Desalination and Water Treatment
www.deswater.com
doi:10.5004/dwt.2019.24156

159 (2019) 402–411
August

Impacts of urbanization and land cover dynamics on underground water in Islamabad, Pakistan

Muhammad Tayyab Sohail[a,e,*], Yusra Mahfooz[b], Kamran Azam[c], Yat Yen[d], Liao Genfu[e,*], Shah Fahad[f]

[a]*School of Management, Xi'an Jiaotong University, Xi'an Shaanxi, 710049, P.R. China, email: tayyabsohail@yahoo.com (M.T. Sohail)*
[b]*Sustainable Development Study Center, GC University, Lahore 54000, Pakistan, email: sdsc8888@gmail.com (Y. Mahfooz)*
[c]*Department of Leadership and Management Studies, National Defence University, Islamabad 44000, Pakistan, email: drkamranazam@ndu.edu.pk (K. Azam)*
[d]*College of Urban and Environmental Science, Peking University, Beijing, 100871, P.R. China, email: yenyat_cambodia@pku.edu.cn (Y. Yen)*
[e]*Faculty of Foreign Studies, Jiangxi University of Science and Technology Ganzhou Jiangxi, 341000, P.R. China, email: liaogenfu@jxust.edu.cn (L. Genfu)*
[f]*School of Management, Xi'an Jiaotong University, Xi'an Shaanxi, 710049, P.R. China, email: shah.fahad@mail.xjtu.edu.cn (S. Fahad)*

Received 5 July 2018; Accepted 23 March 2019

ABSTRACT

Due to accelerated urbanization trend across the globe, unsustainable planning and management has consequently led to tremendous deterioration of ecosystem especially vegetation cover and water resources. Subsequently, posing a great challenge to sustainable urban advancement. Detection and evaluation of such variations would assist the planners to apprehend the factors, which are responsible for land use land cover change (LULCC) to adopt effective measures. GIS and remote sensing techniques have proved to be an effective tool for the assessment of land use changes. This study was conducted to assess the water quality index and analyze the major change in land cover types, vegetation cover, rate of urbanization and its possible impact on ground water resources vegetation, barren land and water lands have been decreased by –101.77 km^2, –2.90 km^2 and –1.10 km^2, while built-up lands expanded from 51.10 km^2 to 105.77 km^2. 16 Sites in Islamabad were categorized as unsuitable (with < 300 WQI value) for drinking water due to highly anthropogenic activities. Decreasing water quality and vegetation cover with alarming rate is posing a pressure on the limiting ground water resource as well. This study would be helpful for the decision makers and planners to take proper sustainable measure to address the repercussions of unplanned urbanization and land use changes to protect the ecosystem.

Keywords: Urbanization; Islamabad; Remote sensing; Land cover change detection; GIS/RS Technology

1. Introduction

Generally, rural-urban migration is a key phenomenon in the present time due to economic development, industrial development and other associated factors. This rapid urban development is absolutely complex in its nature because it reduces vegetation cover inside and around the cities. Due to population explosion, lush green pastures are converted into build areas. As environment of the cities continues to deteriorate by anthropogenic activities, the policy makers, geographers, administrators and urban planners are currently faced with the challenge to monitor the land cover changes and urban land use [1]. LULC (land use and land cover change) are important in its nature because they provide an intimate association between human beings and environment [2]. The study about land cover changes and

*Corresponding author.

1944-3994 / 1944-3986

urban land use (LCLU) is important due to comprehending various impacts of human activities on the ecology, water balance and environment of the cities concerned [3]. LULC change is rapidly increasing in developing countries as compared to developed countries and it is assumed that by 2020, most of the mega cities will be formed in developing countries [4]. Huge population in the cities of developing countries have great impacts on LULC, environmental degradation, ecosystem functions, and on natural resources [5]. In China, rapid urbanization in the first decade of 21th century had a heavy toll on, its environment and ecosystem [6].

Population growth rate is also very important as the world urban population is increasing every year [7]. Urban growth induces the replacement of natural land covers with the impervious urban materials, the modifications of the biophysical environment, adversely impacts land surface characteristics and the alterations of land surface energy processes [8]. Similarly, due to rapid urbanization, agricultural land rate converted into urban area is also on the rise. These changes have not only led to decreasing vegetation but also impacted food production capacity [9]. As these changes on LULC caused by human induced activities and holding strong influences on regional environment of specific area [10]. Land cover is dynamic and fluctuates at different spatial and temporal scales [11]. Consequently, land cover conversions through human or nature's agencies may have reflective influences on climate, biogeochemical and hydrological cycles, biodiversity, human well being and soil quality [12–15]. This rationalizes the importance of land use and land cover change research in the context of environmental variation and sustainable development. This study is important in its nature because Islamabad is the capital city of Pakistan, attracting new residents from different parts of the country for variety of reasons. This trend of movement from other cities to Islamabad have also led to significant deterioration of the climates and urban situation of this city. Due to this trend, the land cover of the study region has been changing rapidly and this change and huge rate of urbanization have specific impacts on climate change and hydrology [16–19]. Absolutely, urbanization have positive impact on the country economy and social development [20–22], but contrary to this, rapid and unplanned urbanization has different kind of problems in developing countries such as traffic, air pollution and pressures on water resources [23].

Islamabad is a planned city having attractive setting at the foot of mountains immediately north of Rawalpindi as protective measure. Construction began in the early 1960's, following extensive surveys and planning. On the other hand, rapid growth of both Islamabad and Rawalpindi has made ever-increasing demands on natural resources and caused adverse effects on the environment. To maintain the quality of the capital, municipal authorities need information on the physical environment to plan the future development. This paper presented the results that aimed at characterizing land cover and its dynamics for about two decades in Islamabad. The specific objectives were to analyze the major land cover types in 1993,1997, 2002, 2007 2013 and 2017,determine the magnitude and nature of the land cover changes that happened between these years, check the trends of Urbanizations in Islamabad and impacts of urbanization on ground water resources of Islamabad.

