SPATIO TEMPORAL MAPPING AND MONITORING OF LAND COVER DYNAMICS OF ISLAMABAD USING MULTI-TEMPORAL REMOTE SENSING DATA

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ABSTRACT: Land cover resources are changing continuously both spatially and temporally whereas the accurate and timely information regarding their dynamics is very important. Spatial growth is an expected phenomenon particularly in fast growing metropolitan areas like Islamabad, the capital of Pakistan. In this study spatial and temporal dynamics of land cover changes were quantified from 1975 to 2010 using Landsat images, a supervised classification algorithm and the change detection technique with Geographical Information Systems were used. The overall accuracy of the land cover derived from satellite images was from 80 to 95%. The land cover maps showed that between 1975 and 2010 the amount of urban or developed land increased from 50 km^2 to 332 km^2 of the total area, while vegetation, including Margalla Hills National Park decreased from 465 km^2 to 145 km^2. The results quantified the land cover change pattern in the city and showed a potential of multi-temporal Landsat data to provide an accurate, cost-effective means to map and analyze changes in land cover over time.

Keywords: landcover change; remote sensing; change detection; urban expansion; GIS, Islamabad.

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INTRODUCTION

Land is the basis of growth and existence for a society. The history of human growth is the history to change the land cover. This change in land cover can be observed using change detection techniques. Change detection is valuable in many fields related to land use and land cover (LULC) variations, such as fluctuating agriculture and landscape are reported by (Strahler, 1980 and Serra *et al.*, 2008), land scarcity and desertification by (Adamo *et al.*, 2006 and Gao and Liu, 2010), coastline change and urban spread by (Shalaby and Tateishi, 2007), change in urban pattern by (Batisani and Yarnal, 2009; Dewan and Yamaguchi, 2009 and Chen *et.al.*,2009), deforestation by (Schulz *et.al.*, 2010 and Wyman and Stein, 2010), and landscape and environment disintegration and other accumulative variations by (Munroe *et al.*, 2005 andNagendra*et.al.*, 2006). At the present time, Geoinformatics i.e. geographic information systems (GIS) and remote sensing (RS) are very effective and economical tools for measuring the spatial and temporal changes in land cover (LC) are also reported by (Hathout, 2002; Herold*et.al.*, 2003; Lambin*et.al.*, 2003; Serra *et al.*, 2008 andMahboob*et.al.*, 2015a,b). The remote sensing tools are the most significant methods to acquire information about land cover of any area.

There are several techniques for classification of remotely sensed data. However, supervised and unsupervised classification techniques are considered as the most reliable. But, one of the drawback related to these methods is that the accuracy of the resulting land cover change maps are subject to the accuracy of the individual classification, which means that these techniques are cause to error transmission (Yuan *et al.*, 2005). Nevertheless, such post-classification methods are generally suitable for producing "from–to" maps (Jensen, 1996), which can be used to explain the scale, site and type of the changes in land cover (Howarth and Wickware, 1981). Also, the method can be applied using data attained from remote sensing devices with different spatial, spectral and temporal resolutions (Alphan, 2003 and Thi *et.al.*, 2015).

Even though most advanced nations have both current and broad land cover information, comparatively nonexistence of geospatial records or their limited access is predominant in developing nations, Like in Pakistan. The surveyed aerial photographs are confidential for the community. A very little information is available about the spatial and temporal dynamics of the land cover changes that has formed the urban development of Islamabad. The city does not have any legal information on land cover patterns, and the Master Plan which does not include both, a changed land cover map and quantifiable information on the current patterns of land cover in the city (MMP, 2005).

