INNSPUB

Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 16, No. 3, p. 125-143, 2020
http://www.innspub.net

RESEARCH PAPER OPEN ACCESS

Spatial-temporal assessment of urban growth and land use change in Islamabad using object-based classification method

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Article published on March 30, 2020

Key words: Land use change, Urban growth, Islamabad, Object-based classification, Google earth

Abstract

Rapid land use changes have taken place in Islamabad, the capital city of Pakistan, over the past decades due to accelerated urbanization and industrialization. In this study, land use changes in metropolitan area of Islamabad was observed by the combined use of GIS and satellite remote sensing for a time period of 20 years. High resolution Google Earth images were downloaded from 1995-2015 and Object-based classification method was used for accurate classification using eCognition software. The information regarding residential area, industrial area, barren land, arable land, agricultural area, vegetation, forest, water and transportation infrastructure was extracted. The results showed that the city experienced a spatial expansion, rapid urban growth, land use change and expanding transportation infrastructure. The study concluded integration of GIS and remote sensing as an effective approach for analyzing the spatial pattern of urban growth and land use change.

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Introduction

The 20th century has seen urbanization, among few dominant trends, mainly in the developing parts of the world, for economic as well as social change. Global trends have also shown that the majority of the population lives in urban areas rather than rural. This global and gradual shift towards the urbanization of the world has taken over almost six decades to take place. Data shows that, almost seventy percent (70%) of the world population was rural compared to only thirty percent (30%) of urban settlements in 1950, which changed to almost fifty four percent (54%) urban population till 2014. This global trend of urban and rural settlements, as measured in the mid-twentieth century, is expected to reverse by 2050, as per estimate, when the urban population is estimated to increase to almost two-third (66%) of the total whereas the rural population is estimated to decline to one-third (34%) of the total population count (United Nations, 2014).

The rapid pace of world's urban population growth, especially in developing countries, is one of the major challenges for governments and planning agencies. Around the globe, megacities continue to emerge (Van Ginkel, 2008), which are powerful centres for economic growth and prosperity, although this growth is accompanied by loss of biodiversity and environmental degradation (Czamanski *et al.*, 2008). Most of this urban growth occur in less developed countries (Girard *et al.*, 2007; Van Ginkel, 2008). The spatial expansion of cities and towns beyond their juridical limits and peripheries in order to accommodate the growing urban population are the inevitable outcomes from this process. Therefore, effective planning and governance is crucial for urban planners and policy makers to achieve a more sustainable urban form.

Urban growth leads to the change of land use and land cover in many areas around the world, especially in developing countries. A major problem with the urban growth and LULC change is associated with negative social, environmental and economic impacts (EEA, 2006). The environmental impacts include open space, loss of fertile lands, and biodiversity (Atu *et al.*, 2013) spoiling water quality (Tu *et al.*, 2007), higher pollutions levels (Glaeser and Kahn, 2004) increasing runoff and increase of energy consumption (Sung *et al.*, 2013). From the socio-economic perspective, the outcomes of urban sprawl are public service costs and excessive infrastructure (Batty, 2008) the decline of public space, loss of a sense of community, reducing social cohesion, reducing public health, security and safety, loss of cultural values (Jaeger *et al.*, 2010; Pereira *et al.*, 2014), traffic congestion (Ewing *et al.*, 2003b;Hathout, 2002), increase of income inequality (Brueckner and Helsley, 2011) limited access and longer travel distance, especially for non-driver people (Bento *et al.*, 2003).

The aggravation of these problems over the last decades has led to the development of new approaches and methods to achieve more sustainable urban form by monitoring urban growth phenomenon and its consequences (Kushner, 2002; Jenks and Dempsey, 2005). In an effort to analyze urban growth, some researchers (Ewing *et al.*, 2003a) measure urban growth by their indicators, while others focus on the temporal and spatial technologies such as remote sensing and GIS in combination with statistical techniques (Thomas *et al.*, 2003; Jat *et al.*, 2008a; Dewan and Yamaguchi, 2009; Tewolde and Cabral, 2011; Rawat *et al.*, 2013; Alexakis *et al.*, 2014; Deep and Saklani, 2014; Liu and Yang, 2015). However, the monitoring and mapping of urban growth and LULC changes using remote sensing and GIS techniques has gathered more interests and has largely proved to be valuable and effective tools for monitoring of urban sprawl over a certain time period (Masser, 2001; Jat *et al.*, 2008b; Belal and Moghanm, 2011; Butt *et al.*, 2015; Dadras *et al.*, 2015).

Beyond methods, monitoring and investigation of LULC change and urban growth are necessary to identify the impacts especially in developing countries. Like most of the developing countries, Pakistan has experienced high urban population growth in the last five decades. The cities have expanded substantially from 1947 to 2019.

In Pakistan, urbanization growth has been fueled by governments' policies and incentives which resulted in rural-urban migrations. One of the major consequences of this trend has been the urban sprawl over the last few decades, also in other parts of Asia (Roshan *et al.*, 2010; Shahraki *et al.*, 2011; Ebrahimpour-Masoumi, 2012; Arsanjani *et al.*, 2013; Mohammady, 2014). Monitoring and understanding of LULC change and urban growth is crucial and would be helpful for the policy makers and city planners to direct future developments and for environmental management (Sudhira *et al.*, 2004; Simmons, 2007). This paper aimed to monitor urban spatial expansion patterns and land use/cover change in the capital city Islamabad from 1995-2015 using remotely sensed data.

Materials and methods

Study area

Islamabad Federal Capital lies between 72° 48' and 73° 22' east longitudes and 33° 28' and 33° 48' north latitudes and this location corresponds to the northern edge of Pothwar Plateau. The city covers a total land area of about 906 Sq. Km. Based on land use, three major segments have been identified in the capital city; namely, i) A stretch of 466. Sq. Km comprising rural area of Islamabad, ii) A land area of about 220 Sq. Km categorized as urban area of Islamabad that also includes an industrial and an institutional area iii) Green area and parks totaling to an area of 220 Sq. Km (GoP, 1999).

As per the data collected in the census of 1998, the total population of Islamabad was found to be 0.80 million. In 2017, this population number has jumped up at above 2 million (PBS, 2017). The environment has been negatively affected as the population has rapidly increased and high demand of natural resources has caused immense pressure on their availability (Sheikh *et al.*, 2007). The population in urban area of Islamabad, has seen a population spike to 1.01 million, estimated in 2017, compared to the population number collected in census of 1998 that was about 0.53 million. Urban area constitutes about 220Sq. Km of Islamabad and in some of the urban areas the population density hits the peak value of nearly 12000/Sq. Km. Comparison of average population growth rate with other cities shows that this rate is more than 3-4 times, the Islamabad stands at an average of 5.75%.

The transit system in the urban area of Islamabad is considered better as compared to many other cities of the country, especially the twin city Rawalpindi. The road network of Islamabad represents a grid like structure as the city is properly planned and the road network is extensive. As a result, the traffic environment and the standard of roads are both superior when compared to the other cities. The study area is shown in Fig. 1.

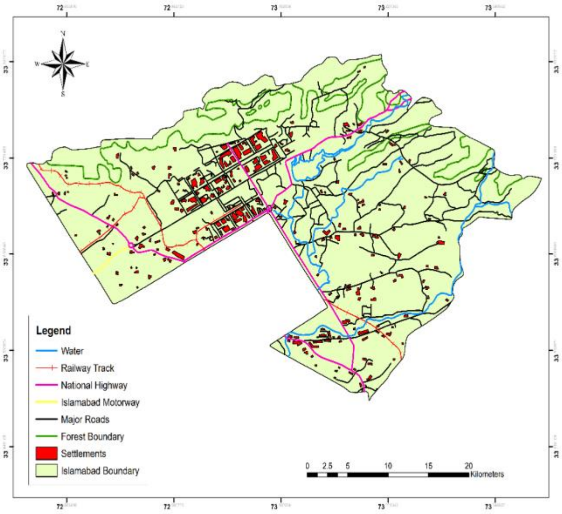

Fig. 1. Study area map.

Data Collection and data preparation

Data collection involved multiple types of data including aerial images of selected years, topographic maps of selected cities, master plans of cities, census data and previous urban growth studies. Table 1 lists the datasets that were collected for use in present study.

Table 1. Data Sources and types.

Dataset	Source	Date	Resolution
Google Earth Imagery	Google Earth	1995, 2000, 2005, 2010, 2015	2.5 m
Topographic Maps	Survey of Pakistan	2003, 2017	1:50,000
Master Plans	Internet	1995, 2000, 2002, 2012, 2015	n.a
Urban Growth Studies	Internet	2003, 2005, 2012, 2014, 2015	n.a

The current research utilized different aerial images from 1995 to 2015 for the assessment and quantification of the spatio-temporal land use/cover changes in the selected area. High resolution images from Google earth were used for years 1995, 2000, 2005, 2010 and 2015. Moreover, this spatio-temporal analysis was facilitated by a diverse secondary data, including the master plans; census data of 1998-2015; and topographic maps.

