



Spatio-temporal analysis of urban sprawl in Islamabad, Pakistan during 1979–2019, using remote sensing

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Abstract Urbanization in Pakistan is increasing at 3% annually, the highest in South Asia. 50% of the population is expected to urbanize by 2025. The capital city of Pakistan, Islamabad has experienced phenomenal increase in the urban population and extent in the last four decades. The aim of this research was to analyze the urban sprawl of Islamabad and changes in the Land Use and Land Cover (LULC), with the help of satellite images. LULC statics were extracted from Landsat Multi-Spectral Scanner (MSS), Thematic Mapper (TM), Enhanced Thematic Mapper Plus (ETM+) and Operational Land Imager (OLI) images, for the years 1979, 1989, 1999, 2008 and 2019. There is an increase of 377 sq. km in built-up areas and slight increase of 47 sq km in the agriculture land. The forest cover has been reduced by 83 sq km and the water bodies have also reduced. The barren land has experienced an unprecedented decrease of 333 sq km in the meanwhile. The master

plan is under revision to regularize such uncontrolled constructions and accommodate the increased demand. The city, as a result, has been facing issues of water supply, sanitation, transportation etc. This has seriously jeopardized the master plan of the city.

Keywords Urban sprawl · Islamabad · Land use · Land cover · Urbanization · Master plan

Introduction

Increased global urbanization is one of the major challenges faced by the world, as about 55% of the world population live in cities today. This proportion is expected to reach 68% by 2050 (UN, 2018). This will also lead to increase in the size of urban population and urban settlements (Vlahov & Galea, 2002). The rapid urbanization is intertwined with the frequent natural disasters (Brown, 2012). Fast urbanization in the developing countries has led to a plethora of problems in the major cities, such as urban floods, air and noise pollution, social inequalities and political instability (Netzband et al., 2007). Rapid urban growth also undermines the capacity of city government to provide necessary amenities to the people such as clean water, transportation, housing, sewerage etc. (Duque et al., 2015). There is a need for research in the areas of urban sustainability for better

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urban planning, policy making for poverty reduction, infrastructure planning, disaster management & prevention and environmental sustainability etc. (Bhatta et al., 2010). The trends of urbanization in Pakistan has shown a high growth rate in the last few decades, with a current rate of 3%, which is highest in South Asia. The urbanization in the country is expected to reach 50% by 2025 as against 36.4% according to the census of 2017 (PBS, 2017). The industrial growth in the country, increased economic activities and inflow of foreign remittances by overseas Pakistanis have led to high urbanization in the country.

The capital city of Pakistan, Islamabad has experienced urban sprawl due to increase in population, internal migration of people from other parts of the country, investment in real estate and enhanced economic activities in the last two decades. This urban sprawl has led to many challenges for the city, which include traffic congestions, housing shortages, water supply and sanitation issues, deforestation, loss of barren lands, increased street crimes etc. In this research, the urban sprawl of the city has been assessed on the basis of Land Use Land Cover (LULC) changes by using the Geographical Information System and Remote Sensing (GIS & RS) techniques. The study has identified the changes in the land use and their contribution to urban sprawl and the causes for urbanization.

Literature review

Urbanization in Pakistan

The trends of urbanization in various provinces of Pakistan are shown in Table 1 (Pakistan Bureau of Statistics, 2018). According to the 2017 census of the county, about 36.4% of the population live in urban areas and the remaining 63.6% population live in the rural areas. Urbanization in Pakistan is fastest in South Asia and it is expected to touch 50% by 2025 as against 36.4% during 2017. The country is at the threshold of major demographic changes (Barki, 2011). Urbanization in Pakistan has mainly happened due to internal migration from rural areas to urban areas and internal displacement of people from terrorism stricken areas (Hassan, 2016; Qureshi & Huapu, 2007). Based on comparative analysis of urban trends developments in Karachi and Beijing with an index system using 36

indicators for 6 years (2012–2017), it is reported that Beijing's development progress is better than that of Karachi in terms of socio-economic and environmental development (Mangi et al., 2020). The urban growth in Pakistan has witnessed substantial increase since 1971, when the democracy was restored in the country after a long military regime, which led to new developments and jobs created by the then elected Government (Shahbaz et al., 2017; PBS, 2017). The major drivers of urbanization in Pakistan include increased industrial and economic activities, better transportation systems, low land prices in the sub urban areas and investment in the real estate developments (Magidi & Ahmad, 2019).