2. Material and method

2.1. Study area

This study is conducted in the capital city of Pakistan, Islamabad, which is located at 33° 29′ 26.7″N and 72° 48′ 42.08″E to 33° 48′ 1.34″N and 73° 22′ 48.51″E (Fig. 1) at the northern edge of the Pothohar Plateau and at the foot of the Margalla Hills having elevation of 540 m (1,770 ft.).After independence, the area encompassing Islamabad has been a part of the Punjab province; more specifically the Pothohar Plateau and later on in 1960 the area was converted into Islamabad and was recognized as the new Capital of the country. As per Capital Development Authority (CDA) the area of Islamabad is 906.50 km^2, in which the urban area consists of 220.15 Sq.km, rural area is 466.20 km^2 and 220.15 Islamabad parks respectively [24]. The climate of Islamabad is humid subtropical (Koppen: Cwa), with five seasons: summer (May and June), winter (November–February), spring (March and April), autumn (September and October) and rainy monsoon (July and August). June is the hottest month with an average temperature of 38°C (100.4°F). Heavy rainfall is observed in July with the possibility of cloudburst and flooding. January is usually the coldest month. Three artificial reservoirs regulate the micro climate of Islamabad i.e. Simli, Khanpur and Rawal Dam. The inhabitants of Islamabad depend on both surface and ground water as their domestic water source. Major source of surface water in the study area is Simly Dam, while ground water is obtained through public tube wells installed in the National park area. Due to climatic variations, the inflow of water to Simly Dam has reduced which has resulted in over exploitation of ground water to meet water demands which has furthered lowered the water table in the capital territory.

2.2. Data sources

The data collected for this study was mainly based on satellite-based remote sensors, spatial databases, field visits and secondary data (Table 1). Remotely sensed data was obtained from Landsat 5 Thematic Mapper (TM) imagery, which was acquired in June 1993 and 1997, Landsat 7 Enhanced Thematic Mapper plus (ETM+) imageries were acquired in June 2002 and 2007, Landsat 8 OLI imagery was acquired in June 2013 and2017 were got from the USGS collection (http://earth explorer.usgs.gov/). Satellite images downloaded and classified for major land use types prevailed in the study area using ArcGIS (10.1) and ERDAS IMANGINE software. The sampling units randomly generated using ArcGIS with a scale of 30 m selected to coincide with the spatial resolution of the Landsat imagery.

Landsat data were carefully chosen due to its open online availability, historic record and appropriate processing approach, swath, cloud reportage, spectral, spatial and time-based purposes. Image pre-processing, classification scheme design, image classification, post-classification processing, spatial reclassification, accuracy assessment and change detection were performed. In order to check the impacts of land cover change on hydrology in the study area, ground water depth of water table data was obtained from piezometer installed at four locations installed and monitored by Pakistan Council of Research in Water Resources (PCRWR). Piezometers were installed at PCRWR, National

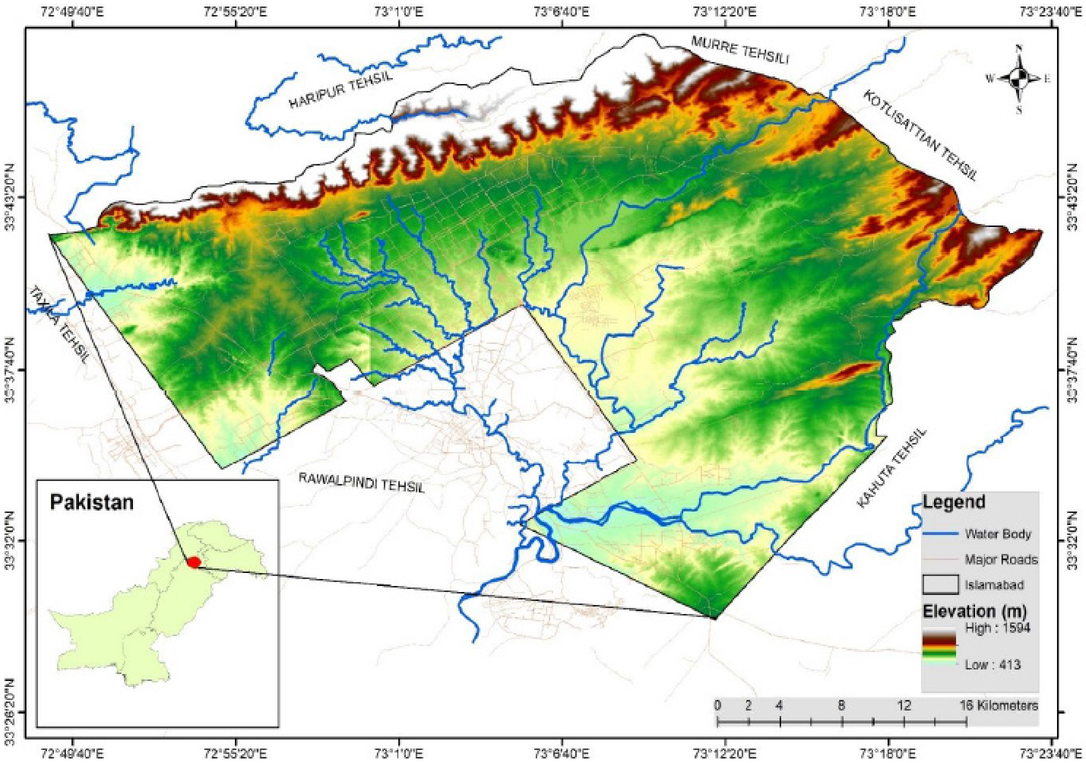

Fig. 1. Geographical location of the study area (DEM Map)

Table 1
Remotely sensed data

Data type	Date of acquisition	Spatial scale	Source
Lands at 5 TM (Path 161 row 060)	June 1993	Multi-spectral: 30_30 m	USGS (http://earthexplorer.usgs.gov/)
Lands at 5 TM (Path 161 row 060)	June 1997	Multi-spectral: 30_30 m	
Lands at 7ETMt (Path 161 row 060)	June 2002	Multi-spectral: 30_30 m Panchromatic: 15_15 m	
Lands at 7ETMt (Path 161 row 060)	June 2007	Multi-spectral: 30_30 m Panchromatic: 15_15 m	
Lands at 8OLI (Path 161 row 060)	June 2013	Multi-spectral: 30_30 m Panchromatic: 15_15 m	
Lands at 8OLI (Path 161 row 060)	June 2017	Multi-spectral: 30_30 m Panchromatic: 15_15 m	

Police Foundation (NPF), Pakistan Council of Scientific and Industrial Research (PCSIR) and Pakistan Institute of Medical Sciences (PIMS).

2.3. Data preparation and analysis

2.3.1. Image pre-processing

Initially, the images were downloaded (Table 1), the down loaded Landsat TM and ETM+ and OLI data for each date were unzipped and 6 bands (excluding the thermal band) were stacked to form multi-band images using ERDAS IMANGINE software. After stacking one image prepared for seamless mosaicking (Islamabad city) and was classified. After that, the images were projected to UTM projection (Zone 43N, WGS 1984) and subsets were prepared. For the clear picture of the selected area, classification was also adopted in ARCGIS 10.1.