The master plan of Islamabad was prepared by the Greek architects Doxiadis Associates in 1960. It was initially designed to be suitable for 40 years (1960-2000) which separated the Islamabad Capital Territory (ICT) into urban area and rural boundary (CDA, 1992). The master plan has been changed over the years. The first change in the master plan was made in 1964 when Islamabad University (later renamed as Quaid-i-Azam University) was geographically relocated from the National Park Area southeast of Rawal Lake to northeast of Diplomatic Enclave. In 1995 the green area of the city was changed to the Convention Centre and Serena Hotel (CDA, 1992).The current study is first of its kind and unique for exploring the spatial and temporal variations of land cover changes for Islamabad using Geo informatics so that both the scientific community and policy makers could get benefit in their future planning of the city. The objective of this study was to explore the change in dynamics of land cover characteristics in the capital of Pakistan, Islamabad by Landsat remotely sensed satellite data. Precisely, the objectives are: (a) to map and monitor the land cover changes of Islamabad using satellite remote sensing data (b) to provide recent and historical land cover maps of Islamabad from 1975 to 2010.

MATERIALS AND METHODS

Study area: Islamabad Capital Territory was divided into five major zones i.e. I, II, III, IV, and V with an area of approximately 906 km^2. The population of the area is increasing constantly. In 2015 the population of Islamabad was estimated to be approximately1.36 million as compared to 0.188 million in 1998 (Durrani, 2015). As shown in figure-1 the study area has very variable topography having plateau like Margalla hilly and plain regions in the urban environments.

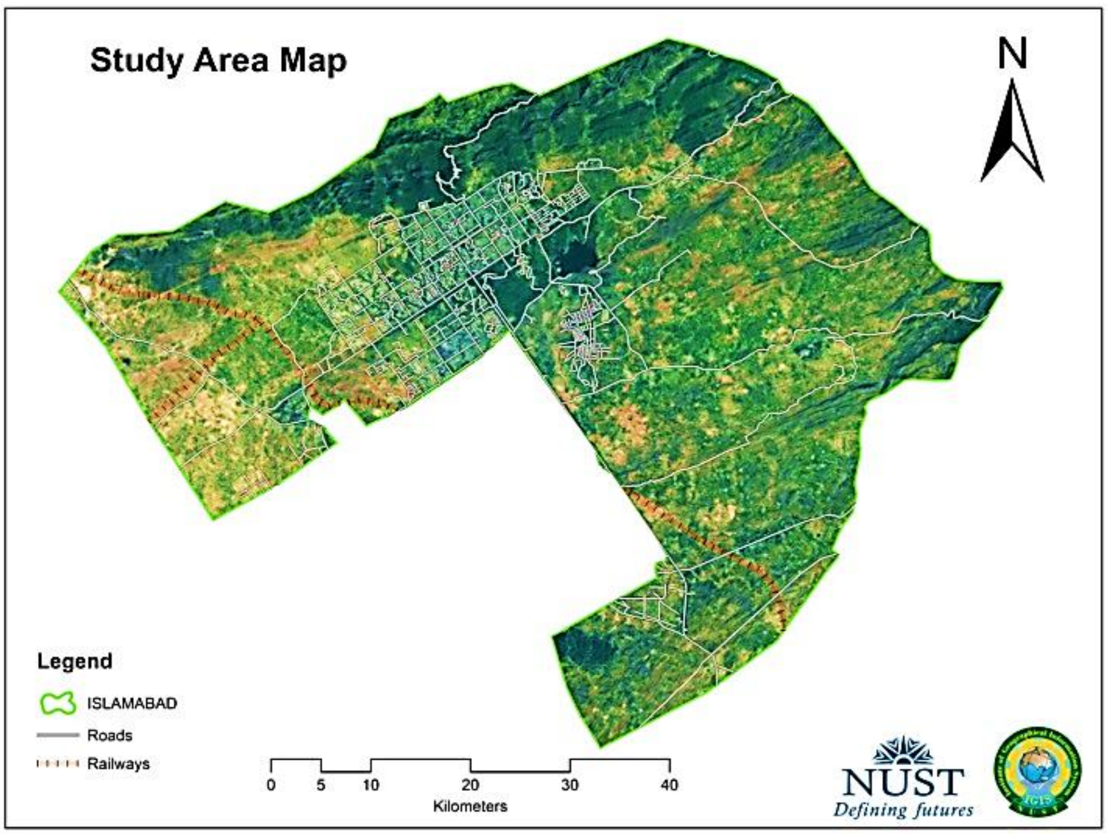


Figure-1.Islamabad Capital Territory the study area.