Trends and drivers of urban sprawl in Islamabad

Islamabad, the capital city of Pakistan, has experienced the urban sprawl over the last 2–3 decades mainly due to transmigration, development of new housing schemes & infrastructure and internal displacement of people owing to terrorism. The territorial limits of Islamabad have expanded by 87.31 sq km during 1972–2009 with the reduction in the forest covers and other natural habitat (Butt et al., 2011). The sporadic Land Use Cover Land (LULC) changes of the city has led to lowering of the ground water and creating severe water shortages in most parts of the city. This has been mainly attributed to increase in impervious surfaces and low recharge of the underground water due to changes in the Land Use Land cover. The impervious part of the city increased from 88.579 km² in 1990 to 330.487 km² in 2018, thereby showing an increase by 273.10%. The impervious area increased from 9.36 to 34.94% of the total area of Islamabad. At the same time, the urban areas increased from 58.854 km² in 1990 to 309.697 km² in 2018, thereby showing an increase by 426.21%. The urban areas increased from 6.22 to 32.74% of the total area of Islamabad during 1990–2018 (Liu et al., 2020). This urban growth of Islamabad city is further attributed to increase in population, extension of transportation systems, revision of master plan, industrial and real estate development in the last three decades and neighbour urban effects. The population of the city also doubled from 0.559 Million to 1.095 Million during 1979–2009. This was the time when a large number of people migrated internally from different parts of the country to Islamabad for property and real

Table 1 Population and its percentage distribution by urban and rural areas (provinces and national)—1951–2017 (Pakistan Bureau of Statistics, 2018; NIP, 2006, 2013)

Province	1951		1962		1972		1981		1998		2017	
	Pop Million	%	Pop Million	%	Pop Million	%	Pop Million	%	Pop Million	%	Pop Million	%
Punjab												
Urban	3.57	17.4	5.48	21.5	9.18	24.4	13.05	27.6	23.02	31.3	40.39	36.7
Rural	16.97	82.6	19.99	78.5	28.42	75.6	34.24	72.4	50.60	68.7	69.63	63.3
Sindh												
Urban	1.77	29.2	3.17	37.9	5.73	40.4	8.24	43.3	14.84	48.8	24.91	52.0
Rural	4.28	70.8	5.20	62.1	8.43	59.6	10.79	56.7	15.60	51.2	22.98	48.0
KP												
Urban	0.50	11.1	1.76	13.2	1.20	14.3	1.67	15.1	2.99	16.9	5.73	18.8
Rural	4.05	88.9	4.97	86.8	7.19	85.7	9.40	84.9	14.75	83.1	24.79	81.2
Baluchistan												
Urban	0.14	12.4	0.23	16.9	0.40	16.5	0.68	15.6	1.57	23.9	3.40	27.5
Rural	1.02	87.6	1.13	83.1	2.03	83.5	3.66	84.4	5.00	76.1	8.94	72.5
Pakistan*												
Urban	5.99	17.7	9.65	23.1	16.59	25.4	23.84	28.3	43.04	32.5	75.58	36.4
Rural	27.75	82.3	32.23	76.9	48.72	74.6	60.41	71.7	89.32	67.5	132.19	63.6

estate businesses. Sharp increases in population has been observed during 2009–2019, when the population of the city increased from 0.777 Million to 1.095 Million. In this period, rapid development in commercial, industrial, residential sectors, population growth, traffic infrastructure and administrative services and expansion in agriculture land have been witnessed. The increase in population during 1979–2019, is shown in Fig. 1 (Hassan et al., 2016, Mundia & Aniya, 2005; Butt et al., 2015).

Drivers of land use land cover (LULC) changes in Islamabad

Some of the key drivers of land use changes also include economic, technological, institutional and policy, cultural, and demographic factors (Rasul, 2009). The economic activities in Islamabad has also experienced exponential rise during 2010–2019, due to increased business and economic activities, particularly the real estate and housing sector. This was the period, where economic activities have boosted due to a number of reforms by the Government in the construction and real estate sector. However, the economic growth has led to significant increase in the

emissions of CO₂ (Rehman & Zeb, 2020). The commercial activities of Islamabad also increased in the last two decades, due to construction of new malls and high rise buildings in the peri-urban areas, due to availability of relatively cheap land. The investment in real estate was more preferred as compared to construction of houses, hence the investment was mainly based on speculative business of real estate. The housing needs of the people of the city increased many times, yet the majority of the investors prefer to invest in residential land developments, which ultimately pushed the expansion of urban land. The real estate industry thus operates under the influence of individual actors and their behaviors (Squires, & Heurkens, 2016). More research is recommended on economic activities due to real estate market motivations on the urban development and urban sustainability (Elmqvist et al., 2019; Zhang & Li, 2018). The financialisation of development activities has led to low density urban sprawl in Islamabad. The large number of new development and housing schemes in the city, has also led to urban sprawl (Rauf & Weber 2020).