2.3.2. Accuracy assessment

In the study Land cover maps were analyzed on basis of qualitative and quantitative data. Initially, each land cover map and the resultant Landsat data were demonstrated on-screen and visually examined. Then the qualms associated to the land cover products of1993, 1997, 2002, 2007, 2013 and 2017 were measured by comparing them with the geographical maps. The related land cover characteristics were also extracted to these points. These sets of random feature points, were likened with the corresponding pixels on the land cover products of the individual years to determine the number of classified pixels for each land cover change classes.

2.3.3. Water quality assessment

Drinking water samples were collected from 32 sites from different locations of Islamabad to determine the 16 Water quality parameters including physiochemical and biological according to APHA method [25]. Water quality index was calculated of all sites with 9 parameters (as per availability of their assigned weight from literature) by following formula

$$WQI = \sum_{i=1}^{n} SI_i \quad (1)$$

Classification of WQI, described by Rama krishnaiah et al. [26] is as follow:

>50 = excellent, 50–100 = good, 100–200 = poor, 200–300 = very poor, <300 = unsuitable

3. Results and discussion

3.1. Land cover classification

The spatial pattern of the four-major land cover types of the capital area Islamabad in 1993, 1997, 2002, 2007, 2013 and 2017 are presented in Figs. 2–7. Table 2 shows that area occupied by barren land in 1993, 1997, 2002, 2007, 2013 and 2017 covering about 542.90 km^2, 498.89 km^2 and 540 km^2 respectively and was dominant in the perspective years, but surpassed by built-up area 26.08 km^2, 77.18 km^2 and 131.85 km^2 respectively. Its alarming to note that vegetation/forest area is decreasing which was 329.77 km^2 in 1993, 324.66 km^2 in 2002 and 228 km^2 in 2017 which is almost half of 1993. Water resources are a basic need and there is simply no substitute. But water resources occupied the least area that varied between 5 to 3 km^2 during this period, Islamabad surface water in 1993, 1997, 2002, 2007, 2013 and 2017 covering about 5.29 km^2, 4.23 km^2, 3.31 km^2, 4.05 km^2, 5.05 km^2 and 4.19 km^2. Fig. 2 also indicates that 1993 bare land is prominent towards western side, while vegetative area is distributed evenly in the whole city, whereas the water body was only concentrated at the central area i.e. Rawal Lake. In 2002, the bare land exceeded to south eastern regions, retreating vegetative area. The prominent

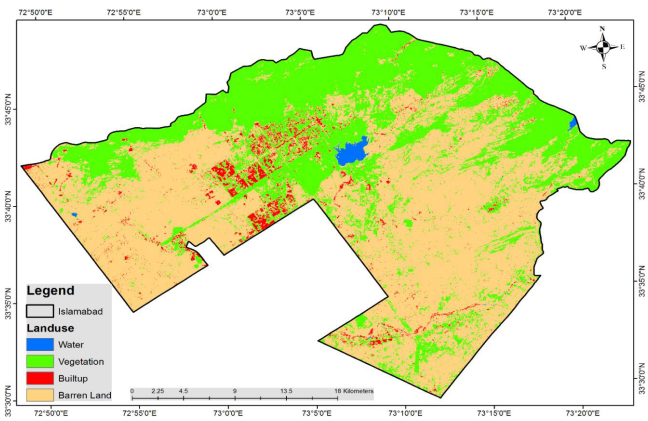

Fig. 2. Land cover classification map of Islamabad, 1993.

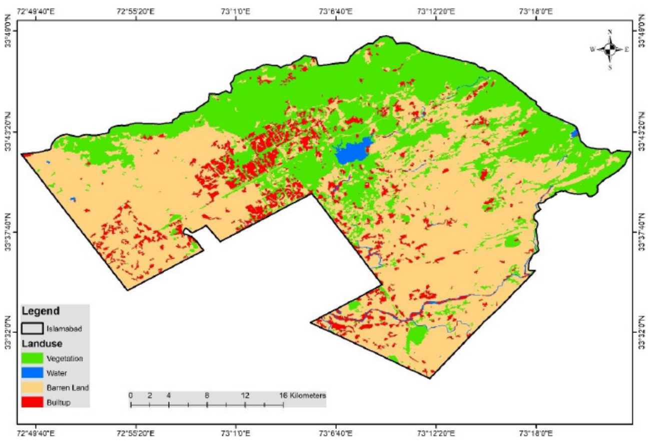

Fig. 3. Land cover classification map of Islamabad, 1997.

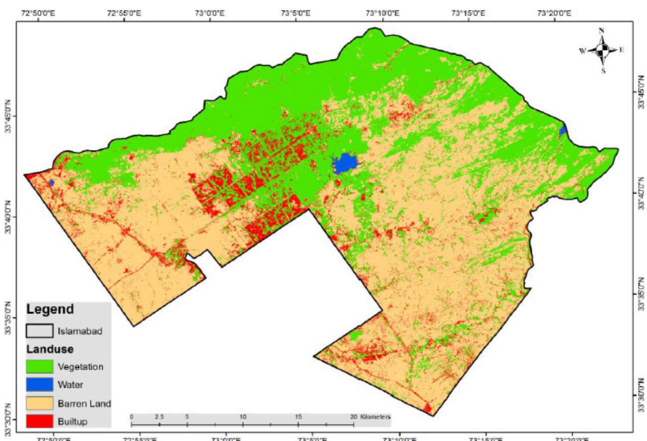

Fig. 4. Land cover classification map of Islamabad, 2002.

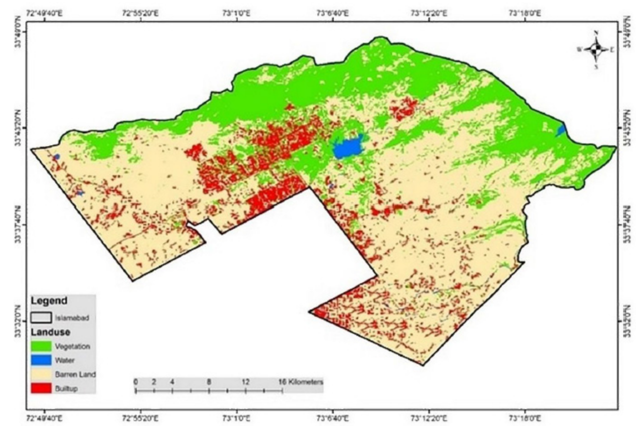

Fig. 5. Land cover classification map of Islamabad, 2007.