Data collection and preparation: The detailed flow chart of the methodology is presented in figure-2. The cloud-free Landsat satellite data for the months of March/April forthe years 1975, 1979, 1992, 1998, 2005 and 2010 of three different sensors including Multi Spectral Sensor (MSS), Thematic Mapper (TM) and Enhanced Thematic Mapper (ETM+) were downloaded and used to assess land cover changes and urban expansion in Islamabad. Landsat TM and ETM+ sensors had seven spectral bands from visible to thermal infrared. The downloaded raw images were stacked and then were subset to Islamabad as area of interest (AOI).

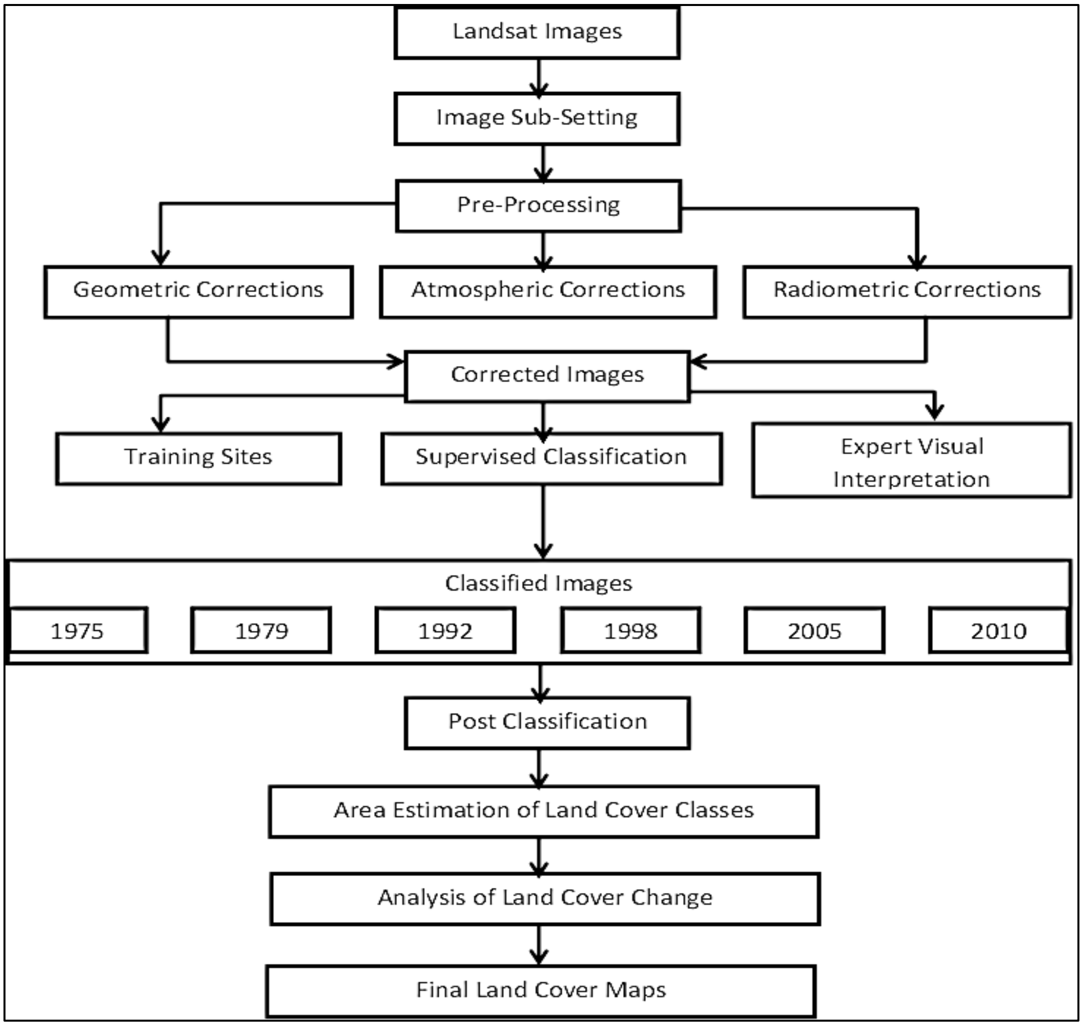


Figure-2. Flowchart of research.