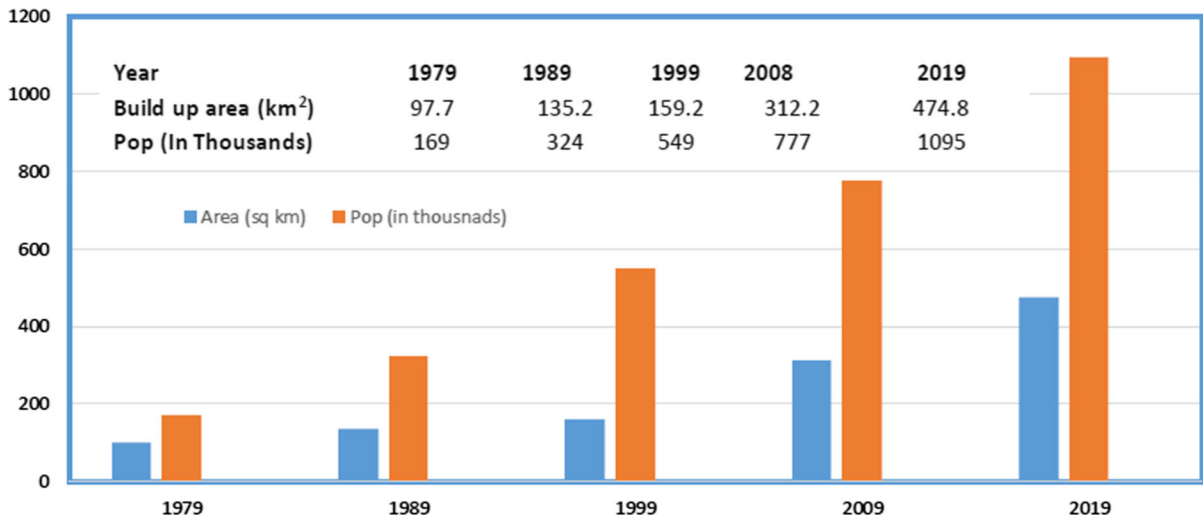


Fig. 1 Comparison of urban sprawl and population growth of Islamabad during 1979–2019 (Hassan et al., 2016)

Major issues in the urbanization of Islamabad

The urban development in Islamabad has been unsustainable in many ways, as it is not linked with creating resilience to natural and man induced disasters, green and clean transportation system, planned expansion of industrial and economic extension (Abdul & Yu, 2020). The unplanned urban growth of Islamabad has forced the city administration to revise the master plan and compromise over the quality of life and environment. This unplanned urban sprawl is continuing as unchecked due to lack of monitoring of the land use, poor adherence to the land use policies and lack of real time data (Mannan et al., 2018). The leapfrog development in the city for the last two decades, has created serious challenges for the city Government in providing the basic amenities to these new settlements. This unscrupulous urban growth is further continuing as unchecked.

Research significance of the study

There is a need to assess the LCLU changes in the city for the last four decades, to document the major changes in the use of different types of lands and their impact on the sustainability of the capital city. This research has been motivated by this dire need to assess the LCLU changes in Islamabad during the last four decades. The major objective of the research is to

assess the spatial and temporal changes in the land use of Islamabad and its possible impact on the master plan of the city, using GIS and remote sensing techniques. The data will provide the latest status of the various classes of land use and changes occurred during last four decades. This can be used for future planning of the city and revision of the master plan due to spatio-temporal changes in the LULC. The data will strengthen the existing database about the LULC changes for comparative assessment and future legislation about the land use in Islamabad.

Study area-geography, demography and economy

Islamabad is the capital city of Pakistan, which was developed in the early 1960s when it was decided to shift the capital of the country from Karachi to Islamabad, by the then president, Field Marshal Muhammad Ayub Khan. Islamabad is regarded as the only modern and planned city of the country. According to the 2017 census, the population of the city is about 1.7 Million and it has spread over an area of 906 km². Hence the population density is 1876 persons/km². The topography of the study areas is Potohar Plateau ranges, with elevation range from 457 to 610 m (above mean sea level: asl). The location and zoning map of the city is given in Fig. 2 (Mohsin and Gough, 2012). The tropical evergreen broadleaf forests and subtropical evergreen coniferous,

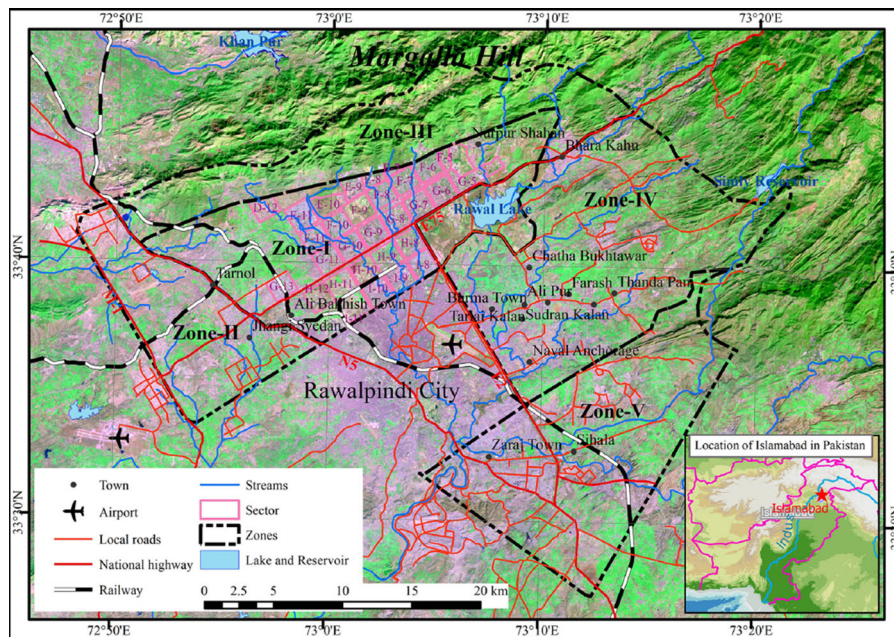


Fig. 2 Location map and zoning of Islamabad-Pakistan (Yong Liu et al., 2020)

deciduous broadleaf forest are found at low and high altitudes respectively (Harry & Seth, 1965). These forests have been removed with the increase in population and construction of new housing schemes. Two cultivation seasons during Oct–April for winter crops and Feb to Oct for summer crops are observed.

