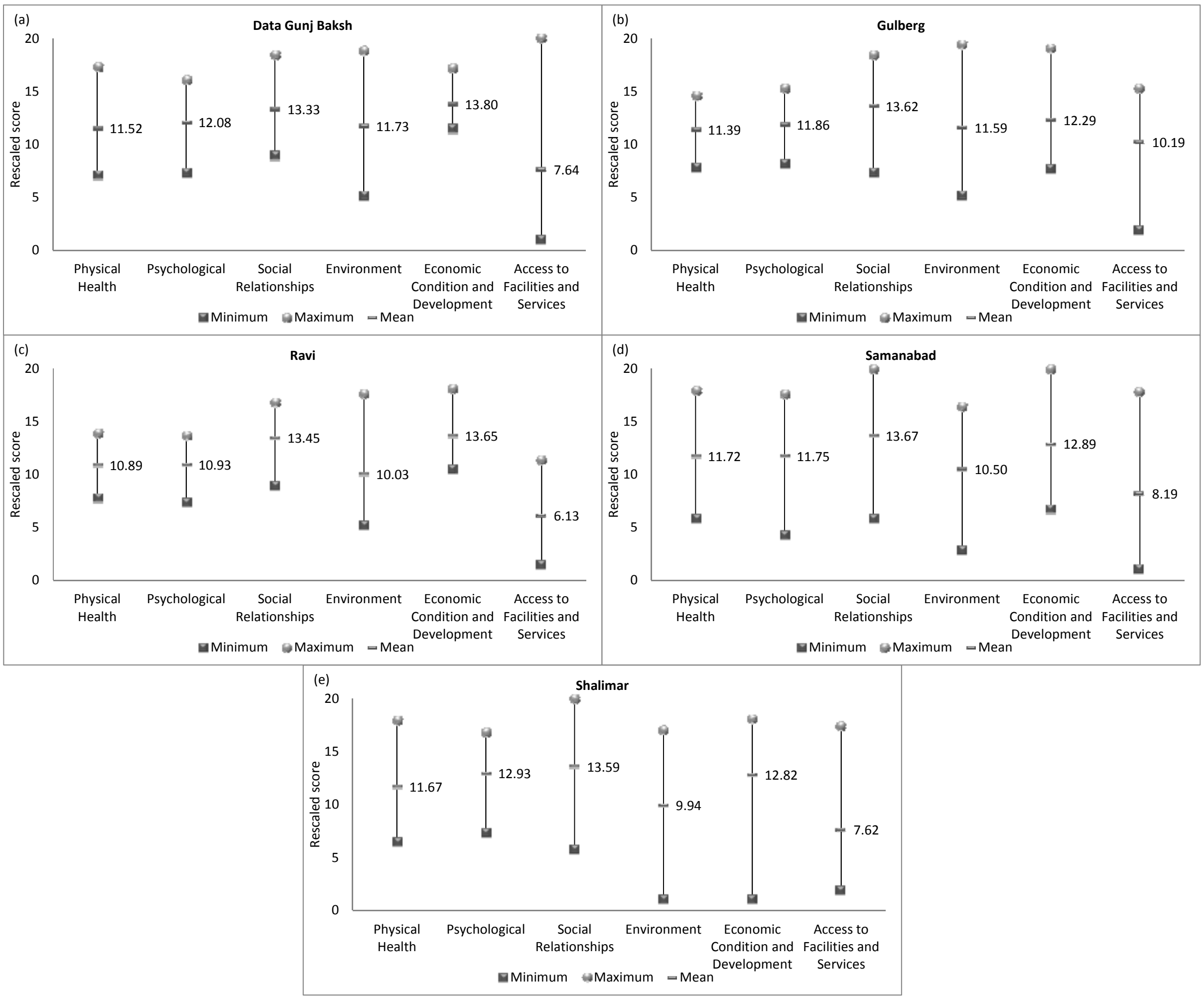

Fig. 2 Descriptive statistics of QOL domains in (a) Data Gunj Baksh, (b) Gulberg, (c) Ravi, (d) Samanabad and (e) Shalimar towns