After sub-setting the data, pre-processing was done to refine the satellite imagery before carrying out detailed analysis. Pre-processing of satellite images included geometric, atmospheric and radiometric corrections. Unprocessed remotely sensed imagery mostly had geometric errors creating primarily from the remote sensing platform, sensor itself, upper atmosphere and speed and rotation of earth (Jensen, 1996). The atmospheric corrections were calculated for each Landsat image using ATCOR-model. The classification system proposed by Anderson and Anderson(1976) was used to conduct this study with four major levels 1 classesas shown in table-1.

Table-1. Land cover classification scheme.

Land Cover Class	Description
Vegetation	Crop fields, pasture, bare fields, deciduous forest land, evergreen forest land, mixed forest land, orchards, groves, vineyards, and nurseries.
Water	Permanent open water, lakes, reservoirs, streams, bays and estuaries
Soil	Exposed, undeveloped and barren land
Urban Area	Residential, commercial services, industrial, transportation, communications, industrial and commercial, mixed urban or build-up land, other urban or built-up land

Supervised classification scheme was used to develop the land cover classes as mentioned in table-1. Generally classification means to allocate a number of pixels in an image to definite class as per the characteristics of that particular class. In terms of database language one could say the feature space was segmented into various parts. The feature space for single pixels was defined by the spectral information which included the multispectral bands of the Landsat imagery as has been reported by (Huth *et.al.,* 2012).

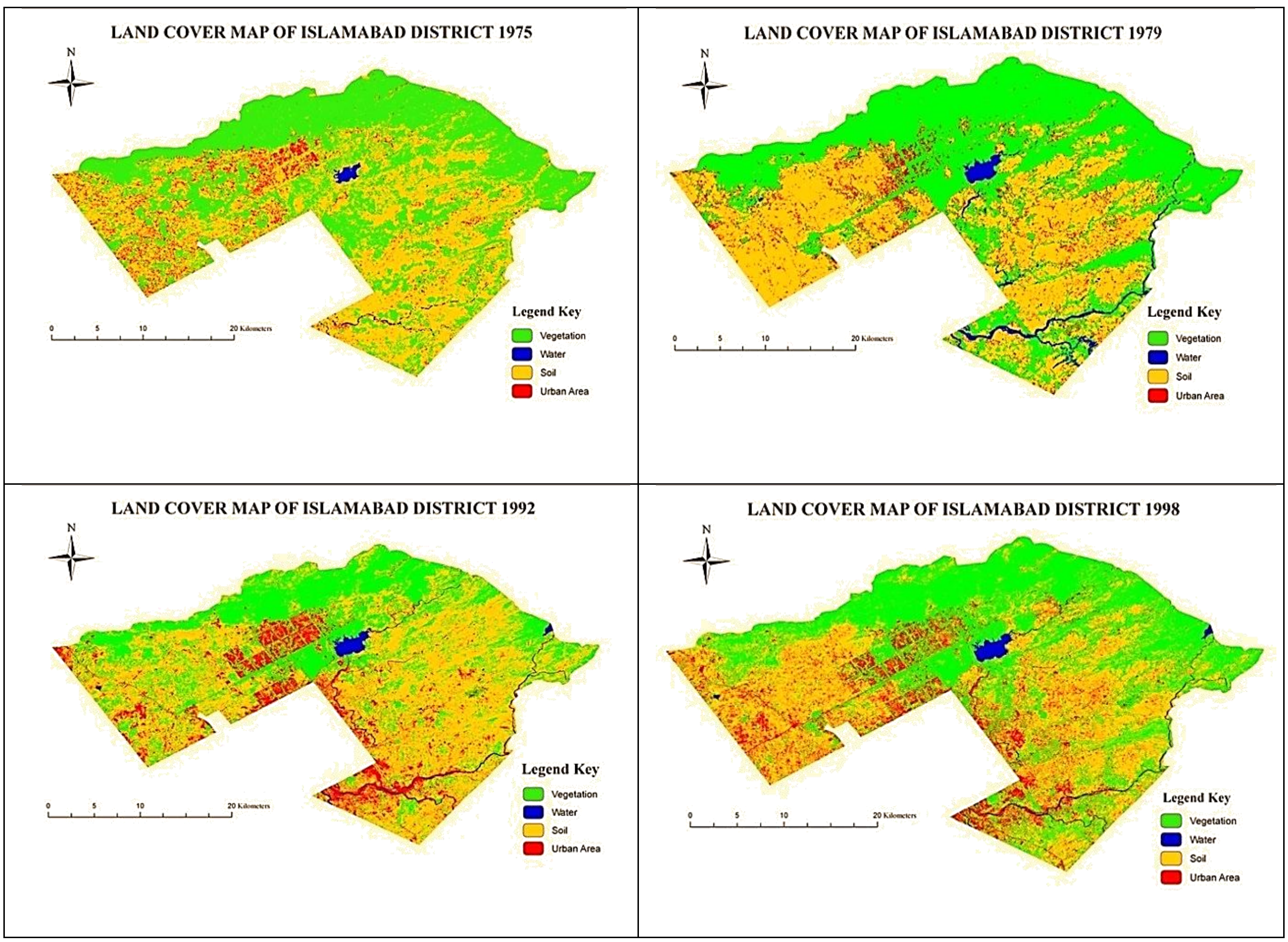
Spectral and spatial profiles of all Landsat images were studied to determine the reflectance values of pixels. These were the reflectance values that represented various land cover classes. On the other hand visual interpretation of satellite images was done based on elements of visual image interpretation. Training samples were selected from the satellites data and a total of ninety to one hundred training sites, ranging in size from 250 to 8000 pixels, were used to train the images.