In the early 1960s, when the development of Islamabad was started, major part of the land consisted of the agriculture farms, bare land or vegetation with some natural water resources. The total population of Islamabad was only 45,400 persons in 1960, which increased to 70,000 in 1970 and 189,300 in 1980. However, there was a sharp increase in population of the city to 342,900 in 1990, 568,700 in 2000, 804,000 in 2010 and 1.100 Million in 2020. In the last one decade, the population of the city has increased with an average growth rate of 3.7%. When the rural population of 0.90 Million is added, the total population of the Islamabad district becomes 2 Million (PBS, 2017). Majority of the people are employed in the public and private sectors, with very thin business sectors. The urban growth patterns of Islamabad have been divided into four types, (1) village sprawl and leapfrog, (2) planning expansion, (3) fringe sprawl and infilling, and (4) merge. In village sprawl, the haphazard and unplanned leapfrog growth is experienced which has occurred in the suburban areas of

Islamabad. The second urban sprawl has occurred due to revision of the master plan of the city, based on the changes in demographics of the city. The third type of urban growth involves the sprawl of urban fringe from the peri-urban areas of the city. The fourth urban pattern merging occurs when the two adjacent cities of Islamabad and Rawalpindi have merged at their boundaries (Bhutta et al., 2010).

The residents of the city mostly work in the public and private offices. Industrial and commercial activities of the city have also grown many times. The Islamabad Capital Territory (ICT) has been divided into five zones. Zone I, II and V are managed as National Park and the rural fringe. Marble, chemical factories, steel mills, flour mills and oil paints, pharmaceuticals are some of the major industries in the city (Shah & Shaheen, 2010). The city has been regulated under Zoning Regulations 1992. The Islamabad Master Plan, being no exception to master plans elsewhere, has resulted in forced urban development and stifling of economic activities. With the market driven forces and demands, the cities are moving from master plans and rather market forces and investors are to determine the nature of buildings and developments in cities now (Haque, 2015, 2017). The same has also happened to Islamabad as the master plan has been

revised under the pressure of market forces and real estate investments.

Material and methods

Use of remote sensing and GIS techniques for assessment of spatio-temporal changes of land

Historically the Satellite imageries like moderate resolution Landsat data have been widely used at no cost for the monitoring and assessment of land cover for urban sustainability and urban sprawl analysis. The urban expansion of various cities were studied with the help of such images for cities like Dhaka Bangladesh, Hangzhou China, Komb Ombo desert Egypt, Izmir Turkey, Mumbai India and Islamabad Pakistan (Dewan & Yamaguchi, 2009; Jingsong et al., 2009, Faid & Abdulaziz, 2012; Hepcan et al., 2013; Moghadam & Helbich, 2013; Hassan et al. 2016). Similarly Sebastián Martinuzzi et al. (2007) and Ranachadra et al. (2015) studied the urban sprawl of Puerto Rico and Delhi India respectively with the help of remote sensing techniques. Arribas-Bel et al. (2011), reviewed the urban sprawl in Europe and located the hot spots of urbanization while using several sources of information. Gharaibeha et al. (2020) used the Geographical Information System (GIS) and Multi-Criteria Evaluation (MCE) Techniques to analyze the urban growth of An-Nummayimah City of Jordan in the post war scenario. He used important factors like slope, land fertility, distance to the urban center and distance to roads. Based on the provincial panel data from 2001 to 2017 in China, Han (2020) reported that most of the provinces are suffering from urban sprawl. Land finances by the Government has made this more serious. He recommended that the less developed provinces must actively promote economic activities and create more jobs to retain their labor.

All similar studies provided useful information in the changes in land use and land cover, over a certain period of time and thereby helped the urban planners and policy makers to study the historic trends in urbanization. Such studies when coupled with ground truth data, can further enrich the quality of data for better planning and policymaking. In this study the Landsat images were used in current study, for analysis of urban sprawl in Islamabad to cover a relatively longer period of 40 years (1979–2019). The

earlier data has covered 2–3 decades and the existing dataset requires further enrichment. This research is expected to strengthen the existing body of knowledge on the urban sprawl and urbanization in the capital city of Islamabad during this period. The urbanization of Islamabad has created high urban poverty, slum and informal dwellings, improper basic facilities, lack of clean water and sanitation, poor public transport, stagnation in economic activities, inadequate housing, environmental degradation, poor governance and difficulties in provision of services to leapfrog development in the cities (Minallh et al., 2016; Alam, 2010; Kim & Pauleit, 2007).