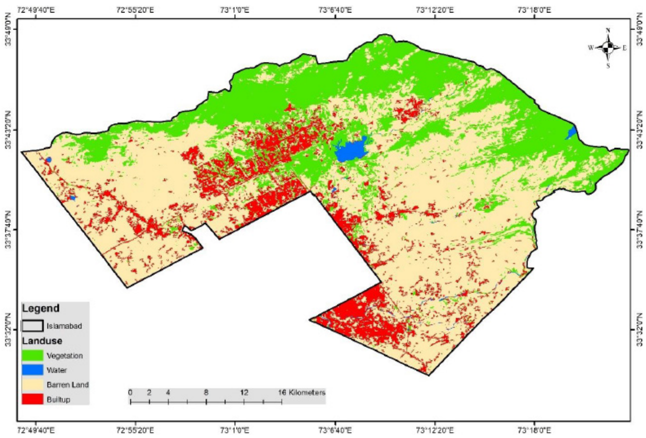

Fig. 6. Land cover classification map of Islamabad, 2013.

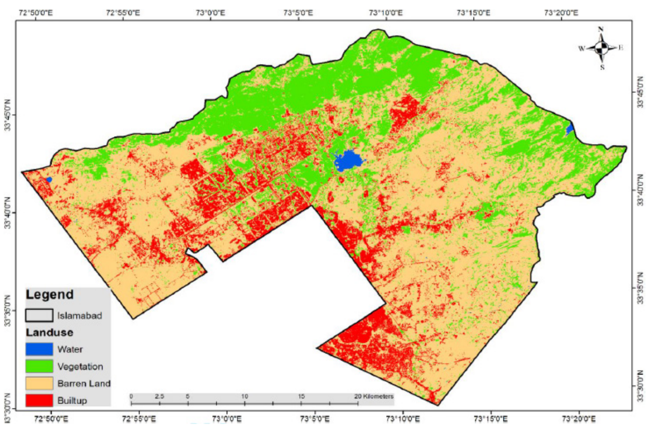

Fig. 7. Land cover classification map of Islamabad, 2017.

change was observed in 2002, built-up area has significantly expanded and resulted in decreasing the vegetation area. In 2017, a spectacular decrease in vegetation area was observed, retreating from 329 km^2 to 228 km^2 area, however built-up area has increased tremendously from 26 km^2 to 131 km^2 from 1993 to 2017 (Figs. 2–7). In the study area, bare land was distributed in the western and eastern side. Overall, a scarce change is observed at the north where lies Margilla Hills and is occupied by forests cover. The area is steep with few inhabitants that's why the area is least perturbed, while a great change in land cover was observed in the plain area of Islamabad.

3.2. Land cover change detection

During analysis, the change maps were as accurate as the product of the overall accuracies of the individual land cover maps that produced them [27,28]. Such outputs explain the popularity of post-classification comparison method for change detection. It may also reduce the impact of radiometric and atmospheric differences because the imagery is classified independently [29,30]. Satellite imagery is a valuable source for the information of land cover. Urban land cover has been identified and mapped by means of remote sensing data with fine spatial resolution. GIS provides the environment to analyze and visualize spatial data with those derived from remote sensing technology, with improvements in Spatial analyst tools and computational facilities [31].

The magnitudes and annual average rates of change for the land cover types are shown in Table 3 and Figs. 2–7. It revealed that most of the land cover changes were unidirectional except for the b are lands and water bodies. Vegetation-shrub lands, grasslands and croplands had higher magnitudes of change compared to the build up lands, bare

Table 2
Land use and land cover changes

LULC Types	2017		2013		2007		2002		1997		1993	
	Area KM^2	Area %	Area KM^2	Area %	Area KM^2	Area %	Area KM^2	Area %	Area KM^2	Area %	Area KM^2	Area %
Water	4.19	0.46	4.23	0.8	4.05	0.47	3.31	0.37	5.05	1.15	5.29	0.59
Vegetation	228	25.22	257.92	28.51	295.76	32.81	324.66	35.91	327.55	36.04	329.77	36.48
Barren Land	540	59.74	532.17	58.50	516.09	56.28	498.89	55.18	498.61	55.13	542.90	60.05
Built-up	131.85	14.58	110.19	12.18	88.18	10.44	77.18	8.54	73.19	7.65	26.08	2.89
Total	904.04	100	904.51	100	904.08	100.00	904.05	100.00	904.4	100	904.05	100.00

Table 3
Magnitude and the annual average rates of land cover changes

LULC types	Δ2017–1993		Δ2017–1997		Δ2017–2002		Δ2007–2002		Δ2017–2013		Δ2002–1993	
	Area KM^2	Area %	Area KM^2	Area %	Area KM^2	Area %	Area KM^2	Area %	Area KM^2	Area %	Area KM^2	Area %
Water	–1.10	–0.12	–0.86	–0.69	0.88	0.10	0.74	0.1	–0.04	–0.34	–1.98	–0.22
Vegetation	–101.77	–11.26	–99.55	–13.79	–96.66	–10.69	–28.9	–3.1	–29.92	–3.29	–5.10	–0.56
Barren Land	–2.90	–0.32	41.39	4.62	41.11	4.55	17.2	1.1	7.83	1.24	–44.02	–4.87
Built-up	105.77	11.70	58.66	6.93	54.67	6.05	11	1.9	21.66	2.4	51.10	5.65

lands and water bodies during 1993–2017 (Tables 2, 3; Figs. 2–7). More specifically, the vegetation land, barren land and water land decreased by –101.77 km^{2}, –2.90 km^2 and –1.10 km^2 respectively, while built-up lands expanded by 105.77 km^2. By using this multi-sensor and satellite data to assess urban sprawl and the changing uses of land in Islamabad. It has been found that urban infrastructural growth has not increased at the same rate as the city's population. Large amounts of natural vegetation have been replaced by built-up area. Urban expansion has increased while the area of agricultural land/vegetation has decreased in the same period. Rapid change in vegetation, build-up and barren land can be seen in Landsat images (Figs. 2, 3, 4). Area which was occupied by vegetation previously has now been transformed into highways and buildings. Islamabad is set out in a grid format, with 11 sectors, each 4 square miles, extending southwest from the Margalla Hills. A major aim was to reduce traffic, and having the blue area expand out that way would prevent gridlock at a central point; a problem experienced in Rawalpindi [32]. Furthermore, it holds major roads, like the Islamabad highway traversing the side of the city in straight lines, would increase efficiency and speed of transport [33].