A low mean value of 6.13 of access to facilities and services domain indicated below average condition of this factor in Ravi town (Figure 2(C)). Rest of the QOL domains exhibited mean values in the range from 10.03 to 13.65, indicating slightly above average conditions of these factors in this town. High range of the data values (min-max difference) of all the domains indicated significant variability of each domain within Samanabad town (Figure 2(D)). The mean values of all the domains ranged between 8.19-13.67 indicating slightly above average living conditions in this town. Shalimar town also exhibited a high range of data values in all the domains except the physical health and psychological ones (Figure 2(E)). A low mean value of 7.62 of access to facilities and services domain indicated below average condition of this factor. A slightly above average condition of the rest of the domains was observed in this town with the mean values ranging from 9.94 to 13.59. Nevertheless, these statistics indicate that the psychological, environment (natural and built), economic condition and development, and access to facilities and services factors of QOL are spatially variable in the study area.

The pairwise comparison matrix of relative importance of QOL domains indicated that the experts preferred the “access to facilities and services” over all other domains for computing the QOL (Table 1). The QOL domain weights calculated through AHP also confirms the same (Table 3). The social relationships domain turned out to have the least weight. Therefore, it can be deduced that the access to facilities and services will have the highest influence over the overall QOL in the study area.

Table 3. Weights of QOL domains computed through AHP.

QOL Domain	Weight
Physical Health	0.1387
Psychological	0.0677
Social Relationships	0.0359
Environment	0.1922
Economic Condition and Development	0.1154
Access to Facilities and Services	0.4501

The domain weights were applied to the rescaled QOL domain values to compute the overall QOL through Equation 5. The overall QOL was computed for each response, as well as for each UC.

QOL = (0.1387 x Physical Health) + (0.0677 x Psychological) + (0.0359 x Social Relationships) + (0.1922 x Environment) + (0.1154 x Economic Condition and Development) + (0.4501 x Access to Facilities and Services) (5)

4.2. Spatial distribution of QOL, LULC and population

Separate maps were prepared for each QOL domain and the overall QOL; the maps of QOL domains are shown in Figure 3.

The map of physical health domain indicated high values is the southern parts of the study area, majorly in the Gulberg and Samanabad towns (Figure 3(A)). All other towns exhibited the values ranging from low to high. Major portion of the study area presented moderate to high values of physical health, indicating that the related facilities, to a little extent or more, were available to the people. Only a few UCs showed low physical health values which may be attributed to inadequate health related conditions in the locality. The psychological domain map chiefly showed high values in Gulberg, Data Gunj Baksh and Shalimar towns (Figure 3(B)). The central portion of the study area, which basically comprise the city center and old city areas, indicated low values of psychological domain. The social relationships domain map (Figure 3(C)) indicated high values in a very few UCs in the study area. Overall, majority of the UCs in the urban towns of Lahore exhibited moderate values of social relationships domain, indicating almost consistent spatial distribution. However, a few UCs also indicated low values of social relationships, majorly in the eastern portion of Gulberg town.

The environment domain (natural and built combined) was observed to have low to moderate values in majority of the study area (Figure 3(D)). High values of environment domain were mainly observed in a few UCs in Gulberg town and towards the south of Data Gunj Baksh town. A few UCs in other portions of the study area also showed high values for environment domain. Low values in many UCs in the study area indicated that the overall environmental condition (both natural and built) was rated inadequate by the local residents. The economic condition and development domain exhibited moderate to high values in majority of the study area (Figure 3(E)). The eastern areas were observed to have low values, indicating the difference in economic conditions and related factors among different areas within the Gulberg town. Other areas showed almost consistent values of economic condition and development domain.

Fig. 3 Union council level maps of QOL domains, (a) physical health, (b) psychological, (c) social relationships, (d) environment, (e) economic condition and development and (f) access to facilities and services of urban towns of Lahore

The access to facilities and services domain map indicated values ranging from low to high in the study area. Lower values were observed in the central portion, whereas higher ones were majorly found towards the south (Figure 3(F)). The reason for this variation can be attributed to the provision of better facilities in the newly developed areas contrary to those in the old parts of the city. High values were mainly observed in the UCs of Gulberg town and the south of Data Gunj Baksh town, as well as in a few areas of Samanabad and Shalimar towns. Overall, the spatial variability in each QOL domain was different in different areas within the urban towns of Lahore; however, almost all the QOL domains exhibited moderate to high values towards the south of the study area.