Land use and land cover change detection

Spatio-temporal mapping included quantitative time series analysis and land cover classes' transformation. As mentioned above high resolution Google Earth images were utilized. Object Based Image Analysis (OBIA) technique was used for accurate quantification. Most of the previous studies on LULCC mostly utilized the medium or low spatial resolution images, like Landsat ETM+/TM, MODIS/TERRA and NOAA/AVHRR (Wijedasa *et al.*, 2012; Zhou *et al.*, 2013). Then remotely sensed data was used to derive different regional and global land cover products, for example, FROM-GLC (Gong *et al.*, 2013), GlobCover (Tchuenté *et al.*, 2011, GLC2000 (Hansen *et al.*, 2000) and NLCD-China (Liu *et al.*, 2003). The relatively low resolution of these productshave unfortunately made them inadequate for study of areas with high heterogeneous and complex landscapes e.g. urban environment,having small features (e.g. buildings and roads) with complex patterns (Zhou *et al.*, 2008; Laliberte *et al.*, 2012). This limitation creates a hindrance for policy makers and researchers in planning and decision making. Thus, requiring for land use mapping of high resolution imagery.

A variety of high resolution satellite imagery have been generated in the past decades, after the development of new satellite sensors e.g. QuickBird, IKONOS and RapidEye. These imageries ensure the provision of comprehensive information about the shape and size of target features, as well as the precise relationships among the neighbouring elements, thus making availability of new opportunities for accurate and detailed regional scale land use and land cover mapping (Batista and Haertel, 2010; Duro *et al.*, 2012). However, because of high economic costs and narrow spatial coverage, the utilization of these high resolution imageries is generally limited to land cover mapping of small areas.

The recent and quick development of Google Earth (GE) tool, with high resolution images, as a free and open data source has provided wider applications in many sectors and excessive support for the OBIA using eCognition software (Kaplan and Avdan, 2017; Liu *et al.*, 2017) or utilization as a visualization tool for land use mapping (Yu and Gong, 2012; Kaimaris *et al.*, 2011). Another advantage of GE is the provision of images at different time periods making urban planners to perform land use change detection studies in a very effective way (Malarvizhi *et al.*, 2016). Therefore, in present study, GE images of selected years were downloaded from Google Earth 7.1.7 using Elshayal Smart GIS 17.003. Elshayal is an open source software with an advantage of downloading rectified and geo-referenced GE imagery, could be utilized in any GIS analysis without the need of geo-referencing (Malarvizhi *et al.*, 2016; El-shayal, 2017; Nkomeje, 2017). A total of 210 images were acquired and downloaded for each selected year covering the entire study area of Islamabad. The individual images were then mosaicked to form one single image in ArcGIS 10.2, reprojected and subset in Erdas Imagine 2014 software using the study areas shapefiles. Fig. 2 represent satellite images of Islamabad for selected years downloaded from Google earth.

Object Based Classification Technique

There has been wide application of traditional pixel-based classification approach for land cover mapping (Aitkenhead and Aalders, 2011; Shao and Lunetta, 2012). Yet, due to increase in imageries spatial resolution, single pixel have become unable to capture the characteristics of targeted objects well. A decrease in statistical separability among different classes has been caused by the rise in intra-class spectral variability, which is very important in the pixel-based approach.

Another drawback of pixel-based classification method is that it lacks the ability to fully analyse the detailed spatial information and rich amount of texture characteristics in the high resolution images. This results in reduction in classification accuracy and serious salt and pepper effect (Yu *et al*., 2006). Due to these reasons, OBIA technique was used in this research for the classification of high resolution GE imagery. In the object based approach, the minimum unit is the object comprised of adjacent pixels' group, instead of a pixel, having specific information. Moreover, other than the spectral characteristics, the topological relationships among different objects, the geometric characteristics and the texture of an object can be used in classification of images (Lisita *et al*., 2013). In the current research, as mentioned earlier eCognition software was utilized for the image classification. It involved 3 steps (a) segmentation of image b) appropriate rule sets selection for classification and (c) accuracy assessment of classification and comparison.

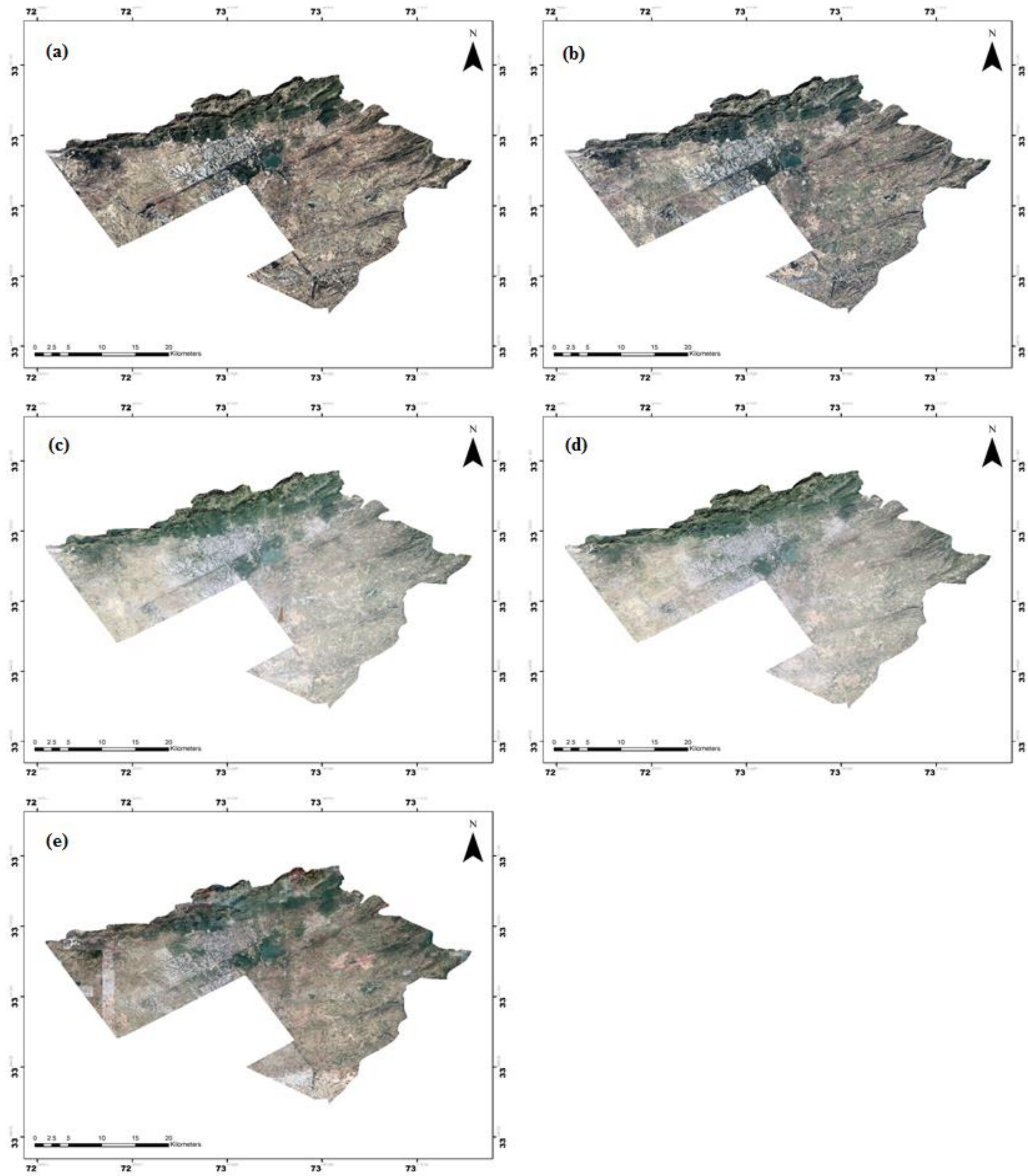

Fig. 2. Satellite images of Islamabad for years a) 1995 b) 2000 c) 2005 d) 2010 e) 2015 downloaded from Google Earth

Multi-scale Segmentation

One of the most important part of OB classification technique is the segmentation of images. "The aim of this segmentation is the adjacent pixels grouping, with similar characteristics to develop different meaningful image objects. This is the foundation of subsequent classification because all object features are dependent on the segmented objects" (Lu and Weng, 2007; Blaschke, 2010). Thus, making a suitable scheme of is like segmentation is very important in classification. In this research, an algorithm of multi-scale segmentation was adopted. This clustering technique of image segmentation for high resolution imageries has been proved to be very suitable (Dribault *et al.*, 2012). "It creates objects using an interactive algorithm, whereby pixels are grouped until a given threshold is reached" (Kaplan and Avdan, 2017).