The study results suggested that there is significant difference in Landsat images in the years 1993, 1997, 2002, 2007, 2013 and 2017 based on area covered by different features. Population increased in south, north south and a little bit in west of Islamabad in 2002 and 2017. On the other hand, vegetation cover has decreased in the whole city except north which is covered by Margalla Hills that is a national park where community rights including cutting, pruning and logging are strictly prohibited. In the last decade, reduction in vegetation cover has increased than the previous decades. If deforestation and vegetation cover reduction continue with the same trend, the city would be devoid of vegetation rendering severe complications on the nearby ecosystem and public health. Pakistan is already a vegetation scarce country where the total forest area is 4.25%, whereas for a well-balanced economy, 25% of vegetation cover is necessary. The current rate of deforestation in Pakistan can be very devastating for the country if no preventive and sustainable measures were adopted. Satellite data and multi spectral data were used by a researcher [24] to assess land use change and urban sprawl in Islamabad. It was found from the analysis that city's population has increased with higher rate than urban infrastructure. A great land of natural vegetation has been replaced by impermeable surface. The author found an increase urban expansion from 1972 to 2009, while vegetative area reduced in the same time period. Based on these statistics, the Capital Development Authority (CDA) has attempted to counter the situation by massive plantation of tress in the city.

Pakistan is a developing country with huge population especially in urban areas, which is about to be 335 million by 2050 and the rate of urbanization is 3.06% per year (GOP Census Reports; Hasan and Mohib [34]. Similarly, Pakistan facing rapid urbanization has witnessed a decrease in rural areas population from 61.4% in 2014 to 60.1% in 2016. However, the population in urban areas increased from 38.5% in 2014 to 40% in 2016. According to statistical data, in Pakistan migration generally takes place for economic reasons and movement from rural to urban areas is causing higher population growth rate in the latter. Yet, the process of urbanization is accompanied with social, health and environmental issues, therefore proper planning required to make the urbanization helpful in economic development of the country [35]. Islamabad, a well-planned modern city is an attractive destination for in-land immigrants due to comparatively advances infrastructure, and better economic opportunities. Hence from 2005 to 2015, the total urban population of the city increased to 73%, which is the highest ratio compared to any other city in Pakistan [36]. According to Government of Pakistan Census 1972, the population of Islamabad was 237 thousand, while as per 1981 census, it increased to 340 thousand and in 1998 census, it reached to 805 thousand which was double than before and in 2017 it reached to 2006 thousand [37,38] (Fig. 8). All these statistics showed the population rate in this city is increasing and such huge population have impacts on the ecosystem and un ground water resources of Islamabad ([39] Fig. 9).

Cities have experienced urbanization since 19th century with massive transportation, developed cultural value of living, has reformed the spatial distribution of metropolises. Natural land cover has been replaced with anthropogenic activates with maxima usage of materials such as metal, concrete, and asphalt which having more negative impacts toward environment and urbanization [40]. In South Asia, Pakistan currently has the highest urbanization rate, which is projected 335 million by 2050 with an

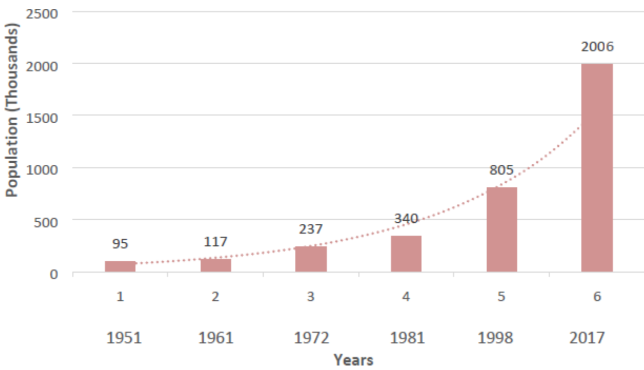

Fig. 8. Population rate in Islamabad. Source: Pakistan Bureau of Statistics (http://www.pbs.gov.pk) population census 1972, 1981, 1998 and 2017 Government of Pakistan).

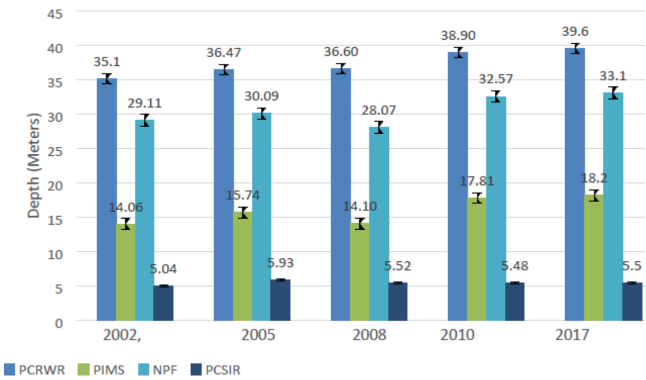

Fig. 9. Underground water depth of four locations of Islamabad.

urbanization rate of 3.06% annually. There are numerous factors for rapid urbanization, but the population growth and rural-urban migration are noteworthy. Decades-long conflicts in the tribal belts of FATA and Balochistan have also pushed millions to mega cities such as Karachi, Lahore and to an extent Islamabad. The pressure of overpopulation becomes burden on the limited resources of earth so, the balance between present requirements of land against future needs is essential. Land cover change deprived of any systematic development plan and investment in infrastructure is caused by urban growth. To avoid urban sprawl on future, it is obligatory to monitor the city's growth for sustainable urban growth [41]. As a result of this economic and demographic transformation, Islamabad conurbation has observed a significant dynamic in social formations, use pattern and land structures, such as the increase in unplanned settlements. Haider reported that according to 1998 census [42], in Pakistan, about 40% of overall urban growth was the result of internal migration. Another reason of higher rate of urbanization in Islamabad is better health indicators than any other in Pakistan with better access to healthcare and education. In Pakistan, the literacy rate in Islamabad city is the highest i.e. 86% and has the highest school enrollment rates in the country [43]. Not only natural factors motivate the population growth in Islamabad conurbation but also migration for the hunt for economic opportunities, social and political conflicts in other localities and natural disasters. The twin cities, Islamabad and Rawalpindi, provides an easy access to basic services like social equality and economic opportunities. Both these cities receive large-scale migrants from other rural areas around 1,063576 people by the 1998 census, having 3.46% growth rate in its urban population. Majority of migrants are from the areas whose rural livelihood has been disturbed by climate change and other disasters [44]. Most of the young people opt to move towards the capital for the better education opportunities. The people leave the rural areas and other parts of the country to Islamabad in order to get away from conflict and insurgencies, either between government and insurgent or between different ethnic groups. The devastating earthquake of 2005 and the 2010 flooding led to large scale clamity-induced migration to Islamabad. Devastating mostly, the twin cities receive maximum number of migrants from Punjab and Khyber Pakhtunkhwa. Another significant reason for high urbanization is the international migrants from Afghanistan in huge numbers that moved towards the twin cities as a consequence of US invasion in 2001 and Soviet invasion in 1990. In Islamabad–Rawalpindi, the living combinations of local population and Afghan Refugees have a complex dimension in unplanned settlements. It is very challenging for the local administration to provide their municipal necessities despite a considerable integration into the local economy and society [43,44].