The highest weight was given to the access to facilities and services domain for computation of overall QOL (Table 3). Thus, the overall QOL map was more influenced by the variations in the access to facilities and services domain (Figure 4). The overall QOL map indicated moderate to high values in majority of the study area. Highest values were observed in a few UCs of Gulberg, Data Gunj Baksh and Samanabad towns, whereas the lowest values were observed towards the north (old city) and west of the study area. It can be inferred that the overall QOL was lower in the old city areas which were developed without any proper planning for provision of facilities and services compared to the newly developed towns towards the south of the study area.

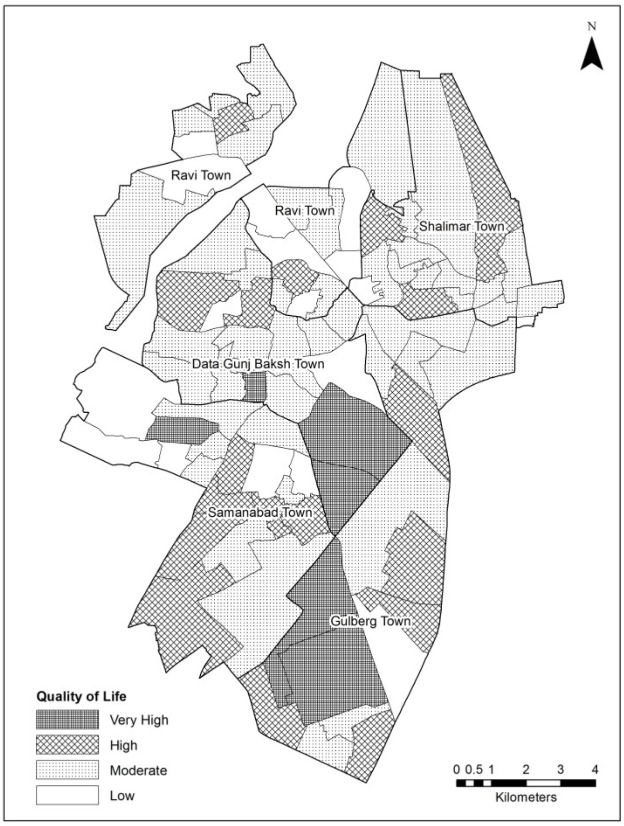

Fig. 4 Union council level QOL map of urban towns of Lahore

The LULC map of urban towns of Lahore generated using BAEM, NDVI and MNDWI is shown in Figure 5(A). The major LULC class in the study area was built-up. The map indicated dense built-up pattern in all the towns except Gulberg, which was comparatively better in terms of open and green space availability. The area covered by each LULC class was computed at UC level in the five towns. The town wise coverage area of each LULC class is shown in Figure 5(B). The highest built-up density was 85% in the Shalimar town, followed by 76% in both Data Gunj Baksh and Ravi towns. Gulberg town had lower built-up density (60%) and better open space/green areas compared to the other urban towns.

The population density was computed for each UC in the study area by linking it to the administrative boundaries. The UC level population density map is shown in Figure 6(A), whereas town wise total population and population density are shown in Figure 6(B).