The two most important parameters for segmentation are heterogeneity criterion and scale factors. The average size of the objects indirectly relates to the scale factor, which determines the maximum possible change in heterogeneity. Whereas, the heterogeneity criterion, which controls the clustering decision is determined by the two important parameters; the shape and the color (Mathieu *et al.*, 2007). The shape is comprised of properties of compactness and smoothness. Compactness compares the pixels to a circle and by this it describes the closeness of pixels clustered in an object. Table 2 shows different segmentation parameters used in this research. In finding the appropriate scale for each land use/cover type, first different scales were set starting from 100 to 10 with a decrement rate of 10. Secondly, the results were analyzed visually to determine the matching of image objects with feature boundaries. This iteration technique helped to determine the relatively optimal scale for each land use/cover type.

Table 2. Multi-scale segmentation parameters.

SN	Scale Parameter	Shape	Compactness
1.	7	0.7	0.7

Selection of Classes, Features and Classification Rules

Keeping in view high resolution of GE imagery, and aim of the research, a total of nine major categories (urban including the industrial were selected to study temporal LULCC as well urban growth), represented in Table 3. Anderson *et al.* (1976) defined nine different classes for classification and LULCC to study urban change in the USA. Similarly, Butt *et al.* (2012) developed eight classes to study urban sprawl in Islamabad using multi-sensor satellite data. In OBIA, these categories were classified on the basis of features selection.

Table 3. Selected land use/land cover classes.

Sr. No.	Class Name	Description
1.	Residential	Total built-up areas including the urban and rural area
2.	Industrial	Industrial area
3.	Bare Soil/Rocks	Bare exposed area and transitional area
4.	Forest	Mixed forest land
5.	Vegetation	Mixed vegetation, grass, tree species
6.	Agriculture	Croplands/Cultivated area
7.	Arable Land	Fallow land
8.	Urban Transport	Urban transportation network including highways, main roads, sub-roads, railway tracks and airports
9.	Water	Water reservoirs and water channels

Size, shape, context, spectral and texture characteristics comprise the object features. These features are usually used for the measurable objects' range by defining their lower and upper limits. Within these defined limits, the image objects are assigned to a specific class, while those assigned to other classes fall outside the range (Manandhar *et al.*, 2009). Thus, the main purpose of the selection of features is to ensure high accuracy of classified images by identification of most relevant features for each class (Blaschke, 2010).

In this research, seven features were selected, including the brightness, neighborhood relationships between classes, standard deviation of DN, mean DN, length, area, ratio of length and width. The selection of these features was based on visual examination, expert knowledge and literature review (Zhou and Troy, 2008; Duro *et al.*, 2012). The standard deviation and mean of the selected features was then used to determine their threshold value (Benz *et al.*, 2004).

Table 4 lists the rule sets and hierarchical features developed for the GE imagery classification in this research. The better classification results were obtained after the inclusion of spatial features such as neighborhood relationships of objects and area, otherwise, only spectral features of the imagery caused confusion among different classes like shadow and building.

Table 4. Variables and Rules Used for Imagery Classification.

Level	Parent Class	Child Class	Rule Sets
1.	Whole Imagery	Land Water	1. Brightness and mean DN of bands were used to classify the two classes based on the nearest neighbor classifier. 2. The inclusion relationships between building and river objects were taken to remove the building objects from river objects.
2.	Land	Vegetation Agriculture Settlements Barren Land Transportation Infrastructure	3. The features including brightness and mean DN of each layer were adopted to classify the vegetation, agriculture and the remaining class based on the nearest neighbor classifier.
3.	Settlements	Residential Industrial	4. The features including brightness and mean DN of each layer were adopted to classify the settlements in to residential and industrial area. Later urban residential area was extracted.
4.	Barren Land	Arable Land Bare Soil/Rocks	5. The features including brightness and mean DN of each layer were adopted to classify the barren land in to agricultural fields and bare soil/rocks.
5.	Vegetation	Forest Other Vegetation	6. The features including brightness and mean DN of each layer were adopted to classify the vegetation in to forest and other vegetation.

Classification Accuracy Assessment

In this study, available reference maps, ground truth data and data (National Institute of Public Administration, 1989; Agriculture Census Organization, 1990; Survey of Pakistan, 2003, 2017; Federal Bureau of Statistics, 2004) from various agencies were used to validate the classified images, a method widely used in existing studies (Gao *et al.*, 2009; Zhou *et al.*, 2009; Butt *et al.*, 2012; Hu *et al.*, 2013). The reference maps were assumed to be most suitable to measure the accuracy of classified images. During field visits, the geographical locations of some of the features were collected like vegetated areas, water bodies and important buildings. This location data was used as ground truth data. In addition to this, in order to avoid errors in the reference data, the satellite data was also used for accuracy assessment. Some statistics including overall accuracy and Kappa coefficient were computed individually for each image and error matrices were then generated for all the images, using more than 200 randomly selected points as a reference data set.

Change Detection Analysis

Change detection analysis after LULC classification is critically dependent upon appropriate algorithm selection (Jensen, 1996). Two approaches are mostly used for this change detection analysis; one basic technique is post classification comparisons while the other technique involves multi-temporal data sets and their simultaneous analysis. Training areas with high accuracy are required for post classification technique, sources of which are either high spatial resolution imagery or study area's local knowledge. Each defined class accuracy thus contributes to the overall accuracy of the classified image. On the other hand, data with similar seasonal and atmospheric conditions are required to observe land cover changes in simultaneous analysis approach (Butt *et al.*, 2012). In this study, post classification comparison technique was adopted for LULC change detection.

Indicator of Growth and Change

Annual Land Use Change Index

In the current study, first of all, land use change index was used for the quantification of change in each land cover class during the selected time period. Land use change is one of the major driving forces of urban growth and development, reflecting the urban areas dynamics (Xie *et al.*, 2005; Zhang and Guindon, 2006). Therefore, it is considered critical in different regional, global and urban spatio-temporal analyses.

For this purpose, a land use change index (LUCI) was used to ascertain the land cover change in each class (Equation 1).

$$ALUCI_{a,t} = \frac{(LU_{a,t} - LU_{a,t-1}) / LU_{a,t-1}}{(N_t - N_{t-1})} \times 100 \quad (1)$$

Where $ALUCI_{a,t}$ (%) referred to the annual land use change index; $LU_{a,t-1}$ and $LU_{a,t}$ were the land use class a's total area in hectares at time t-1 (former year) and time t (current year); N was the total number of years from current year (t) and former year (t-1).

Annual Urban Spatial Expansion Index

After analysis of land cover change, urban spatial expansion index was developed for further quantification and analysis of the urban growth and change in the study area. This index is important for the description of the change in an urban area with respect to its growth area and urban growth rate annually (Fan *et al.*, 2009; Tian *et al.*, 2005). The AUSEI (Annual Urban Spatial Expansion Index) was considered to assess the temporal spatial urban growth of Islamabad, and is given in Equation 2.

$$AUSEI_t = \frac{(U_t - U_{t-1}) / U_{t-1}}{(N_t - N_{t-1})} \times 100 \quad (2)$$

Where $AUSEI_t$ (%) referred to the annual urban spatial expansion index; U_{t-1} and U_t were the urban areas in hectares at time t-1 (former year) and time t (current year); N was the total number of years from current year (t) and former year (t-1).

Results

The land use/cover classification maps of the years 1995, 2000, 2005, 2010 and 2015 of Islamabad are given in Fig. 3. Land cover maps were generated OBIA technique. The land cover maps were discriminated among the following nine categories as mentioned above, i.e. Residential, Industrial, Urban roads, Vegetation, Forest, Agriculture, Arable Land, Bare Soil/Rocks and Water.

Accuracy assessment was done to determine the reliability and applicability of classification results in change analysis. Based on the reference data and visual interpretation methods the Kappa coefficient and overall classification accuracy for land cover maps were determined (Table 5). The overall accuracy of classification was 87%, 86%, 90%, 89% and 92% for the years 1995, 2000, 2005, 2010 and 2015 respectively. These results of accuracy assessment are reliable according to Anderson (1976) and Lea and Curtis (2010), where >80% and > 90% standard accuracy recommended by LULC studies.

Table 5. Accuracy Assessment of LULC maps of 1995, 2000, 2005, 2010 and 2015 (Islamabad).