The importance of landscape change information can be gauged from the fact that it helps geographical and ecological basis for more sustainable land use development plans 44]. The land cover changes especially vegetation cover lost have abundant impacts on biodiversity [46,47] water quality [48], temperature distribution [49] and hydrological regime [50]. Land-use changes are known to impact the hydrology of the catchment area. However, the quantitative effects of land-use changes on the groundwater system have not been investigated so far [51]. Rapid land cover and land use changes greatly influence water resources [52]. The impact of land-use changes on the hydrology has been a major hydrological research area over the last decade. The potential for urbanization processes to have an impact on the underlying groundwater is a function of its susceptibility to the consequences of excessive abstraction. Ground water resources are decreasing with increasing demands for irrigation and urban utilization. There is clear evidence that underground water use is higher average recharge in Pakistan [53].

In order to assess the effect of urbanization and land cover change on the ground water of Islamabad, ground water level data was obtained from piezometers (Four piezometer operated by PCRWR and data was collected by PCRWR Islamabad office) which are installed at four different locations in Islamabad namely PCRWR, NFP, PCSIR and PIMS hospital. All the piezometers were monitored twice monthly from 2002 to 2017 in order to understand the monthly and yearly water level fluctuation. A graph was plotted based on the average value of ground water level (Fig. 9). The average water level in Islamabad ranges from 5 m to 39.5 m. The figure illustrates that water table at Pakistan Council of Research in Water Resources (PCRWR) and (National Police Foundation) NPF (which is mostly a residential area) was found considerably lower than Pakistan Institute of Medical Sciences (PIMS) and Pakistan Council of Scientific and Industrial Research (PCSIR). Apart from PCSIR, the other three locations observed a declining trend in the annual ground water level. Apart from PCSIR where little ground water utilized is least due as the area is mostly dwelled by only government's official departments, the water level in the remaining three locations was found to be lowest in 2017 which reflects the pressure of increasing population and urbanization. Due to excessive urbanization, the ground water level is constantly declining in the overall region. As a consequence of climate vulnerability and urbanization, it is not only making the extraction of ground water harder but also causing some irreversible negative impacts on the whole ecosystem and human population [54–56]. Frappart et al. [57] found the inter-annual changeability of rain water influence on storage of land water and determined the association between time variation of land water storage consistence with rainfall discloses huge variances in terms of water storage, delayed time and rainfall amount. In another study Prakash et al. [58] determined that terrestrial water storage decreased over the time,using remote sensing satellite data, which was not consistent with rainfall so the major impact of this decreased was industrialization and over population on land water resources.

4. Water quality assessment

The water quality of 32 sites were analyzed (Supplementary Table S1) to calculate the water quality index (WQI). Out of 32 sites only one site was suitable for drinking water purpose which was Pak secretariat P Block. 5 sites were categorized in poor water quality with 100–200 WQI value which were G 9/3, G 7/4, G 6/1-2, G 11/3 and I-10/1 Islamabad. 10 sites fall under very poor water quality and 16 came under unsuitable for drinking purpose. The location

Table 4
WQI of selected 32 sites in Islamabad

Sr. #	Sampling site	WQI value	Category
1	I–8/3, Islamabad	214.1305	Very Poor
2	I–9/4, Islamabad	273.0712	Very Poor
3	G–9/2, Islamabad	352.2362	Unsuitable
4	G–9/3, Islamabad	171.2166	Poor
5	Sitara Market, G–7/2, Islamabad	279.5818	Very Poor
6	G–7/4, Islamabad	116.155	Poor
7	Abpara G–6, Islamabad	420.1747	Unsuitable
8	F–6/1, Islamabad	486.1483	Unsuitable
9	G–6/1-2, Islamabad	188.5548	Poor
10	G–10/2	204.3481	Very Poor
11	G–11/2	242.7827	Very Poor
12	G–11/3	112.9947	Poor
13	F–10 Markaz	483.0809	Unsuitable
14	F–10/1	522.6934	Unsuitable
15	G–10 Markaz	1054.109	Unsuitable
16	I–10 Markaz	252.3167	Unsuitable
17	I–10/1	187.7314	Poor
18	I–10/4	210.7829	Very Poor
19	I–9 Mangal Bazar	356.5382	Unsuitable
20	I–10/2	922.623	Unsuitable
21	I–8/1	299.2981	Very Poor
22	G–8/2	299.9476	Very Poor
23	G–8/1	590.2722	Unsuitable
24	Minister Colony	385.7925	Unsuitable
25	Pak Sectariet, P Block	21.10353	Excellent
26	Parliament House	414.0186	Unsuitable
27	Awan-e-Sadar Colony	363.6362	Unsuitable
28	Parliament Lodges	333.8299	Unsuitable
29	Masjid Noor Qadimi	321.4103	Unsuitable
30	Abpara Bazar, G–6	568.3333	Unsuitable
31	Margalla Town	206.2557	Very Poor
32	I–10/2, Chambeli Road	213.2237	Very Poor

and value of WQI has been given in Table 4. This indicated that water quality deteriorated with population expansion. Al-Mutairi et al. [59] determined the WQI of surface water and found that 31.9% were classified as excellent and this percentage was decreased to 1.5% on next year due to contamination. Alobaidy et al. [60] also found that with passage of time WQI abruptly decreased to poor WQI due to anthropogenic activities and population expansion. So, the water quality of Islamabad also declined due to urbanization within 20 years which ultimately put the bad impacts on residence health as well as on ecosystem.

5. Conclusion

The major land cover types comprise of grasslands, built-up lands, bare lands and water bodies were analyzed in the year 1993, 1997, 2002, 2007, 2013 and 2017 in the capital city of Pakistan, Islamabad. Partitioning, hybrid classification and spatial reclassification technique used for the discrimination of these land cover types on Landsat imagery thus provides a promising alternative for classification of this city. Within 25-year period, notable land cover transformations were detected. The gross loss was highest built-up and barren land has taken its place due to increase rate of urbanization. Noticeably, the spatial scale of human activities widened with time. The main hot spots of these land cover changes occurred in all directions, at different times with the requirement of new houses, roads and commercial places. This rapid urbanization also has impacts on the ground water which is decreasing by increasing rate of its use and by anthropogenic activities which badly impact on its quality as well. This study recommends that sustainability of ecosystem should be considered with increasing rate of urbanization, as it resulted in declining of flora and fauna and precious water resource. Proper management should be taken for the sustainability of limited underground water. This study would provide a base for research related to urbanization and land change impacts information for policy formulation.