Methodology

Multi-spectral data of satellite imagery for the years 1979, 1989, 1999, 2008 and 2019, were developed from Landsat satellite mission data provided by USGS glovis (Free of cost). The commonly used earth observing data such as Multi Spectral Scanner (MSS) Landsat 4/5, Thematic Mapper (TM), Landsat 7 Enhanced Thematic Mapper plus (ETM+) and Landsat 8 Operational Land Imager (OLI) are used, which are mostly available free of cost (Hansen & Loveland, 2012; Zhu, 2017; Zhu et al. 2019). The specifications of the data are given in Table 2. Satellite data were preprocessed in ERDAS imagine 14 software for layer stacking, mosaicking, and subsetting of the image on the basis of Area of Interest (AOI). All image data were assessed by allocating per-pixel signatures and distinguishing the Islamabad capital into five classes with reference to specific Digital Number (DN) value. Images classification were established for 1979, 1989, 1999, 2009 and 2019. For each classified image, accuracy assessment was performed to obtain the useful data as proposed by Owojori and Xie (2005). 50 stratified random points were selected from each image and the reference image was compared with the classified image at these 50 randomly selected points, to detect change in the image. In addition, a nonparametric Kappa test was also applied to assess the extent of classification accuracy. Post-classification change detection technique was performed in the ArcGIS 10.5 as suggested by Hardin et al. (2007). The overall classification accuracy for all images was above 90% and the Kappa statistic was also 0.90, which showed a successful classification (Lea & Curtis, 2010). To assess the

Table 2 Satellite data specifications

Data	Years of acquisition	Bands/color	Resolution (m)	Source
Landsat 1 MSS	1979	Multispectral	79	USGS Glovis
Landsat 4 TM	1989	Multispectral	30	
Landsat 7 TM	1999	Multispectral	30	
Landsat 7 ETM	2009	Multispectral	30	
Landsat 8 OLI	2019	Multispectral	30	

changes in the various forms of land cover and increase the built-up area, the entire land cover was divided into built-up area, agriculture, water bodies, forest and barren land as shown in Table 3.

Results and discussion on changes in land cover and urban sprawl

For comparison of changes in land cover, the year 1979 has been based as a benchmark for various forms of land cover and the results have been depicted in Table 4. Similarly, the changes with respect to preceding year are also given in Table 5. The land under different classes of land use have been given in Fig. 3 and their area under each class in a decade has been given Fig. 4. The net increase or decrease in each class of land are given in Figs. 5, 6).

Land cover changes under built-up areas

The built up area of Islamabad has experienced gradual increase during the first decade of 1979–1989 (39%) at an average rate of 3.9% per year. This trend continued during 1990–1999 as the increase was 64% during 10 years, showing an average increase of 2.5%. However, during 1999–2008, there was a sharp and abrupt increase in the built-up areas by 8 times (221%) as compared to the base year 1979 and almost doubled (96% increase) during 10 years (1999–2008) at an average rate of 9.6% per year. This

is the decade of high urbanization of Islamabad, which can be attributed to the extensive development of housing schemes by private societies, internal migration of the people from other parts of the country due to Internally Displaced People (IDPs) after surge in terrorism activities in other parts of the country. At the same time, the Government provided high incentives to the developers involved in housing sectors. The cheap land available in the suburban areas was purchased by these developers. The increase in built up area during 2008–2019, however is 52%, which shows that the city has reached its carrying capacity, as more than half of the total areas of the city has been consumed by buildings and other physical infrastructure. The high urbanization of the Islamabad can be further attributed to the following facts:

- i. Unregulated, leapfrog expansion in the suburbs of the city
- ii. Poor urban planning of the city by the regulators particularly Capital Development Authority (CDA)
- iii. Huge investment by the private developers in the Housing Schemes in both the authorized and the unauthorized parts of the city for construction of houses.

This high urban sprawl in Islamabad has led to many problems, as discussed below (Qadeer, 2014):

- i. Poor housing quality and affordability
- ii. Growing Water and Sanitation issues
- iii. Transportation issues

Table 3 Description of different land cover classes on the basis of supervised classification

Sr.No	Class name	Description home
1	Built-up area	Residential, commercial, industrial, infrastructures, etc
2	Agriculture	Cropland, greenhouses, horticulture farms, other agriculture crops
3	Forest	Thick and mixed forest land
4	Water bodies	River, stream, water reservoirs and water channels
5	Bare soil	No vegetation cover areas and exposed rocks