Years	Overall Accuracy	Kappa Coefficient
1995	87%	0.86
2000	86%	0.85
2005	90%	0.88
2010	89%	0.89
2015	92%	0.90

The results of land cover classification of Islamabad from 1995-2015 are shown in Fig. 4. The agricultural land occupied major part of an area of 24,977.4 hectares in 1995. In years 2000, 2005, 2010 and 2015, the distribution value changed to 23, 209.8, 23, 917, 18880.4 and 10,993.9 hectares respectively. The values shows that the agricultural land started to decrease from 1995 to 2015, but it faced a major change in 2015. Likewise, the second major class covering major part of the area was bare soil/rocks. It occupied an area of 22,487.6 hectares, which changed to 22,182.4, 25.061.5, 22598, and 19224.9 in 2000, 2005, 2010 and 2015 respectively. Its area increased in 2005 but till 2015, it faced a declining trend. Vegetation also as a major class changed from 22310.7 hectares in 1995 to 18036.7, 15069.4, 20845.5 31534.7 hectares in 2000, 2005, 2010 and 2015 respectively. According to its distribution value, this class decreased till 2005, then increased in 2010 and 2015. Similarly classification results showed that the area of arable land increased from 9977.6 hectares in 1995 to 13184.2 hectares in 2000, then changed to 10523.4, 11034.2 and 6698.9 hectares in 2005, 2010 and 2015 respectively. Residential area faced a continuous positive shift and it increased from 4135.2 hectares to 6196.5, 8106, 8930 and 12366.3 hectares in 1995, 2000, 2005, 2010 and 2015 respectively. Likewise urban roads also faced a positive shift in 20 years and increased from 1563 hectares in 1995 to 3577, 5251.5, 5946.9 and 6772.8 hectares in 2000, 2005, 2010 and 2015 respectively. Forest cover value was 2882.4 hectares in 1995, reduced to 2225.9, and 1004.8 hectares in 2000 and 2005 respectively, but again started to increase in 2010 and 2015 with area of 1090.6 and 1721.1 hectares respectively. Considering area distribution values, it was observed that industrial class occupied the smallest area i.e. 60.5, 91.3, 118.1, 135.2 and 165.7 hectares in 1995, 2000, 2005, 2010 and 2015 respectively, and according to distributional values this class also followed a positive increasing trend. Water was the only class which showed continuous negative shift in area from 1878.2 hectares in 1995 to 1569.4, 1222.8, 809.6 and 796.7 hectares in 2000, 2005, 2010 and 2015 respectively.

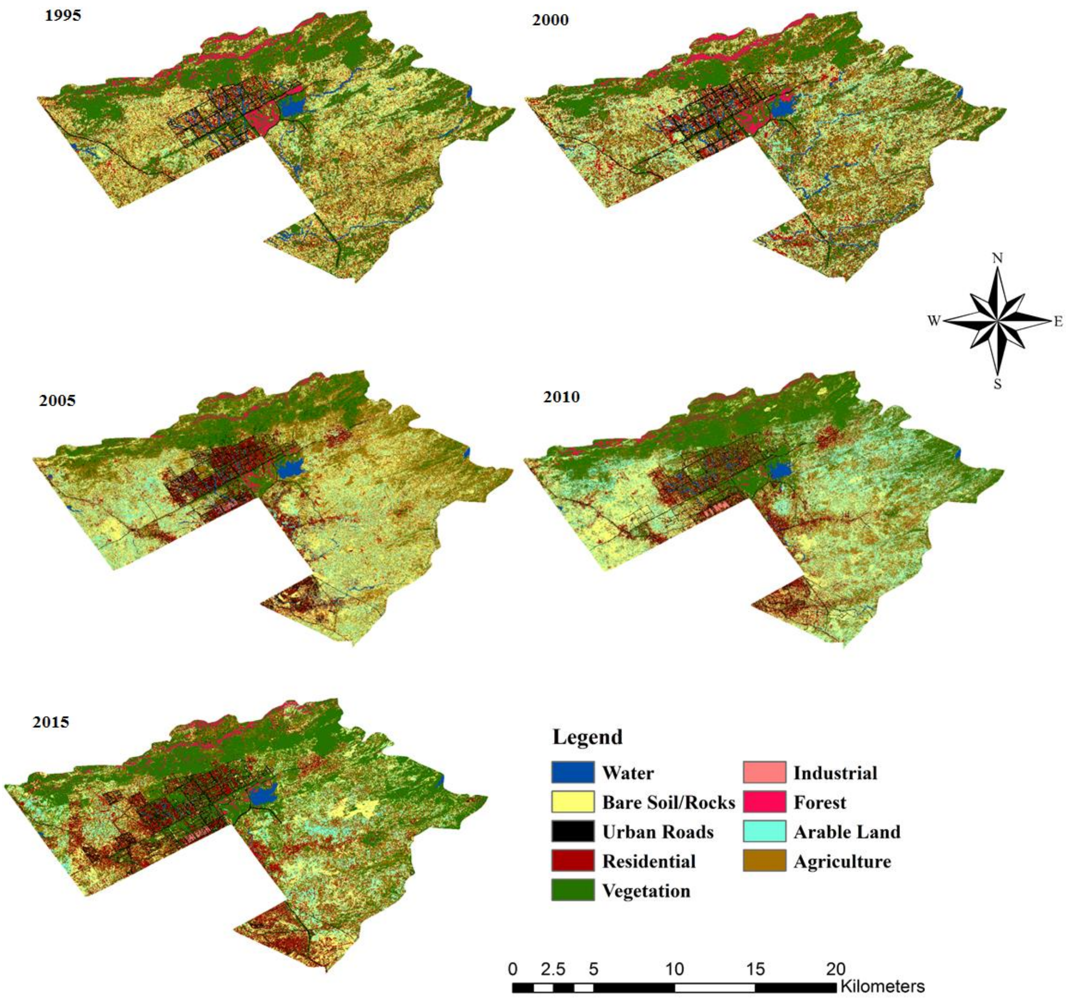

Fig. 3. Classified land cover maps of Islamabad from 1995-2015.

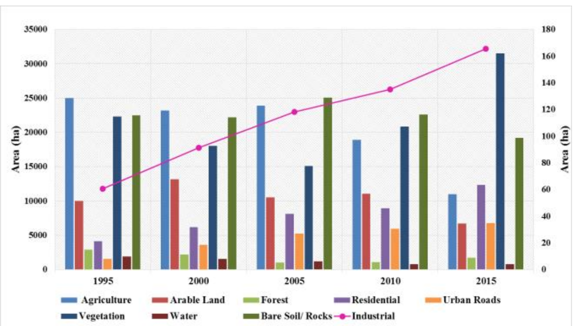

Fig. 4. Area statistics of land cover Islamabad from 1995-2015.

Post Classification Comparison

Change detection analysis was done for the comparison of classified images of Islamabad. The images selected for comparison were of years 1995, 2005 and 2015.

The comparison among these were done in order to study significant change among classes. Change was observed from 1995-2005, 2005-2015 and 1995-2015 and results of these are given below.

LULC Dynamics (1995–2005)

Comparison results of classified images of Islamabad from 1995-2005 are given in Fig. 5 and Table 6. Results of cross tabulation matrix (Table 6) show that out of total 22310.7ha of vegetation area in 1995, 8794ha remained in the same class in 2005, 6780.2ha was changed to agriculture, and rest to other classes. Residential and urban roads replaced 1259.6ha and 920.5ha respectively. Similarly agriculture class retained only 6872.9ha in 2005, out of 24977.4ha in 1995. Major replacement was caused by bare soil/rocks (8174.6ha). Arable land also lost its major part to bare soil (3664.9ha). Residential area also shared its area with other classes. The shift of urban roads to other classes given in Table 6 and other cross tabulation results in this chapter was due to misclassification, which reduced the classification accuracy.

Table 6. Cross-tabulation of Islamabad land cover classes between 1995 and 2005 (area inha).

		1995									
		Water	Bare soil/rocks	Urban Roads	Residential	Vegetation	Industrial	Forest	Arable Land	Agriculture	Total
2005	Water	644.5	143.2	25.3	116.7	124.3	0	8.4	10.8	149.6	1222.8
	Bare soil/rocks	284.4	8411.2	160.1	1080.4	3119.5	22.1	124.3	3664.9	8174.6	25061.5
	Urban Roads	208.5	1202.7	727.5	661.4	920.5	2.9	48.4	427.6	1036.3	5251.5
	Residential	185.4	2388.6	235.9	978.8	1259.6	6.3	65.3	810.9	2175.8	8106
	Vegetation	197.1	1029.9	179	17	8794	0	1428.9	507.6	2909.5	15069.4
	Industrial	14.7	18.9	8.4	10.5	12.6	28	0	6.3	18.9	118.1
	Forest	0	27.4	6.3	8.4	337	0	608.7	6.3	50.6	1004.8
	Arable Land	88.5	3774.5	46.3	457.4	962.6	0	29.5	1575.5	3589.2	10523.4
	Agriculture	254.9	5491.2	174.8	804.6	6780.2	2.1	568.7	2967.7	6872.9	23917
	Total	1878	22487.6	1563	4135.2	22310.7	60.5	2882.4	9977.6	24977.4	90274

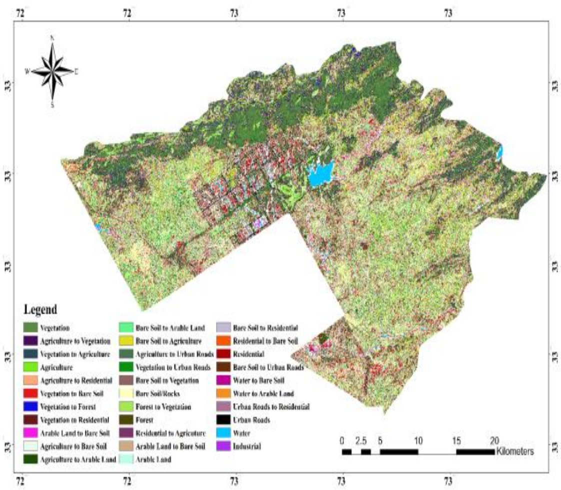

Fig. 5. Major Land use conversions in Islamabad from 1995-2005.