References

[1] D.O. Appiah, E.K. Forkuo, J.T. Bugri, Land use conversion probabilities in a peri-urban district of Ghana, CJUES., 3(3) (2015) 1550026.

[2] M.A. Oyinloye, O. Kufoniyi, Analysis of land use, land cover change and urban expansion in Akure, Nigeria, J. Innov. Res. Eng. Sci., 2(4) (2016).

[3] Z. Sun, F. Wu, C. Shi, J. Zhan, The impact of land use change on water balance in Zhangye city, China, Physics and Chemistry of the Earth, Parts A/B/C (2016).

[4] World Bank (2007). Dhaka: Improving living conditions for the urban poor. Sustainable Development Unit, South Asia Region, Report No. 35824-BD.

[5] Z. Wang, X. Deng, C. Wong, Integrated land governance for eco-urbanization, Sustainability, 8(9) (2016) 903.

[6] Y. Tao, F. Li, J.C. Crittenden, Z. Lu, X. Sun, Environmental impacts of China's urbanization from 2000 to 2010 and management implications, Environ. Manage., 57(2) (2016) 498–507.

[7] United Nations (2006). Department of Economic and Social Affairs, Population Division World Urbanization Prospects: The 2007 Revision, United Nations, New York; United Nations Statistics Division, Demographic and Social Statistics: Demographic Yearbook 2006 accessed on 17-8-2008.

[8] Y. Cai, H. Zhang, P. Zheng, W. Pan, Quantifying the impact of land use/land cover changes on the urban heat island: a case study of the natural wetlands distribution area of Fuzhou City, China, Wetlands, 36(2) (2016) 285–298.

[9] B. Mu, A.L. Mayer, R. He, G. Tian, Land use dynamics and policy implications in Central China: A case study of Zhengzhou, Cities, 58 (2016) 39–49.

[10] F. Zhang, T. Tiyip, H. Kung, V.C. Johnson, M. Maimaitiyiming, M. Zhou, J. Wang, Dynamics of land surface temperature (LST) in response to land use and land cover (LULC) changes in the Weigan and Kuqa river oasis, Xinjiang, China, Arabian J. Geosci., 9(7) (2016) 1–14.

[11] M.L. Clark, N.E. Kilham, Mapping of land cover in northern California with simulated hyper spectral satellite imagery, ISPRS J. Photogramm. Remote Sens., 119 (2016) 228–245.

[12] G.V. Asenjo, D. Sharma, C. Potvin, Engaging stakeholders: Assessing accuracy of participatory mapping of land cover in Panama, Conserv. Lett., 8(6) (2015) 432–439.

[13] E.F. Lambin, H.J. Geist, E. Lepers, Dynamics of land use and land cover changes in tropical regions, Annu. Rev. Environ. Resour., 28 (2003) 205–241.