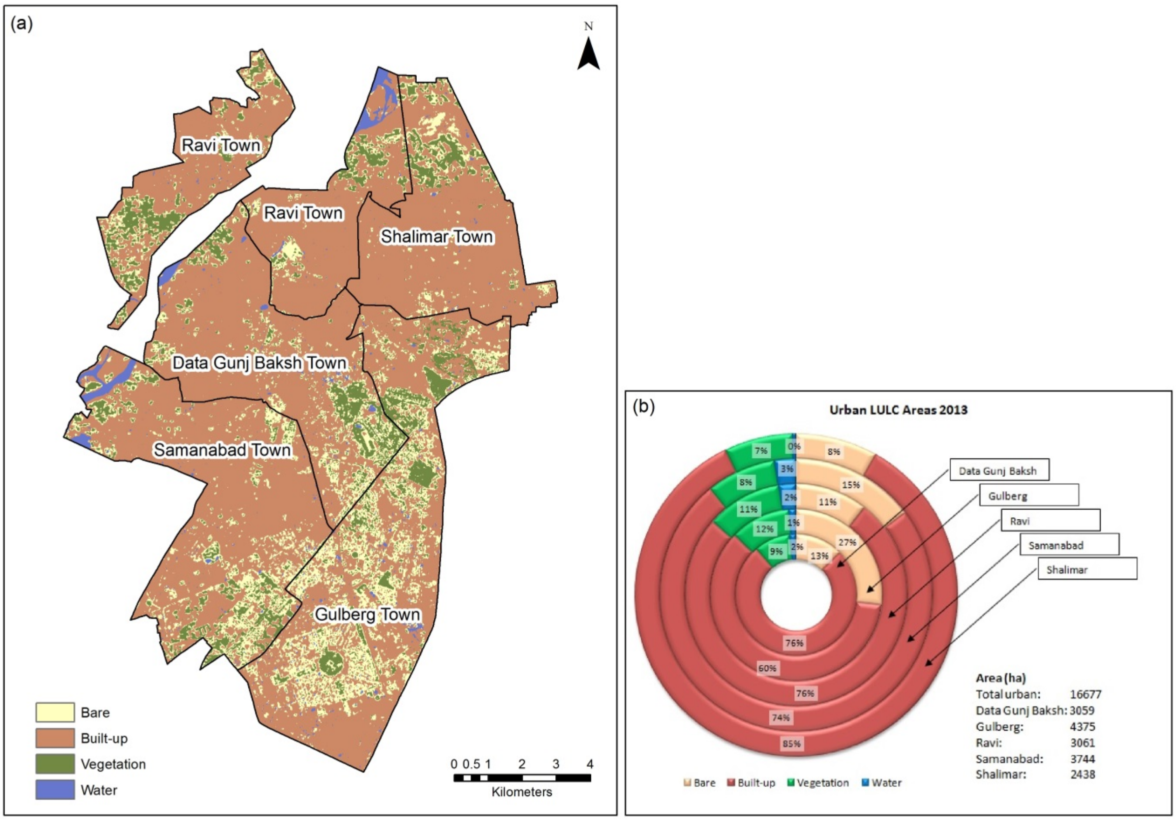

Fig. 5 (a) LULC map and (b) area statistics of urban towns of Lahore (2013)

The population density map (Figure 6(A)) indicates that the northern parts of the study area are densely populated. These areas basically comprise the city center, including the UCs of Ravi and Shalimar towns, where the construction is rather old and congested, and therefore exhibits quite high population density. The other areas having high population density comprise UCs of Data Gunj Baksh and Samanabad towns. Some UCs of Samanabad town also exhibits a high population density. A very few UCs in the Gulberg town were observed to have moderate to high population density, where majority of the area features a low population density in this town.