The final spectral signatures created based on training sites were then refined after evaluation of the class histogram and statistical parameters and Signature Alarm utility. Basically this utility highlighted the pixels in the Viewer that belonged to, or were estimated to belong to a class according to the parallelepiped decision rule.

A hard classifier such as maximum likelihood classification (MLC) was used since they direct the pixels to a particular class only in a binary manner i.e. thereby assigning a membership of 1 or 0 to the pixels, expressing whether a pixel belongs to a certain class or not. Maximum likelihood classification (MLC) algorithm, formerly verified to get the best results from remotely sensed data if each class had a Gaussian spread was then applied to each image (Bolstad and Lillesand, 1991). Classes of the resulting image were recoded into the four major land cover classes. The overall accuracy of classified images of 2010 was 77%.

RESULTS AND DISCUSSION

Land cover maps: The land cover of Islamabad observed for the years 1975, 1979, 1992, 1998, 2005 and 2010 are presented in Fig-3, which included the major classes of soil, urban area, vegetation and water.



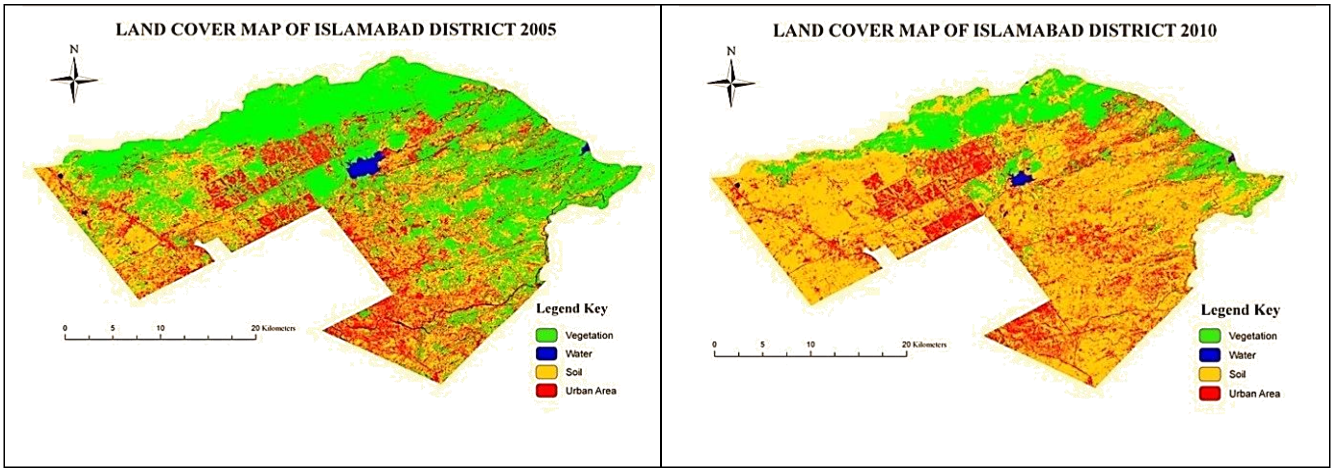


Figure-3. Temporal (1975-2010) change in the landcover of Islamabad.

The detailed statistical analysis of landcover classification is discussed below. The table-2 shows the absolute area and percentage coverage of each landcover class in Islamabad from 1975 to 2010. The similar kind of statistics was also observed by (Shaheen,., *et al*.,2015). A study conducted by Rujoiu-Mare, M. R (2016) also concluded that vegetation decreases over the time as the city expands. By monitoring urban land cover change the satellite image pixels can be reclassified using logical decision rules into different classes. (Stefanov *et al.*,2001).

Table-2. Absolute area (sq. km) and percentage of different land cover classes in Islamabad.

Year	Soil		Urban Area		Vegetation		Water	
	Area	%	Area	%	Area	%	Area	%
1975	380	42	50	6	465	51	11	1
1979	374	41	81	9	430	47	21	2
1992	440	49	106	12	346	38	14	2
1998	412	45	154	17	330	36	10	1
2005	371	41	237	26	290	32	8	1
2010	414	46	332	37	145	16	15	2