[14] K.P. Overmars, P.H. Verburg, Analysis of land use drivers at the watershed and household level: linking two paradigms at the Philippine forest fringe, Int. J. Geogr. Inf. Sci., 19(2) (2005) 125–152.
[15] C. Potter, V. Genovese, P. Gross, S. Boriah, M. Steinbach, V. Kumar, Revealing land cover change in california with satellite data, EOS, Trans. Amer. Geophys. Union, 88(26) (2007) 269.
[16] G. Camorani, A. Castellarin, A. Brath, Effects of land use changes on the hydrologic response of reclamation system, Phys. Chem. Earth, 30 (2005) 561–574.
[17] Y. Chen, Y. Xu, Y. Yin, Impact of land use change scenarios on storm-runoff generation in Xitiaoxi basin, China, Quatern. Int. 1 (2009) 1–8.
[18] M. Hernandez, S.N. Miller, D.C. Goodrich, B.F. Goff, W.G. Kepner, C.M. Edmonds, K.B. Jones, Modeling runoff response to land cover and rainfall spatial variability in semi-arid watersheds. In Monitoring, Ecological Condition in the Western United States (pp. 285–298) (2000). Springer Netherlands.
[19] A.D. Roo, G. Schmuck, V. Perdigao, J. Thielen, The influence of historic land use changes and future planned land use scenarios on floods in the Oder catchment, Phys. Chem. Earth, 28 (2003) 1291–1300.
[20] J. Zhou, X. Zhang, L. Shen, Urbanization bubble: Four quadrants measurement model, Cities, 46 (2015) 8–15.
[21] T.W. Ann, Y. Wu, B. Zheng, X. Zhang, L. Shen, Identifying risk factors of urban-rural conflict in urbanization: A case of China, Habitat Int., 44 (2014) 177–185.
[22] L.Y. Shen, J. Zhou, Examining the effectiveness of indicators for guiding sustainable urbanization in China, Habitat Int., 44 (2014) 111–120.
[23] L. Jiao, L. Shen, C. Shuai, B.A. He, Novel approach for assessing the performance of sustainable urbanization based on structural equation modeling: a China case study, Sustainability, 8(9) (2016) 910.
[24] M.J. Butt, A. Waqas, M.F. Iqbal, G. Muhammad, M.A.K. Lodhi, Assessment of urban sprawl of Islamabad metropolitan area using multi-sensor and multi-temporal satellite data, Arabian J. Sci. Eng., (2011). DOI: 10.1007/s13369-011-0148-3.
[25] APHA, Standard Methods for the Examination of Water and Waste Water, 17th ed., American Public Health Association, Washington DC, 2012.
[26] C.R. Ramakrishnaiah, C. Sadashivaiah, G. Ranganna, Assessment of water quality index for the ground water in Tumkur Taluk, E.-J. Chem., 6 (2) (2009) 523–530.
[27] P. Mather, B. Tso, Classification Methods for Remotely Sensed Data. CRC Press, 2016.
[28] F. Yuan, K.E. Sawaya, B.C. Loeffelholz, M.E. Bauer, Land cover classification and change analysis of the twin cities (Minnesota) metropolitan area by multi-temporal Landsat remote sensing, Remote Sens. Environ., 98 (2005) 317–328.
[29] P. Coppin, I. Jonckheere, K. Nackaerts, B. Muys, E. Lambin, Digital change detection methods in ecosystem monitoring: a review, Int. J. Remote Sens., 25(9) (2004) 1565–1596.
[30] D. Lu, P. Mausel, E. Brondizio, E. Moran, Change detection techniques, Int. J. Remote Sens., 25(12) (2004) 2365–2401.
[31] M.A. Saeed, A. Ashraf, B. Ahmad, M. Shahid, Monitoring deforestation and urbanization growth in Rawal watershed area using remote sensing and GIS techniques, Scient. J. Comsats – Science Vision, 16 (2011) 93–104.
[32] M.A. Sawas, N.H. Anwar, H. Iqtidar, M.S. Viqar, Urbanization, Gender and Violence in Rawalpindi and Islamabad: A Scoping Study, 2014.
[33] A.Z.K. Mahsud, Representing the State: Symbolism and Ideology in Doxiadis' Plan for Islamabad. In M. Swenarton, I. Troiani, H. Webster, eds., The Politics of Making, Abingdon: Routledge, 2007, pp. 61–74.
[34] A. Hasan, M. Mohib, Urban Slums Reports: The Case of Karachi, Pakistan, (2003) pp. 1–32.
[35] P. Gong, S. Liang, E.J. Carlton, Q. Jiang, J. Wu, L. Wang, J.V. Remais, Urbanisation and health in China, The Lancet, 379(9818) (2012) 843–852.
[36] M.A. Mahboob, I. Atif, A. Riaz, Spatio temporal mapping and monitoring of land cover dynamics of Islamabad using multi-temporal remote sensing data, Pak. J. Sci., 68(2) (2016) 146.
[37] Pakistan Bureau of statistics. population size and growth of major cities. url:http://www.pbs.gov.pk/sites/default/files//tables/population%20size%20and%20growth%20of%20major%20cities.pdf accessed: 2016-10-30.
[38] Pakistan Bureau of statistics. district and tehsil level population summary with region breakup. http://www.pbscensus.gov.pk/sites/default/files/bwpsr/islamabad/ISLAMABAD_SUMMARY.pdf accessed: 2018-07-05.
[39] B.J. Hibbs, J.M. Sharp, Hydrogeological impacts of urbanization, Environ. Eng. Geosci., 18(1) (2012) 3–24.
[40] Y. Jiang, P. Fu, Q. Weng, Assessing the impacts of urbanization-associated land use/cover change on land surface temperature and surface moisture: a case study in the mid western United States, Remote Sens., 7 (2015) 4880–4898.
[41] J.A. Tali, S. Divya, K. Murthy, Influence of urbanization on the land use change: a case study of Srinagar City, Am. J. Res. Commun., 1(7) (2013) 271–283.
[42] M. Haider, M.G. Badami, Urbanization and local governance challenges in Pakistan, Environ. Urban Asia, 1(1) (2010) 81–96.
[43] Mustafa, A. Sawas, Urbanization and political change in Pakistan: exploring the known unknowns, Third World Quart., 34(7) (2013) 1293–1304.
[44] M. Kugelman, (2013) Urbanization in Pakistan: causes and consequences. Washington DC: NOREF Norwegian Peacebuilding Resource Center.
[45] H. Alphan, L. Güvensoy, Detecting coastal urbanization and land use change in Southern Turkey, J Environ. Eng. Landscape Manage., 24(2) (2015) 97–107.
[46] J.A. Raini, Impact of land use changes on water resources and biodiversity of Lake Nakuru catchment basin, Kenya. Afr. J. Ecol., 47(1) (2009) 39–45.
[47] M. Kiedrzyński, E. Kiedrzyńska, P. Witosławski, M. Urbaniak, J.K. Kurowski, Historical land use, actual vegetation and the hemero by levels in ecological evaluation of an urban river valley in perspective of its rehabilitation plan, Pol. J. Environ. Stud., 23(1) (2014) 109–117.
[48] W.A. Shivoga, M. Muchiri, S. Kibichi, J. Odanga, S.N. Miller, T.J. Baldyga, Influences of land use/cover on water quality in the upper land middle reaches of river Njoro, Kenya. Lakes Reservoirs: Res. Manage., 12 (2007) 97–105.
[49] P. Hesslerová, J. Pokorný, Effect of Mau forest clear cut on temperature distribution and hydrology of catchment of Lakes Nakuru and Naivasha: preliminary study. In J. Vymazal (Ed.), Water and nutrient management in natural and constructed wetlands, London: Springer Science Business Media B.V., (2010) pp. 263–273.
[50] K.K. Mwetu, B.M. Mutua, P.M. Kundu, J. Fürst, W. Loiskandl, Effects of deforestation and climate variability on river discharge in the Njoro river catchment, Kenya. In Proceedings of the Sumawa Mau forest complex conference, Egerton University, (2009) 27–29.
[51] O. Batelaan, F. Medt, L. Triest, Regional groundwater discharge: phreatophyte mapping, groundwater modelling and impact analysis of land-use change, J. Hydrol., 275(1) (2003) 86–108.
[52] P.D. Wagner, S.M. Bhallamudi, B. Narasimhan, L.N. Kantakumar, K.P. Sudheer, S. Kumar, P. Fiener, Dynamic integration of land use changes in a hydrologic assessment of a rapidly developing Indian catchment, Sci. Total Environ., 539 (2016) 153–164.
[53] A.S. Qureshi, Improving food security and livelihood resilience through groundwater management in Pakistan, GARJAS., 4(10) (2015) 687–710.
[54] X. Cao, P. Wu, Y. Wang, X. Zhao, Challenge of water sources in urbanizing China: an analysis of agricultural water footprint, Pol. J. Environ. Stud., 24(1) (2015) 9–18.
[55] UN-Habitat, Pakistan - Climate Change Vulnerability Assessment, United Nations Human Settlements Programme, 1st ed., Islamabad, 2014.
[56] C. Li, M. Liu, Y. Hu, J. Gong, Y. Xu, Modeling the quality and quantity of runoff in a highly-urbanized catchment using storm water management model, Pol. J. Environ Stud., 25(4) (2016) 1573–1581.

[57] F. Frappart, G. Ramillien, J. Ronchail, Changes in terrestrial water storage versus rainfall and discharges in the Amazon basin, Int. J. Climatol., 33 (2013) 3029–3046.

[58] S. Prakash, R.M. Gairola, F. Papa, A.K. Mitra, An assessment of terrestrial water storage, rainfall and river discharge over Northern India from satellite data, Current Sci., 107(9) (2014) 1582–1586.

[59] N. Al-Mutairi, A. Abahussain, A. El-Battay, Spatial and temporal characterizations of water quality in Kuwait Bay, Mar. Pollut. Bull., 83(1) (2014) 127–131.

[60] A.H.M.J. Alobaidy, H.S. Abid, B.K. Maulood, Application of water quality index for assessment of Dokan Lake ecosystem, Kurdistan Region, Iraq, J. Water Resour. Protect., 2 (2010) 792–798.