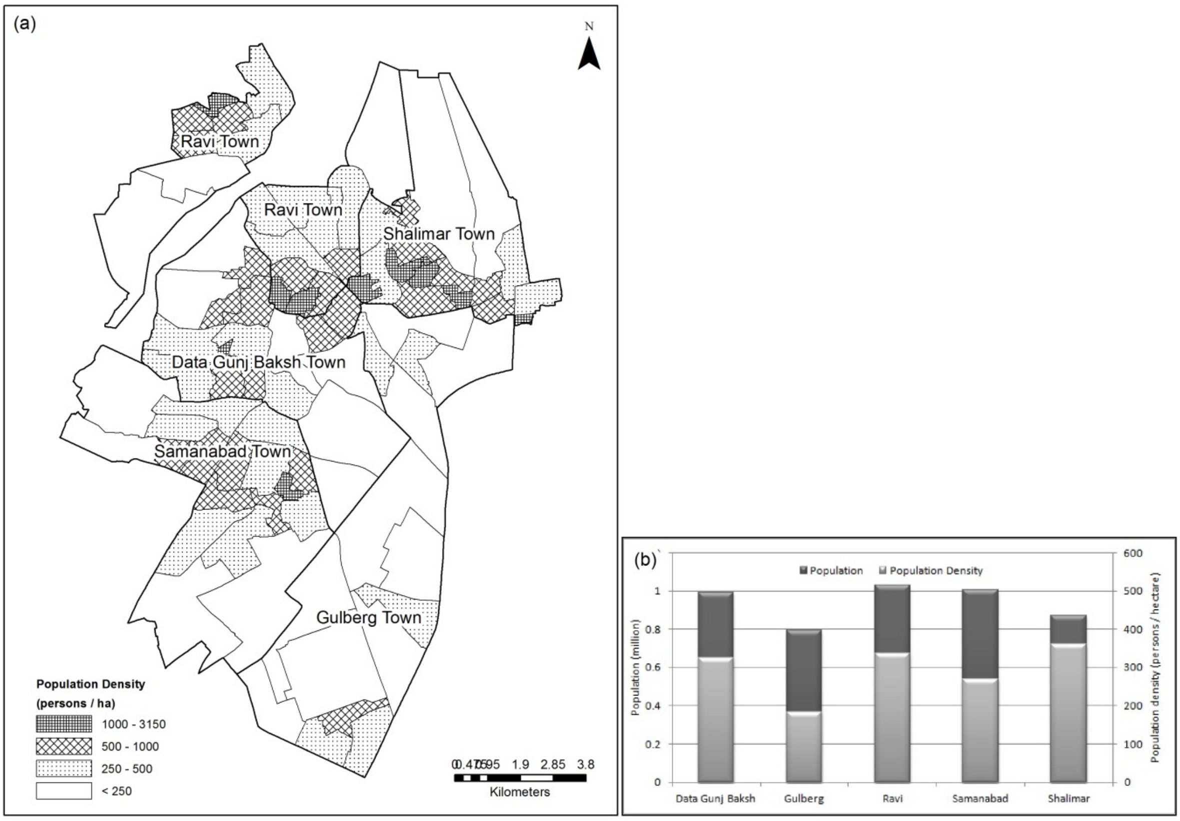

Fig. 6 (a) UC level population density map and (b) town wise population and population density in urban towns of Lahore

The town wise population and population density statistics indicate that Ravi, Samanabad and Data Gunj Baksh towns have the highest population of the five urban towns of Lahore (Figure 6(B)). However, the population density is the highest in Shalimar town (about 360 persons/ha), followed by Ravi (340 persons/ha) and Data Gunj Baksh (325 persons/ha) towns. The lowest population density was observed in Gulberg town (182 persons/ha). The spatial variability in population density indicates that the living conditions are also likely to be somewhat variable within the urban towns on Lahore.

4.3. Relationship between QOL, LULC and population

The QOL was analyzed for relationship with the LULC and population in the study area. The density of each LULC class was calculated for each UC (percentage area covered by each class per UC) through the LULC map. Similarly, the population density was also computed for each UC using the population data and UC area.

The map showing LULC overlaid by the QOL is shown in Figure 7(A). This map indicates high density of built-up areas in the north of the study area, towards city center. The southern and eastern parts are comparatively better in terms of availability of open areas and vegetation. Apparently, the QOL indicates an inverse relationship with the built-up density, high built-up density areas show lower QOL and vice versa. However, the correlation between LULC and QOL was quantitatively analyzed at town level to test the inference.

The results indicated that there was no significant correlation between built-up density and QOL (Table 4). Moreover, no significant relationship was observed between the rest of the LULC classes and the QOL, except for a positive relationship between bare density and QOL in Data Gunj Baksh, and a negative relationship between water density and QOL in Samanabad towns. The positive relationship between bare and QOL indicated that QOL increases, to some extent, with an increase in availability of open spaces. However, the inverse relationship between water density and QOL in Samanabad town can be attributed to the low QOL identified in the west of this town (Figure 4), which is basically the river Ravi floodplain. This finding implies that the primary reason of low QOL in the west of Samanabad town could be the water class. Figures 3(D) and (F) indicates that this area had low values for environment and access to facilities and services domains, and thus the low QOL value can be attributed to these factors.

The spatial distribution of population density and QOL in the five urban towns of Lahore is shown in Figure 7(B). Apparently, the relationship between these two factors was somewhat bewildering. At some locations, the QOL tend to increase with an increase in population density (some UCs in the west), whereas in other instances, an inverse relationship was observed (some UCs in the south and east). Thus, it can be inferred that the spatial relationship between population density and QOL was variable in the study area.