Classification statistics: In 1975, the dominant feature of vegetation was 51%whereas the extent of the soil, urban area and water was42%, 6% and 1% respectively of the total area of Islamabad during the year. For the year 1979 the trend of vegetation and soil was towards the lower side with the decrease in areal coverage of about 4% and 1% respectively, while an increasing trend was found in the water and the urban land cover which was approximately 9% and 2% as compared to previous year. The soil coverage was about 41% and area of water was 2% and are increase of 1% was not as compared to the year 1975. The features variation for the year 1992 was found to be having a gradual decrease of vegetation and increase in the urban development as compared to the year 1979. In 1992 the total area of vegetation, urban area, water and soil were 38%, 12%, 2% and 49% respectively. The soil, urban area and vegetation areas calculated for the year 1998 were nearly 46%, 17% and 36% respectively. These evaluated land covers showed an increase in the spread as compared to year 1992. The amount of water calculated in 1998 was nearly 1% (figure-4).

Vegetation: During the time span of 1975 to 2010 (35 years) there was a decreasing trend of vegetation in Islamabad. In 1975, the vegetation was about 465 Sq. Km. which decreased gradually and reached to the value of 145 Sq. Km. A sudden decline was found from 2005 to onwards. The same effect has also been observed by (Shaheen *et al.*,2015).Prominent change in the areal extent was also observed with the decline of area of vegetation up to 320 Sq. Km. Approximately 35% vegetation area shrank during the last 35 years i.e. from 1975 to 2010 as is shown in figure-5.

Urban Area: Since 1975 to 2010 a prominent areal expansion of urbanization was found with an increase in population from 95,940 to 1.70 million for the years under study as has been reported by (Government of Pakistan, 1998 and 2007). The urban sprawl was about 50 Sq. Km in 1975 and it reached to 332 Sq. Km. in

2010(figure-6) A study conducted in 2016 showed that urbanization was increasing at an alarming rate in twin cities of Pakistan (Adeel*et al.*,2016). The main reason is the economical opportunities present there.