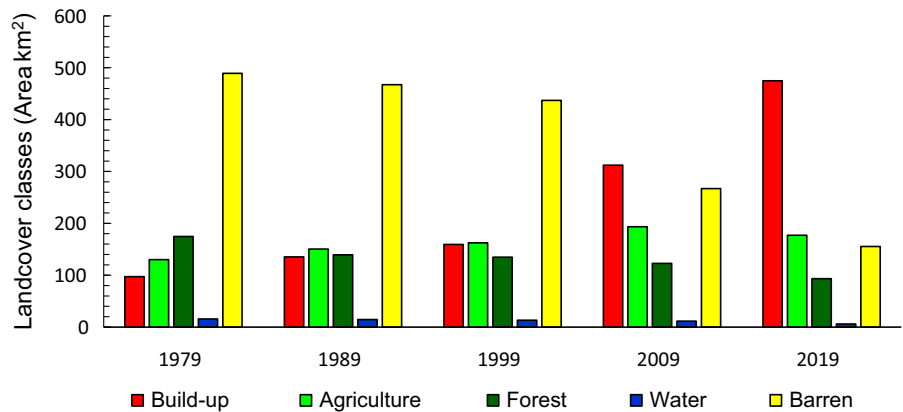
Table 4 Various forms of land use and land cover and their changes during 1979–2019

Land use/cover categories	1979		1989		1999		2008		2019	
	km ²	%	km ²	%	km ²	%	km ²	%	km ²	%
Built-up land	97.2	10.7	135.2	14.9	159.2	17.6	312.2	34.4	474.8	52.4
Agriculture land	130.0	14.3	150.4	16.6	162.3	17.9	193.4	21.3	177.0	19.5
Forest land	174.7	19.3	139.2	15.4	134.8	14.9	122.7	13.5	93.4	10.3
Water bodies	15.6	1.7	14.5	1.6	13.3	1.5	11.4	1.3	6.0	0.7
Barren land	489.1	53.9	467.3	51.5	437.0	48.2	267.0	29.4	155.4	17.1

Table 5 Changes in land cover use and their comparison with the preceding year

Land use/cover categories	1979		1989			1999			2008			2019		
	km ²	%	km ²	%	% Chg	km ²	%	% Chg	km ²	%	% Chg	km ²	%	% Chg
Built-up land	97.2	10.7	135.2	14.9	39	159.2	17.6	18	312.2	34.4	96	474.8	52.4	52
Agriculture land	130.0	14.3	150.4	16.6	16	162.3	17.9	8	193.4	21.3	19	177.0	19.5	- 8
Forest land	174.7	19.3	139.2	15.4	- 20	134.8	14.9	- 3	122.7	13.5	- 9	93.4	10.3	- 24
Water bodies	15.6	1.7	14.5	1.6	- 7	13.3	1.5	- 8	11.4	1.3	- 14	6.0	0.7	- 47
Barren land	489.1	53.9	467.3	51.5	- 4	437	48.2	- 6	267.0	29.4	- 39	155.4	17.1	- 42

Fig. 3 Land Use Land Cover LULC changes of Islamabad during 1979–2019



- iv. Health related issues
- v. Short of elementary, secondary and post-secondary education facilities
- vi. Poor Land Management leading to unregulated slum dwellings.

Land cover changes under agriculture

The land cover under agriculture has been increased as the farmers in the peri-urban areas have been developing the barren lands. A bigger part of such land has been developed by Afghan refugees settled in the sub urban area of Islamabad. This has also increased the agricultural produce of the city. There has been gradual increase in the agricultural land of the city,

Fig. 4 Distribution of various form of land cover and changes during 1979–2019

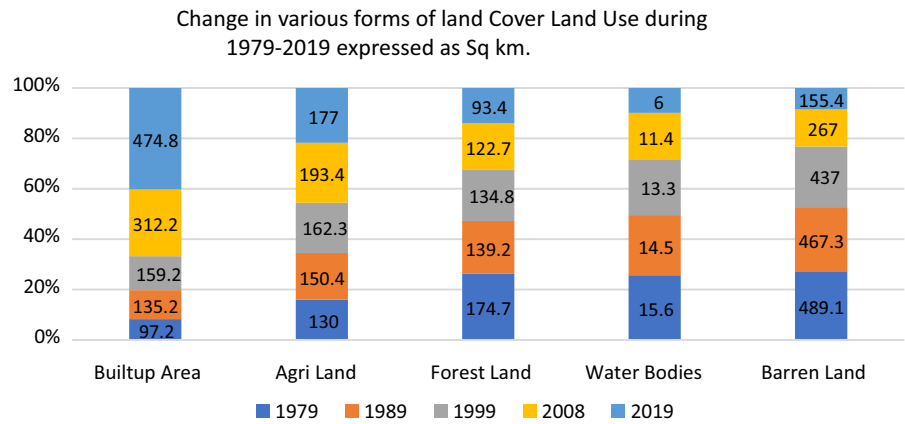
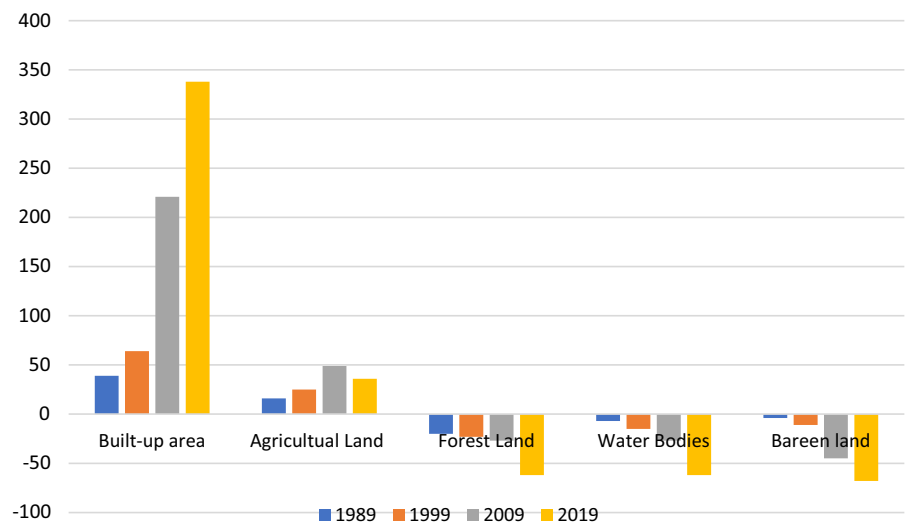