LULC Dynamics (2005–2015)

Comparison results of classified images of Islamabad from 2005-2015 (Fig. 6 and Table 7) show that major land use conversion took place from agriculture to vegetation. Out of total 23917ha of agriculture in 2005, 3374ha remained in the same class in 2015, 10338.3ha was changed to vegetation, and rest to other classes. Residential and urban roads replaced 2249.7ha and 1044.8ha respectively. Similarly bare soil/rocks class retained only 7683ha in 2015, out of 25061.5ha in 2005. Major replacement was caused by residential (4065.4ha) and vegetation (5070ha). Arable land also lost its major part to bare soil (3664.9ha). Residential area also shared its area with other classes. Other classes which majorly contributed to residential area was arable land (1777.8ha).

LULC Dynamics (1995–2015)

Fig. 7 and Table 8 show the cross tabulation results of classified images of Islamabad from 1995-2015. Results show that during the period of 20 years major land use conversion took place from agriculture to bare soil, vegetation and residential. Out of total 24977.4ha of agriculture in 1995, 3893.6ha remained in the same class in 2015, 7249.7ha was converted to vegetation, 6080.8ha to bare soil and 3555.4ha to residential. 1772.3ha of agriculture was converted to urban roads. Similarly arable land contributed 2639.1ha to vegetation, 2761.4ha to bare soil and 1473ha to residential. Bare soil/rocks class retained only 6194ha in 2015, out of 22487.6ha in 1995. Major replacement was caused by agriculture (3176.9ha), residential (4147.3ha) and vegetation (4532.8ha). Bare soil contributed 1843.2ha to urban roads.

Table 7. Cross-tabulation of Islamabad land cover classes between 2005 and 2015 (area inha).

		2005									
		Water	Urban Roads	Residential	Vegetation	Indu strial	Forest	Bare soil/rocks	Arable Land	Agriculture	Total
2015	Water	582	18.9	16.8	65.3	0	0	37.9	16.9	58.9	796.7
	Urban Roads	77.9	1829	1116.4	450.8	16.8	12.6	1609.3	615	1044.8	6772.8
	Residential	117.9	1039	2476	600.3	25.3	14.7	4065.4	1777.8	2249.7	12366.3
	Vegetation	254.8	1253.3	1870.5	10576.3	17.8	558.2	5070	1594.6	10338.3	31534.7
	Industrial	6.3	35.8	40	16.9	46.3	0	9.9	2.1	8.4	165.7
	Forest	4.2	27.4	27.4	895.2	0	341.4	147.5	12.6	265.4	1721.1
	Bare soil/ rocks	94.8	591.9	1522.9	1025.8	6.3	35.8	7683	3411	4853.2	19224.9
	Arable Land	27.4	115.9	267.5	193.8	0	4.2	2932.5	1432.4	1725.2	6698.9
	Agriculture	46.3	306	768.8	1270	6.1	37.9	3524.6	1659.9	3374	10993.9
	Total	1222.8	5251.5	8106	15069.4	118.1	1004.8	25061.5	10523.4	23917	90274

Table 8. Cross-tabulation of Islamabad land cover classes between 1995 and 2015 (area inha).

		1995									
		Water	Urban Roads	Residential	Vegetation	Indus trial	Forest	Bare soil/rocks	Arable Land	Agriculture	Total
2015	Water	501.3	6.3	8.4	77.9	0	4.2	52.7	18.9	126.5	796.7
	Urban Roads	183.3	737.2	655	912	10.5	67.4	1843.2	591.9	1772.3	6772.8
	Residential	256.9	202.2	1168.9	1482.8	12.6	67.4	4147.3	1473	3555.4	12366.3
	Vegetation	478.1	465.5	716.1	13663.6	6.3	1782.8	4532.8	2639.1	7249.7	31534.7
	Industrial	12.6	6.3	12.6	16.9	27.3	0	35.8	0	53.9	165.7
	Forest	12.6	8.4	4.2	760.4	0	705.6	63.2	59.9	107.4	1721.1
	Bare soil/ rocks	252.8	86.3	986.6	2708.7	4.2	149.5	6194.6	2761.4	6080.8	19224.9
	Arable Land	67.4	8.4	242.2	803.3	0	25.3	2441.2	973.1	2137.8	6698.9
	Agriculture	108.3	42.5	341.5	1895	0	80.6	3176.9	1455	3893.6	10993.9
	Total	1878.2	1563	4135.2	22310.7	60.5	2882.4	22487.6	9977.6	24977.4	90274

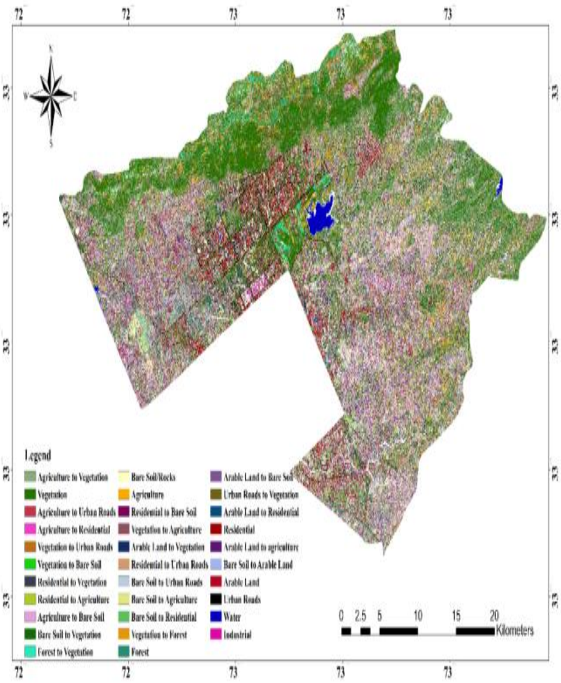

Fig. 6. Major Land use conversions in Islamabad from 2005-2015.

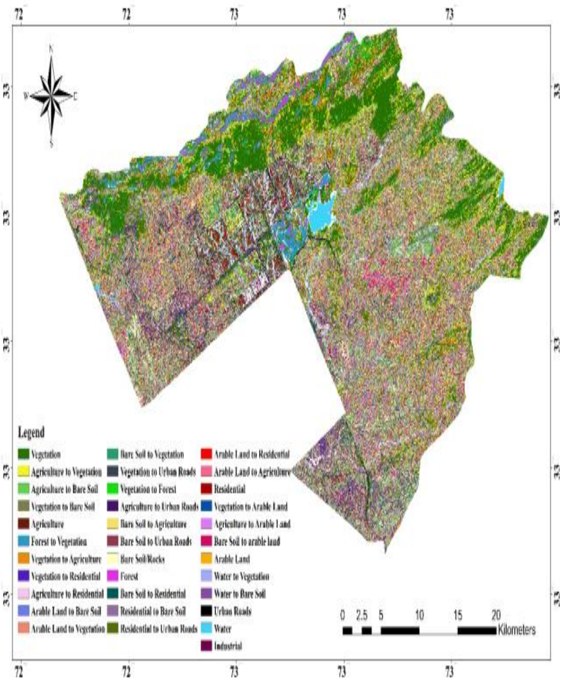

Fig. 7. Major Land use conversions in Islamabad from 1995-2015.

Indicator of Growth and Change

Land Use Change Index (LUCI) was computed to as an indicator of growth and change. It was used to observe land use changes in each class. LUCI showed remarkable changes over a period of 20 years (Table 9). Although all land use classes faced change during the study periods, either positive or negative, but the significant positive shift was observed by three classes i.e. residential, industrial and urban roads, and maximum growth rate of these classes was during the 1995-2000 (9.9%, 10.2%, 25.8%). Rest showed a mixed trend except water due to major shift in these classes. Vegetation showed a maximum increase of 10.3% during 2010-2015. Agriculture and arable land showed a maximum decrease of 8.4% and 7.8% respectively during period of 2010-2015. Forest cover was first decreased, then increase by maximum 11.6% during 2010-2015. Bare soil showed a maximum decrease of 2.9% in 2010-2015. Water as mentioned earlier continuously reduced in area from 1995-2015 and maximum reduction was observed during 2005-2010 with growth rate of -6.8%.