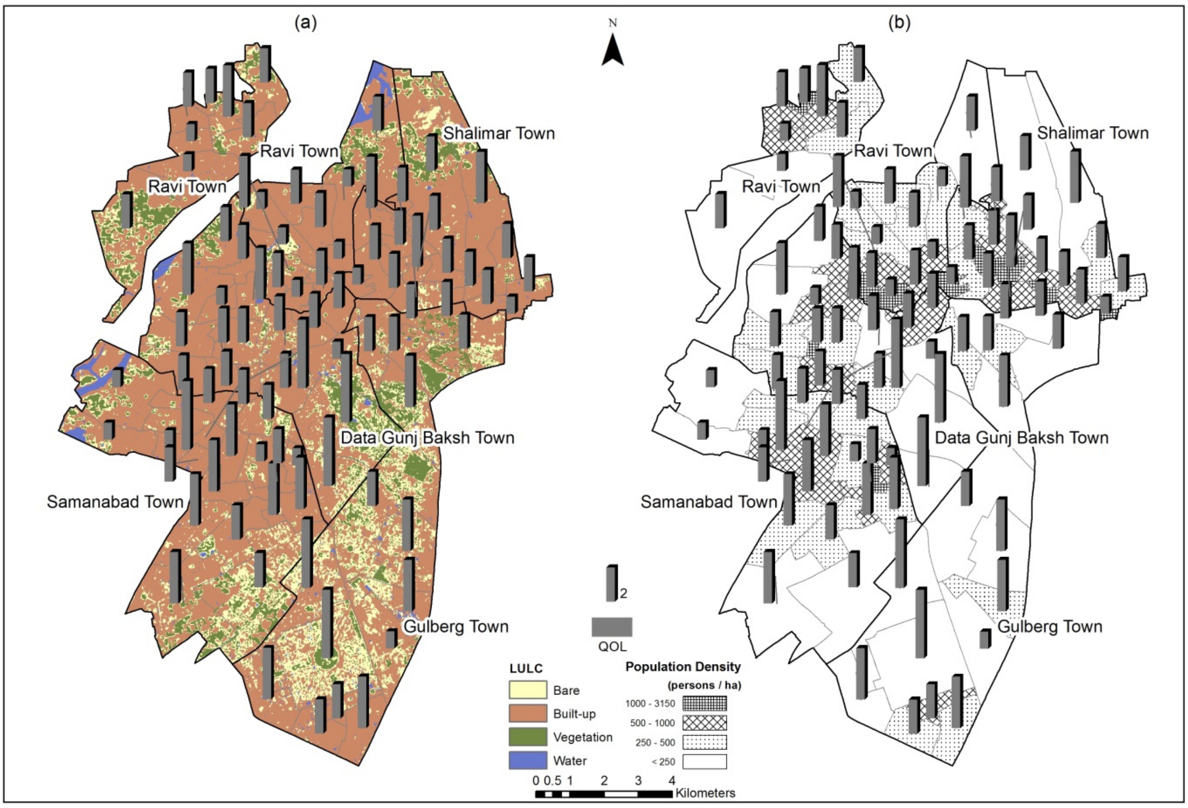

Fig. 7 UC level QOL overlaid on (a) LULC and (b) population density maps of urban towns of Lahore

* The grey colored QOL bars are drawn at a scale of 1 to 4 (low to high QOL).

Table 4. Correlation between QOL and LULC.

Town		Bare Density	Built-up Density	Vegetation Density	Water Density
Data Gunj Baksh	QOL	0.494*	-0.437	0.317	0.127
Gulberg		0.46	-0.358	0.036	0.344
Ravi		0.356	-0.304	0.241	0.042
Samanabad		-0.134	0.231	-0.143	-0.483*
Shalimar		0.466	-0.4	0.229	0.291

*. Correlation is significant at the 0.05 level

The relationship between population density and QOL was examined quantitatively; the results suggested that there was no significant correlation between the two variables, except in Shalimar town where a significant and negative correlation was observed between the two (Table 5). This finding indicates the deficiency in provision of the required QOL facilities in Shalimar town compared to the other urban towns of Lahore.

Table 5. Correlation between QOL and population density.

Town		QOL
Data Gunj Baksh	Population Density	-0.17
Gulberg		-0.355
Ravi		0.085
Samanabad		0.044
Shalimar		-0.631*

*. Correlation is significant at the 0.01 level

The relationship between QOL, built-up density and population density was also examined at urban Lahore level using the data at UC scale. The results shown in Table 6 indicate that the QOL exhibited a significant and negative relationship with population density and built-up density. This analysis provided an overall picture of the relationships among QOL, built-up density and population density in urban Lahore, and it can be inferred that an overall rise in built-up area and population density could have reduced the overall QOL. Another finding was the positive correlation between built-up density and population density, which confirmed that the built-up area was increasing in urban Lahore with the rise in population.