Fig. 5 % change in various forms of land cover during 1979–2019 as compared to base year 1979



which initially increased by 16% in first decade of 1979–1988 and 8% during 1989–1999, followed by 19% increase during 1999–2008 and then abrupt decrease by 8% during 2009–2019, which can be attributed to rent seeking by the farmers to sell their lands for construction of new townships and commercial properties by the developers.

Land cover changes under forests

The deforestation has been the major challenge in Islamabad as the land cover under forests have been witnessing continuous decline right from the first decade at 20%, 23%, 30% and 47% during 1979–1988, 1989–1999, 2000–2008, 2009–2019 respectively. This decrease in the forest cover can be attributed to increase in the built up area, as new

infrastructure and housing schemes have been developed in the meanwhile. During the last two decades, the construction of new highways and avenues in Islamabad have consumed large tracts of the forest lands. This has seriously threatened the climate of the city also.

Land cover changes under water bodies

The land cover under water bodies has witnessed a drastic decrease from 15.6 sq km to 6 Sq km, showing a decrease of 7%, 15%, 27% and 62% during 1979–1988, 1989–1999, 2000–2008, 2009–2019 respectively. The urban sprawl and construction of new infrastructure led to radical changes in the existence of water and recharge of underground water, which has reached from a depth of few feet originally

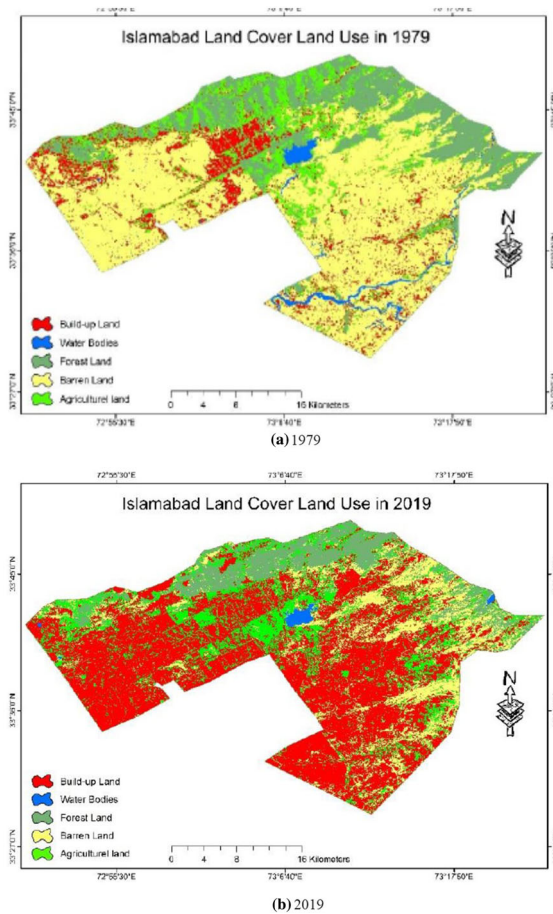


Fig. 6 Land Use and Land cover types of Islamabad in 1979 and 2019 based on satellite images

to 200 feet or more in most parts. During the last 20-year availability and supply of clean drinking water has become one of the major challenges for the city municipal authorities.

Land cover changes under the barren land

The barren land has also experienced an extraordinary decrease from 489.1 sq km in 1979 to 155.4 sq km in 2019, which has been reduced by one third. This decrease has been 4%, 6%, 39% and 42% from decade to decade during 1979–1988, 1989–1999, 2000–2008, 2009–2019 respectively. The barren land loss can be partly attributed to gain in built up, which has also consumed the land under forest and water bodies.

The increased urbanization and unsustainable land use changes in Islamabad and subsequent urbanization

has created the plethora of problems in the city as witnessed in other urban parts of the country. This has also led to increase in annual mean temperature and reduction in annual mean rainfall. The cross tabulation of the land use land cover change is shown in Table 6. The satellite images of 1979 and 2019 clearly reveal that the urban sprawl of the Islamabad city has been made at the cost of exploiting the barren lands, water bodies and forest lands. The extensive concentration of built areas during these four decades has exhausted the carrying capacity of the city and sustainability of the city remains a major challenges.