Table 9. LUCI of Islamabad from 1995 to 2015.

Year	Agriculture		Arable Land		Forest		Residential		Industrial		Urban Roads		Vegetation		Water		Bare Soil/ Rocks	
	Area (ha)	LUCI (%)	Area (ha)	LUCI (%)	Area (ha)	LUCI (%)	Area (ha)	LUCI (%)	Area (ha)	LUCI (%)	Area (ha)	LUCI (%)	Area (ha)	LUCI (%)	Area (ha)	LUCI (%)	Area (ha)	LUCI (%)
1995	24977.4	-	9977.6	-	2882.4	-	4135.2	-	60.5	-	1563	-	22310.7	-	1878.2	-	22487.6	-
2000	23209.8	-1.4	13184.2	6.4	2225.9	-4.5	6196.5	9.9	91.3	10.2	3577	25.8	18036.7	-3.8	1569.4	-3.2	22182.4	-0.3
2005	23917	0.6	10523.4	-4	1004.8	-10.9	8106	6.2	118.1	5.9	5251.5	9.4	15069.4	-3.3	1222.8	-4.4	25061.5	2.5
2010	18880.4	4.2	11034.2	0.9	1090.6	1.7	8930	2.03	135.2	2.9	5946.9	2.6	20845.5	7.6	809.6	-6.8	22598	-2
2015	10993.9	-8.4	6698.9	-7.8	1721.1	11.6	12366.3	7.7	165.7	4.5	6772.8	2.8	31534.7	10.3	796.7	-0.3	19224.9	-2.9

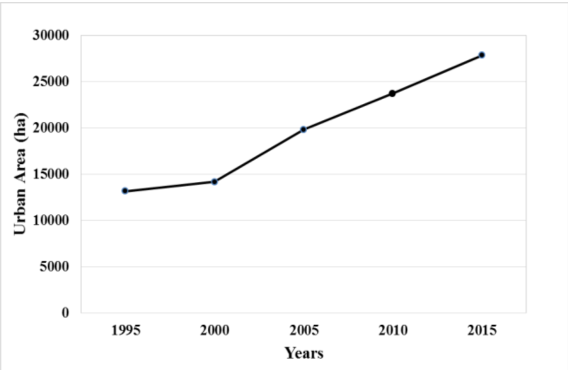

Fig. 8. Urban spatial expansion of Islamabad from 1995-2015.

Table 10. Spatial-temporal urban expansion of Islamabad from 1995 to 2015.

Year	Urban Area (ha)	% of Urban Area	Spatial Expansion (ha)	AUSEI (%)
1995	13144.7	14.6	-	-
2000	14149.6	15.7	1004.9	1.53
2005	19828	22	5678.4	8
2010	23718	26.3	3890	3.9
2015	27828.7	30.8	4110.7	3.5

After calculation of LUCI, urban area was extracted for each study year. The extracted urban area of Islamabad was comprised of residential, industrial, urban roads, vegetation (green spaces), bare soil (open spaces), forest and water. The total of these classes for each year is given in Table 10. Results showed that the percentage of urban area increased from 14.6 to 15.7, 22, 26.3 and 30.8 for years 1995, 2000, 2005, 2010 and 2015 respectively. Islamabad observed a dramatic spatial expansion from 1995-2015. This continuous increase was due to increase in population. The rapid urban expansion was observed during 2000-2005; 8% annual growth rate. After this pace of urban expansion got a little bit slower.

Discussion

The first part of the research involved the temporal analysis of LULCC classification (1995-2015), with selection of different classes including vegetation, bare soil, arable land, agriculture, forest, water and most importantly urban area and urban transportation infrastructure. LUCI was developed as an indicator of growth and change. Through this indicator a significant change was observed in all classes. Detection of LULCC is required for better understanding of landscape dynamics (Rawat and Kumar, 2015). Policymakers, researchers and planners make use of land cover information for evaluation of urban growth patterns (Adeel, 2010). Proper knowledge of LULC is required by the effective management programs (Iqbal and Khan, 2014). A lot of developing countries, unfortunately, face problems such as climate change, substantial urban sprawl prompted by swift growth of population, inadequate planning caused by land use change and human disturbances. Residential and industrial zones, agricultural activities, mining and deforestation are some of the activities and influences of humans on land use (Zubair, 2006). Therefore, currently, the simplest indicator to detect human influence on land is LULCC detection (Iqbal and Khan, 2014).

During the selected time period, the change in residential and transportation class was continuously positive while the vegetation, agriculture and arable land faced non-uniform change. Cross tabulation analysis was done for this purpose to exactly quantify contribution of each class in change. The reason in the increase in agricultural activity first was due to population growth and then decline due to land clearing activities for the settlements and construction of new housing societies. Hagler Bailly (2007) stated the reason of increase in agricultural activity near population to fulfil basic necessities of life. Vegetation showed increase during some study periods due to plantation in newly constructed housing societies. Some of the images were also taken after rainy season, could be an important factor in this increase. It was also observed that there was significant decrease in bare soil area in the selected area. Forest cover also reduced at rapid rate and then due to replantation, it got increased from 2010-2015. Tanvir *et al.* (2006); IUCN (2005); Ogundare (2016) reported that illegal forest wood cutting, ineffective forest management and the increased household use of forest wood some of the major factors that contribute towards decline of forests. Similar trends were observed by Ali *et al.* (2008); Arfan (2008); Butt *et al.* (2015) and Shafiq *et al.*, 1997 for Islamabad. According to them a significant decrease in vegetation, agriculture, forest and arable land occurred in and around Islamabad due to the fast pace of built up area increase. During the selected time period, a continuing decrease was observed in water class. Reason behind this could be easy accessibility to water, resulting in its depletion and drying up of tributaries. Another reason could be increased deforestation and increased runoff as compared to recharge capacity of groundwater, lowering its water table (Ali *et al.*, 2008; Hagler Bailly, 2007; Mendoza *et al.*, 2011).

After quantification of LUCI, urban areas were extracted and urban spatial expansion index was developed in order to analyse the spatio-temporal change in urban growth. UNCHS (1995) reported the use of an indicator for monitoring and assessment of cities conditions, provided benchmark for the urban conditions development over space and time.

Fig. 8 reflects the continuous and rapid urban expansion in study areas from 1995-2015 like other urban centres of the world. The results showed the percentage of urban expansion during the study period was 111%. Similar urban studies were conducted by Kotkin and Cox (2013); Kugelman (2014), which reported Karachi as the fastest growing city of the world from 2000-2010.

Conclusion

Multi-temporal land use/cover classification technique was employed in this research for change detection in Islamabad using Google earth images. The result revealed that Islamabad has been experiencing rapid growth from 1995-2015 leading to the loss of agriculture, arable lands and barren soil (55.9%, 32.9% and 14.5% respectively). Further, urban expansion index results showed rapid urban growth from 1995-2015, with urban area increased to 30.8% in 2015 from 14.6% in 1995.

There was rapid annual increase from 1995-2005, which is mainly attributed to the fast increase of population due to large rural–urban migration. After this pace of urban expansion got a bit slower. Consequently, cultivated lands, vegetation, water bodies and barren area are reducing apace. In order to reduce the adverse environmental impacts of urban expansion, planning regulations need to be enforced to save the fast declining natural resource base for sustainable development. Furthermore, local and regional land use management policy need to be revised, and integrated multi-disciplinary research should be initiated so that sustainable urban development strategy can be formulated.

References

Adeel M. 2010. Methodology for identifying urban growth potential using land use and population data: A case study of Islamabad Zone IV. Procedia Environmental Sciences **2,** 32-41.

Aitkenhead MJ, Aalders IH. 2011. Automating land cover mapping of Scotland using expert system and knowledge integration methods. Remote Sensing of Environment **115(5),** 1285-1295.

Alexakis DD, Gryllakis MG, Koutroulis AG, Agapiou A, Themistocleous K, Tsanis IK, Michaelides S, Pashiardis S, Demetriou C, Aristeidou K, Retalis A, Tymvios F,hadjimitsis DG. 2014. GIS and remote sensing techniques for the assessment of land use changes impact on flood hydrology: the case study of Yialias Basin in Cyprus. Naturalhazards and Earth System Sciences **14,** 413-426.

Ali M, Khan SJ, Aslam I, Khan Z. 2008. Simulation of the impacts of land-use change on surface runoff of Lai Nullah Basin in Islamabad, Pakistan. Landscape and Urban Planning **102,** 271-279.

Anderson JR, Hardy EE, Roach JT, Witmer RE. 1976. A land use and land cover classification system for use with remote sensor data, Vol. 964. Washington: US Government Printing Office.

Arfan M. 2008. Spatio-temporal Modeling of Urbanization and its Effects on Periurban Land Use System (M.Sc. Thesis). Department of Plant Sciences, Quaid-e-Azam University, Islamabad, Pakistan.