Table 6. Correlations between QOL, built-up density and population density.

	QOL	Built-up Density	Population Density
QOL	1	-	-
Built-up Density	-0.271*	1	-
Population Density	-0.229*	0.528**	1

*. Correlation is significant at the 0.05 level

**. Correlation is significant at the 0.01 level

Nevertheless, the correlation analysis between overall QOL and built-up density indicated that an increase in built-up areas is likely to affect the QOL negatively in the urban Lahore. This finding suggests that appropriate measures need to be taken to cope with the negative impacts of non-reversible urbanization process and inevitable population growth on QOL. Provision of the required and appropriate facilities is essential to sustain and improve the QOL. A more specific finding is related to the Shalimar town, out of the five urban towns of Lahore, which is most likely to get negatively affected in terms of QOL (Table 5). The results indicate that the rise in population density would negatively affect the QOL in this town. Appropriate measures need to be taken to sustain and improve the QOL in urban Lahore, especially in the Shalimar town.

5. Conclusions

The proposed approach for mapping and examining the QOL, LULC and population density provided the means to analyze the spatial distribution and dynamics of these factors at a detailed spatial scale (within a city) in an urban environment. Not only the population density and living conditions were spatially variable in the study area (urban towns of Lahore city), the extent and nature of relationship of QOL with LULC and population density also varied significantly. This finding implies that examining the QOL at a finer spatial scale could help the urban policy makers to: (1) better understand the spatial variation in QOL across different administrative units within the city; and (2) devise efficient and effective plans (separate policies for smaller administrative units within the city) to improve the QOL. One of the interesting characteristics of the proposed approach is that it methodically incorporates the local context while determining the relative importance/weights of the QOL domains; the opinion of local field experts was included in this regard. This method, therefore, makes this approach adaptable to a variety of urban environments, which is quite essential as the perception of QOL as well as the importance of different QOL indicators varies in the developed, developing and underdeveloped areas (Lotfi & Solaimani 2009; Ulengin et al. 2001). Moreover, the overlooked relationship between the QOL and LULC was examined in this study which provided interesting results; the LULC served as an indirect indicator to other variables, such as population, infrastructure and environment. Since mapping the LULC (remote sensing satellite images) is rather easier than the QOL (mostly field surveys), a significant relationship between these two variables could be helpful in assessing temporal QOL, which otherwise is a difficult task through primary data collection methods. Therefore, an insight to this new dimension can be quite helpful from the urban planning and policy making perspective.

This study revealed a variety of important attributes of QOL and its relationships with the LULC and population in the urban towns of Lahore where these variables have not been comprehensively examined previously. The analyses revealed that the QOL was highest in a few UCs of Gulberg, Data Gunj Baksh and Samanabad towns, whereas the lowest values were observed towards the north (old city) and west of the city. This variability can be attributed to the adequate provision of facilities and services in the newly developed towns compared to the old ones. Further, an inverse relationship of QOL with built-up and population densities was observed in the study area. Shalimar town, in particular, exhibited a significant relationship indicating the deficiency in provision of the required QOL facilities in this town. It can be concluded that an increase in the population and built-up area, which is expected in the coming years (Bhatti et al. 2015), will probably affect the QOL negatively in the study area; Shalimar town is likely to be affected the most. Since access to facilities and services was determined as the most important factor for determining the QOL, future urban policies should focus more on providing the basic facilities in order to improve the overall QOL in the study area.

The assessment of QOL can be considered as an initial step towards formulating appropriate public policies for improving the living conditions. Understanding the perception and priorities of local residents regarding QOL can play a significant role in prioritizing the sectors that need to be addressed for enhancing the overall QOL. Moreover, the QOL assessment assists the urban planners and policy makers in two ways. First, it helps formulating and implementing the public policies for improving the QOL and second, it can be used for evaluating and monitoring the outcomes of the implemented public policies. The results of this study indicated that the QOL varies within the urban areas, thus signifying that distinct policy measures for each administrative unit could help achieving better results in terms of improving the QOL. The confidence in the results obtained through the proposed approach can be further improved by increasing the sample size, and incorporating more domains (for instance, religious/spiritual practices, material possessions, working life, self-development, acquisition and consumption of goods/services and school/college life) for assessing the QOL.