Impact of land use land cover changes on the master plan of Islamabad

The master plan of Islamabad was originally developed by M/S Doxiadis Associates, a Greek firm in the 1960s, but later the plan was modified to account for various changes. Initially the metropolitan area of Islamabad was planned in three parts, i. Islamabad ii. Islamabad National Park, iii. Rawalpindi, Cantonment. The Capital Development Authority (CDA) was entrusted the task to develop the new capital. It was mandatory to revise the plan every 20 years, based on the changes of physical and socio-economic conditions. The first revision of the master plan was made and executed in 1978, when the Blue Areas (BA) was created, the Industry and Trade (I&T) Zone was discontinued and a large restrictive areas was assigned to military forces in the sectors of E-8, E-9, E-10 and D-10 sectors of the city. The subsequent Governments, however, failed to revise the master plan further. After the promulgation of 1979 Islamabad Capital Territory (ICT) Local Government Ordinance, the union councils were formed in the rural area, which led to unplanned and unapproved mushroom growth of the buildings and housing societies in the suburbs of the city. Later, CDA approved the Zoning Regulations from the Cabinet and Zone-4 was further divided into 4 subzones from A to D in 1992. In 2015, the Metropolitan Corporation was established with an elected Mayor with Union Councils to work. The Supreme Court of Pakistan, in a Suo-moto notice, directed the Federal Government to find a solution for regularization of the irregular settlement after imposing penalties and charges. The urban sprawl of Islamabad has forced the regulators to regularize the unauthorized construction and unapproved

Table 6 Cross-tabulation of landscape change from 1979 to 2019 (km²) showing gain and losses under various forms of land cover

	Build-up	Agriculture	Forest	Water	Barren	Sum	Loss	Net
Build-up	57.35	26.11	0.12	2.19	11.45	97.22	– 39.87	377.58
Agriculture	44.71	44.24	21.11	0.13	19.83	130.02	– 85.78	46.98
Forest	20.28	34.14	71.55	0.57	48.19	174.73	– 103.18	– 83.33 (Loss)
Water	6.39	1.23	0.07	2.48	5.43	15.6	– 10.37	– 6.85 (Loss)
Barren	346.09	71.29	0.55	0.65	70.47	489.05	– 418.58	– 333.60 (Loss)
Sum	474.8	177.0	93.4	6.0	155.4			
Gain	417.45	132.76	21.85	3.52	84.93			

developmental schemes in the suburbs of the city. This uncontrolled spatial extension of the capital city has made it more vulnerable to environmental degradation. The future Islamabad Master Plan Framework (IMPF), has been based on the following principles (CDA, 2020).

- i. Conceptualize sustainable regional and metropolitan development
- ii. Promote integrated compact development patterns at all scales
- iii. Think implementation at each scale from the start

As way forward, CDA has recommended the following plans.

- i. Long Range Regional Plan (LRRP)-2050
- ii. Framework for Islamabad-Rawalpindi Metropolitan Urban Plan (FIRMUP)-2050
- iii. Islamabad Master Plan (ISP) 2040

The future long term master plan must carefully incorporate the principles of sustainable urban planning to protect the capital city from further environmental degradation. The urban sprawl of the capital city has remained a dominant factor due to negligence of the concerned authorities, however to save the city from further devastations, careful land management is required on the principles of sustainable urban planning.

Conclusions and recommendations

This research involved assessment of the urban sprawl based on the LCLU changes of Islamabad, capital city

of Pakistan on the basis of satellite images extracted for the years 1979,1989,1999,2009 and 2019. The land uses were divided into four classes of land. The changes in these land types, during this period were reviewed under the land classes for agriculture use, built up areas, barren land, land under forests and land under water bodies.

The following conclusions are made.

The built up areas has been substantially increased from 97.2 km² (10%) to 474.8 km² (52.4%), from 1979 to 2019, showing a highly unsustainable development due to new housing schemes and unauthorized settlements. The agriculture land has increased from 130 km² (14.3%) to 177 km² (19.5%) during this period, as the barren land in the suburban areas have been developed by the farmers. Substantial decrease has been witnessed in the land under forests from 174.7 km² (19.3%) to 93.4 km² (10.3%), due to deforestation and construction of new infrastructure and highways in the city. A Large part of the forest has been removed by the people for construction of their houses. Land under water bodies has also experienced a sharp decrease from 15.6 km² (1.7%) to 6 km² (0.7%). This has resulted in lowering of aquifer and severe water shortage in the city. The barren land has decreased from 489.1 km² (53.9%) to 155.4 km² (17.1%) during 1979–2019. This barren area has been partly consumed by new construction and partly by the increase in agricultural land. The unplanned and unregulated land cover land use changes of Islamabad Pakistan during 1979–2019, has forced the building control authorities to revise the master plan of the city and by regularizing the unauthorized constructions, which has seriously jeopardized the ecosystem of the city.

It is recommended that after revision of the master plan the Capital Development Authority must deploy stringent monitoring and regulating systems for unauthorized use of land, involving modern tools, creating awareness and deploying strict enforcement of laws.

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