Arsanjani JJ, Helbich M, de Noronha Vaz E. 2013. Spatiotemporal simulation of urban growth patterns using agent-based modeling: the case of Tehran. Cities **32,** 33-42.

Atu JE, Ayama OR, Eja EI. 2013. Urban sprawl effects on biodiversity in peripheral agricultural Lands in Calabar, Nigeria. Journal of Environment and Earth Science **3(7),** 219-231.

Batista MH, Haertel V. 2010. On the classification of remote sensing high spatial resolution image data. International Journal of Remote Sensing **31(20),** 5533-5548.

Batty M. 2008. The size, scale, and shape of cities. Science **319 (5864),** 769-771.

Belal AA, Moghanm FS. 2011. Detecting urban growth using remote sensing and GIS techniques in Al Gharbiya governorate, Egypt. The Egyptian Journal of Remote Sensing and Space Sciences **14(2),** 73-79.

Bento AM, Cropper M, Mobarak AM, Vinha K. 2003. The impact of urban spatial structure on travel demand in the United States. World Bank p. 3007.

Benz UC, Hofmann P, Willhauck G, Lingenfelder I, Heynen M. 2004. Multi-resolution, object-oriented fuzzy analysis of remote sensing data for GIS-ready information. ISPRS Journal of Photogrammetry and Remote Sensing **58(3-4),** 239-258.

Blaschke T. 2010. Object based image analysis for remote sensing. ISPRS Journal of Photogrammetry and Remote Sensing **65(1),** 2-16.

Brueckner JK, Helsley RW. 2011. Sprawl and blight. Journal of Urban Economics **69(2),** 205-213.

Butt A, Shabbir R, Ahmad SS, Aziz N. 2015. Land use change mapping and analysis using Remote Sensing and GIS: a case study of Simly watershed, Islamabad, Pakistan. The Egyptian Journal of Remote Sensing and Space Sciences **18(2),** 251-259.

Butt MJ, Waqas A, Iqbal MF, Muhammad G, Lodhi MAK. 2012. Assessment of urban sprawl of Islamabad metropolitan area using multi-sensor and multi-temporal satellite data. Arabian Journal for Science and Engineering **37(1),** 101-114.

Czamanski D, Benenson I, Malkinson D, Marinov M, Roth R, Wittenberg L. 2008. Urban sprawl and ecosystems can nature survive? International Review of Environmental and Resource Economics **2,** 321-366.

Dadras M, Shafri HZ, Ahmad N, Pradhan B, Safarpour S. 2015. Spatio-temporal analysis of urban growth from remote sensing data in Bandar Abbas city, Iran. The Egyptian Journal of Remote Sensing and Space Sciences **18 (1),** 35-52.

Deep S, Saklani A. 2014. Urban sprawl modeling using cellular automata. The Egyptian Journal of Remote Sensing and Space Sciences **17 (2),** 179-187.

Dewan AM, Yamaguchi Y. 2009. Land use and land cover change in Greater Dhaka, Bangladesh: using remote sensing to promote sustainable urbanization. Applied Geography **29 (3),** 390-401.

Dribault Y, Chokmani K, Bernier M. 2012. Monitoring seasonal hydrological dynamics of minerotrophic peatlands using multi-date GeoEye-1 very high resolution imagery and object-based classification. Remote Sensing **4(7),** 1887-1912.

Duro DC, Franklin SE, Dubé MG. 2012. A comparison of pixel-based and object-based image analysis with selected machine learning algorithms for the classification of agricultural landscapes using SPOT-5 HRG imagery. Remote Sensing of Environment **118,** 259-272.

Ebrahimpour-Masoumi H. 2012. Urban sprawl in Iranian cities and its differences with the western sprawl. Spatium **27,** 12-18.

EEA. 2006. Urban Sprawl in Europe, The ignored challenge. European Environmental Agency Report 10/2006.

El-shayal M. 2017. Elshayal Smart GIS ver. 17.003, http://elshayal-smart.en.lo4d.com

Ewing R, Pendall R, Chen D. 2003a. Measuring Sprawl and Its Impacts. Smart Growth America, Washington, DC.

Ewing R, Pendall R, Chen D. 2003b. Measuring sprawl and its transportation impacts. Transportation Research Record: Journal of the Transportation Research Board **1831,** 175-183.

Fan F, Wang Y, Qiu M, Wang Z. 2009. Evaluating the temporal and spatial urban expansion patterns of Guangzhou from 1979 to 2003 by remote sensing and GIS methods. International Journal of Geographical Information Science **23(11),** 1371-1388.

Gao Y, Mas JF, Navarrete A. 2009. The improvement of an object-oriented classification using multi-temporal MODIS EVI satellite data. International Journal of Digital Earth **2(3),** 219-236.

Girard LF, Cerreta M, de Toro P, Forte F. 2007. The human sustainable city: values, approaches and evaluative tools. In: Deakin M, Mitchell G, Nijkamp P, Vreeker R, Eds. Sustainable urban development 2: The environmental assessment methods, London: Routledge p. 65-93.

Glaeser EL, Kahn ME. 2004. Sprawl and Urban Growth.handbook of Regional and Urban Economics, vol. IV. Elsevier, Amsterdam p. 2481-2527.

Gong P, Wang J, Yu L, Zhao Y, Zhao Y, Liang L, Niu Z, Huang X, Fu H, Liu S, Li C, Li X, Fu W, Liu C, Xu Y, Wang X, Cheng Q, Hu L, Yao W, Zhang H, Zhu P, Zhao Z, Zhang H, Zheng Y, Ji L, Zhang Y, Chen H, Yan A, Guo J, Yu L, Wang L, Liu X, Shi T, Zhu M, Chen Y, Yang G, Tang P, Xu B, Giri C, Clinton N, Zhu Z, Chen J, Chen J. 2013. Finer resolution observation and monitoring of global land cover: First mapping results with Landsat TM and ETM+ data. International Journal of Remote Sensing **34(7),** 2607-2654.

Government of Pakistan (GoP). 1999. District census report of Islamabad. Population census organization. Statistics Division. Census Publication Report No.16, Government of Pakistan, Islamabad.

Hagler B. 2007. Environmental baseline study of Margalla and Margalla north blocks. MOL Pakistan Oil and Gas Company BV, Islamabad, Pakistan.

Hansen MC, DeFries RS, Townshend JR, Sohlberg R. 2000. Global land cover classification at 1 km spatial resolution using a classification tree approach. International Journal of Remote Sensing **21(6-7),** 1331-1364.

Hathout S. 2002. The use of GIS for monitoring and predicting urban growth in East and West St Paul, Winnipeg, Manitoba, Canada. Journal of Environmental Management **66 (3),** 229-238.

International Union for Conservation of Nature (IUCN). 2005. Rapid environmental appraisal of developments in and around murree hills. IUCN, Islamabad Pakistan.

Iqbal MF, Khan IA. 2014. Spatiotemporal land use land cover change analysis and erosion risk mapping of Azad Jammu and Kashmir, Pakistan. The Egyptian Journal of Remote Sensing and Space Science **17(2),** 209-229.

Jaeger JA, Bertiller R, Schwick C, Kienast F. 2010. Suitability criteria for measures of urban sprawl. Ecological Indicators **10 (2),** 397-406.

Jat MK, Garg PK, Khare D. 2008a. Modelling of urban growth using spatial analysis techniques: a case study of Ajmer city (India). International Journal of Remote Sensing **29 (2),** 543-567.

Jat MK, Garg PK, Khare D. 2008b. Monitoring and modelling of urban sprawl using remote sensing and GIS techniques. International Journal of Applied Earth Observation and Geo-information **10 (1),** 26-43.

Jenks M, Dempsey N. 2005. Future Forms and Design for Sustainable Cities. Oxford: Elsevier.

Jensen JR. 1996. Introductory Digital Image Processing: A Remote Sensing Perspective (2nd Ed.). Englewood Cliffs, New Jersey: Prenticehall.

Kaimaris D, Georgoula O, Patias P, Stylianidis E. 2011. Comparative analysis on the archaeological content of imagery from Google Earth. Journal of Cultural Heritage **12(3),** 263-269.

Kaplan G, Avdan U. 2017. Object-based water body extraction model using Sentinel-2 satellite imagery. European Journal of Remote Sensing **50(1),** 137-143.

Kotkin J, Cox W. 2013. The World's Fastest-Growing Megacities, Forbes. Retrieved from http://www.forbes.com/sites/joelkotkin/2013/04/08/the-worlds-fastest-growing megacities

Kugelman M. (Ed.). 2014. Pakistan's Runaway Urbanization: What Can be Done? Asia Program, Woodrow Wilson International Center for Scholars.

Kushner JA. 2002. Smart growth, new urbanism and diversity: progressive planning movements in America and their impact on poor and minority ethnic populations. UCLA Journal of Environmental Law and Policy **21,** 45.