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Appendix: Questionnaire for Assessment of Urban Quality of Life

Where do you live? ______________________________ (Town / Tehsil)

______________________________ (Union Council Name / Number)

Since when? ______________________________ (Year)

The following questions ask how you feel about your quality of life, health, or other areas of your life. Please choose the answer that appears most appropriate. If you are unsure about which response to give to a question, the first response you think of is often the best one.

Please keep in mind your standards, hopes, pleasures and concerns. We ask that you think about your life in the last two months.

		Very poor	Poor	Neither poor nor good	Good	Very good
1	How would you rate your quality of life?	1	2	3	4	5

		Very dissatisfied	Dissatisfied	Neither satisfied nor dissatisfied	Satisfied	Very satisfied
2	How satisfied are you with your health?	1	2	3	4	5

The following questions ask about how much you have experienced certain things in the last two months.

		Not at all	A little	A moderate amount	Very much	An extreme amount
3	To what extent do you feel that physical pain prevents you from doing what you need to do?	5	4	3	2	1
4	How much do you need any medical treatment to function in your daily life?	5	4	3	2	1
5	How much do you enjoy life?	1	2	3	4	5
6	To what extent do you feel your life to be meaningful?	1	2	3	4	5
7	How well are you able to concentrate?	1	2	3	4	5
8	How safe do you feel in your daily life?	1	2	3	4	5
9	How healthy is your physical environment?	1	2	3	4	5

The following questions ask about how completely you experience or were able to do certain things in the last two months.

		Not at all	A little	Moderately	Mostly	Completely
10	Do you have enough energy for everyday life?	1	2	3	4	5
11	Are you able to accept your bodily appearance?	1	2	3	4	5
12	Have you enough money to meet your needs?	1	2	3	4	5
13	How available to you is the information that you need in your day-to-day life?	1	2	3	4	5
14	To what extent do you have the opportunity for leisure activities?	1	2	3	4	5

		Very poor	Poor	Neither poor nor good	Good	Very good
15	How well are you able to get around?	1	2	3	4	5

		Very dissatisfied	Dissatisfied	Neither satisfied nor dissatisfied	Satisfied	Very satisfied
16	How satisfied are you with your sleep?	1	2	3	4	5
17	How satisfied are you with your ability to perform your daily living activities?	1	2	3	4	5
18	How satisfied are you with your capacity for work?	1	2	3	4	5
19	How satisfied are you with yourself?	1	2	3	4	5
20	How satisfied are you with your personal relationships?	1	2	3	4	5
21	How satisfied are you with your married life? (if married)	1	2	3	4	5
22	How satisfied are you with the support you get from your friends?	1	2	3	4	5
23	How satisfied are you with the conditions of your living place?	1	2	3	4	5

		Very dissatisfied	Dissatisfied	Neither satisfied nor dissatisfied	Satisfied	Very satisfied
24	How satisfied are you with your access to health services?	1	2	3	4	5
25	How satisfied are you with your transport?	1	2	3	4	5

The following question refers to how often you have felt or experienced certain things in the last two months.

		Never	Seldom	Quite often	Very often	Always
26	How often do you have negative feelings such as blue mood, despair, anxiety, depression?	5	4	3	2	1

		Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
27	My personal income is sufficient to fulfill my daily needs.	1	2	3	4	5
28	I feel that housing prices in my town are still affordable to me.	1	2	3	4	5
29	I am satisfied with my current income.	1	2	3	4	5
30	Local government should increase the number of jobs in my town.	1	2	3	4	5
31	Local government should increase the number of urban facilities in my town.	1	2	3	4	5

What is your level of access to the following facilities…?

		Very poor / not available	Poor	Neither poor nor good	Good	Very good
32	Clean drinking water	1	2	3	4	5
33	Sanitation and cleanliness	1	2	3	4	5
34	Public transport	1	2	3	4	5
35	Cycling facilities	1	2	3	4	5
36	Leisure activities	1	2	3	4	5
37	Services for elderly	1	2	3	4	5
38	Services for people with special needs	1	2	3	4	5

		Very poor / not available	Poor	Neither poor nor good	Good	Very good
39	Health services	1	2	3	4	5
40	School services	1	2	3	4	5
41	Playgrounds and parks	1	2	3	4	5
42	Recycling services	1	2	3	4	5

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