Laliberte AS, Browning DM, Rango A. 2012. A comparison of three feature selection methods for object-based classification of sub-decimeter resolution UltraCam-L imagery. International Journal of Applied Earth Observation and Geo information **15,** 70-78.

Lea C, Curtis AC. 2010. Thematic accuracy assessment procedures: National Park Service Vegetation Inventory, version 2.0. Natural Resource Report NPS/2010/NRR-2010/204, National Park Service, Fort Collins, Colorado, USA.

Liu M, Li H, Li L, Man W, Jia M, Wang Z, Lu C. 2017. Monitoring the invasion of *Spartina alterniflora* using multi-source high-resolution imagery in the Zhangjiang Estuary, China. Remote Sensing **9(6),** 539.

Liu T, Yang X. 2015. Monitoring land changes in an urban area using satellite imagery, GIS and landscape metrics. Applied Geography **56,** 42-54.

Liu Y, Phinn SR. 2003. Modelling urban development with cellular automata incorporating fuzzy-set approaches. Computers, Environment and Urban Systems **27(6),** 637-658.

Lu D, Weng Q. 2007. A survey of image classification methods and techniques for improving classification performance. International Journal of Remote Sensing **28(5),** 823-870.

Malarvizhi K, Kumar SV, Porchelvan P. 2016. Use of high resolution google earth satellite imagery in landuse map preparation for urban related applications. Procedia Technology **24 (2016),** 1835-1842.

Manandhar R, Odeh I, Ancev T. 2009. Improving the accuracy of land use and land cover classification of Landsat data using post-classification enhancement. Remote Sensing **1(3),** 330-344.

Masser I. 2001. Managing our urban future: the role of remote sensing and geographic information systems. Habitat International **25 (4),** 503-512.

Mathieu R, Aryal J, Chong A. 2007. Object-based classification of Ikonos imagery for mapping large-scale vegetation communities in urban areas. Sensors **7(11),** 2860-2880.

Mendoza ME, Granados EL, Geneletti D, Pérez-Salicrup DR, Salinas V. 2011. Analysing land cover and land use change processes at watershed level: a multitemporal study in the Lake Cuitzeo Watershed, Mexico (1975–2003). Applied Geography **31(1),** 237-250.

Mohammady S. 2014. A Spatio-Temporal Urban Expansion Modeling, a Case Study Tehran Metropolis, Iran. Acta Geography Debrecina Landscape and Environment Series **8 (1),** 10.

Nkomeje F. 2017. Comparative Performance of Multi-Source Reference Data to Assess the Accuracy of Classified Remotely Sensed Imagery: Example of Landsat 8 OLI Across Kigali City-Rwanda 2015. International Journal of Engineering Works **4(1),** 10-20.

Ogundare BA. 2016. A comparative analysis of agricultural land use in Ikere Ekiti, Nigeria. An International Peer-reviewed Journal **27,** 1-6.

Pakistan Bureau of Statistics (PBS). 2017. District wise census results **2017,** p. 1-100.

Pereira PA, Monkevicˇius A, Siarova H. 2014. Public perception of environmental, social and economic impacts of urban sprawl in Vilnius. Socialiniuz Moksluz Studijos **6(2),** 259-290.

Rawat JS, Biswas V, Kumar M. 2013. Changes in land use/cover using geospatial techniques: a case study of Ramnagar town area, district Nainital, Uttarakhand, India. The Egyptian Journal of Remote Sensing and Space Science **16 (1),** 111-117.

Rawat JS, Kumar M. 2015. Monitoring land use/cover change using remote sensing and GIS techniques: A case study ofhawalbagh block, district Almora, Uttarakhand, India. The Egyptian Journal of Remote Sensing and Space Science **18(1),** 77-84.

Roshan GR, Shahraki SZ, Sauri D, Borna R. 2010. Urban sprawl and climatic changes in Tehran. Journal of Environment and Health. Science **7(1),** 43-52.

Shahraki SZ, Sauri D, Serra P, Modugno S, Seifolddini F, Pourahmad A. 2011. Urban sprawl pattern and land-use change detection in Yazd, Iran.habitat International **35(4),** 521-528.

Shao Y, Lunetta RS. 2012. Comparison of support vector machine, neural network, and CART algorithms for the land-cover classification using limited training data points. ISPRS Journal of Photogrammetry and Remote Sensing **70,** 78-87.

Sheikh IM, Pasha MK, Williams VS, Raza SQ, Khan KSA. 2007. Environmental geology of the Islamabad-Rawalpindi Area, Northern Pakistan. Geological Survey of Pakistan. Bulletin **2078-G,** p. 1-2.

Simmons C. 2007. Ecological footprint analysis: A useful method for exploring the interaction between lifestyles and the built environment. Sustainable Urban Development, London: Routledge p. 223-235.

Sudhira HS, Ramachandra TV, Jagadish KS. 2004. Urban sprawl: metrics, dynamics and modelling using GIS. International Journal of Applied Earth Observation and Geo-information **5(1),** 29-39.

Sung CY, Yi YJ, Li MH. 2013. Impervious surface regulation and urban sprawl as its unintended consequence. Land Use Policy **32,** 317-323.

Tanvir A, Shahbaz B, Suleri A. 2006. Analysis of myths and realities of deforestation in northwest Pakistan: implications for forestry extension. International Journal Agriculture and Biology **8,** 107-110.

Tchuenté ATK, Roujean JL, De Jong SM. 2011. Comparison and relative quality assessment of the GLC2000, GLOBCOVER, MODIS and ECOCLIMAP land cover data sets at the African continental scale. International Journal of Applied Earth Observation and Geo-information **13(2),** 207-219.

Tewolde MG, Cabral P. 2011. Urban sprawl analysis and modeling in Asmara, Eritrea. Remote Sensing **3(10),** 2148-2165.

Thomas N, Hendrix C, Congalton RG. 2003. A Comparison of Urban Mapping Methods using High-resolution Digital Imagery. Photogrammetric Engineering and Remote Sensing **69(9),** 963-972.

Tian G, Liu J, Xie Y, Yang Z, Zhuang D, Niu Z. 2005. Analysis of spatio-temporal dynamic pattern and driving forces of urban land in China in 1990s using TM images and GIS. Cities **22(6),** 400-410.

Tu J, Xia ZG, Clarke KC, Frei A. 2007. Impact of urban sprawl on water quality in eastern Massachusetts, USA. Environmental Management **40(2),** 183-200.

UNCHS. 1995. Indicators programme: Monitoring human settlements: Urban indicators worksheet (Vol. 2). Centre for Human Settlements, United Nations.

United Nations. 2014. World Urbanization Prospects. United Nations Population estimates and projections of major Urban Agglomerations. http://worldpopulationreview.com/world-cities/ lahore -population/

Van Ginkel H. 2008. Urban future. The cities of the developing world are spectacularly ill-prepared for the explosion in urban living. Nature **456,** 32-33.

Wijedasa LS, Sloan S, Michelakis DG, Clements GR. 2012. Overcoming limitations with Landsat imagery for mapping of peat swamp forests in Sundaland. Remote Sensing **4(9),** 2595-2618.

Xie Y, Mei Y, Guangjin T, Xuerong X. 2005. Socio-economic driving forces of arable land conversion: A case study of Wuxian City, China. Global Environmental Change **15(3),** 238-252.

Yu L, Gong P. 2012. Google Earth as a virtual globe tool for Earth science applications at the global scale: progress and perspectives. International Journal of Remote Sensing **33(12),** 3966-3986.

Yu Q, Gong P, Clinton N, Biging G, Kelly M, Schirokauer D. 2006. Object-based detailed vegetation classification with airborne high spatial resolution remote sensing imagery. Photogrammetric Engineering and Remote Sensing **72(7),** 799-811.

Zhang Y, Guindon B. 2006. Using satellite remote sensing to survey transport-related urban sustainability: Part 1: Methodologies for indicator quantification. International Journal of Applied Earth Observation and Geoinformation **8(3),** 149-164.

Zhou H, Aizen E, Aizen V. 2013. Deriving long term snow cover extent dataset from AVHRR and MODIS data: Central Asia case study. Remote Sensing of Environment **136,** 146-162.

Zhou W, Huang G, Troy A, Cadenasso ML. 2009. Object-based land-cover classification of shaded areas in high spatial resolution imagery of urban areas: A comparison study. Remote Sensing of Environment **113(8),** 1769-1777.

Zhou W, Troy A, Grove M. 2008. Object-based land cover classification and change analysis in the Baltimore metropolitan area using multi-temporal high resolution remote sensing data. Sensors **8(3),** 1613-1636.

Zhou W, Troy A. 2008. An object-oriented approach for analysing and characterizing urban landscape at the parcel level. International Journal of Remote Sensing **29(11),** 3119-3135.

Zubair AO. 2006. Change detection in land use and Land cover using remote sensing data and GIS: A case study of Ilorin and its environs in Kwara State (MSc. Thesis). Department of Geography, University of Ibadan, Nigeria p. 176.