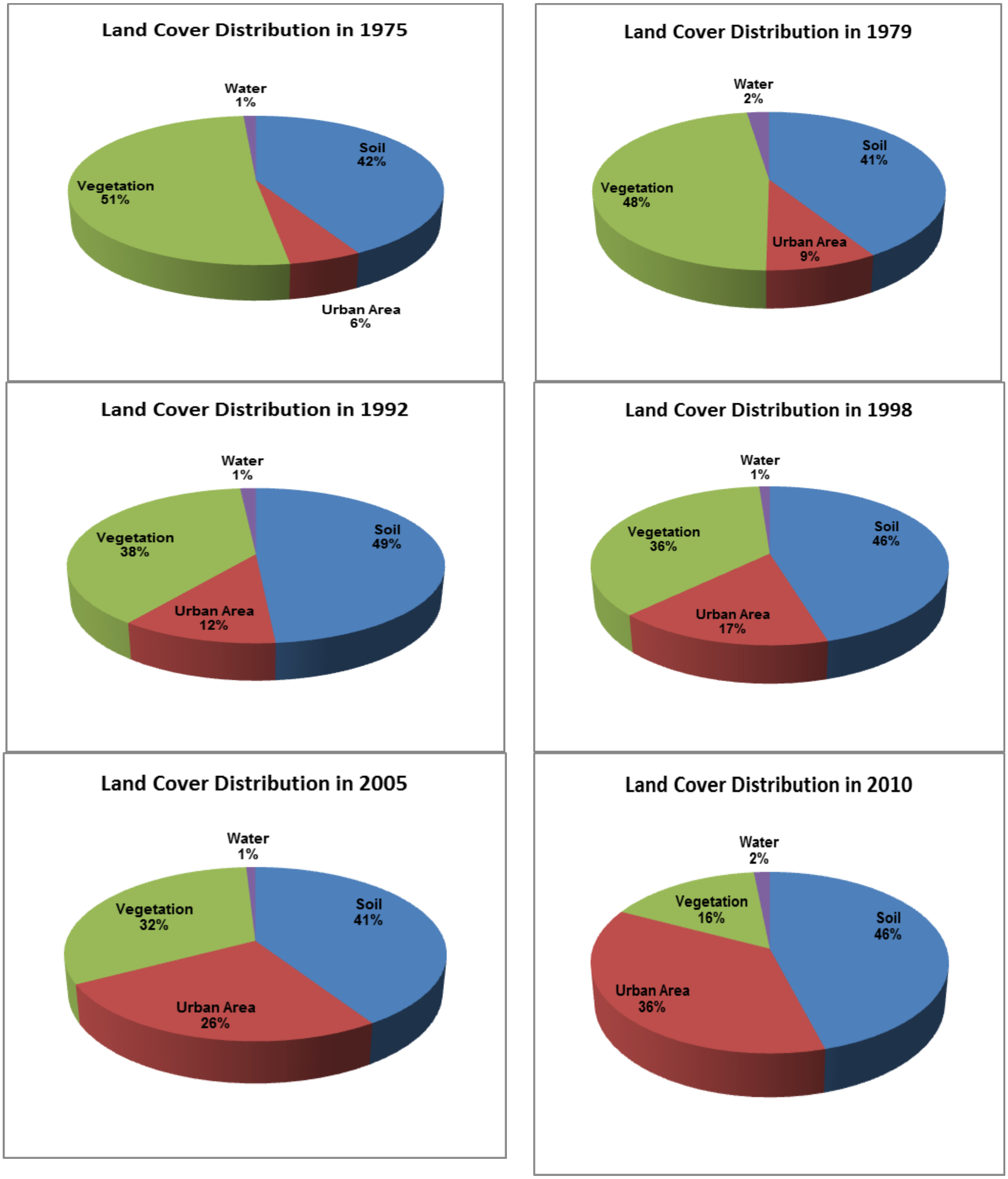


Figure-4. Temporal variations in landcover of Islamabad.

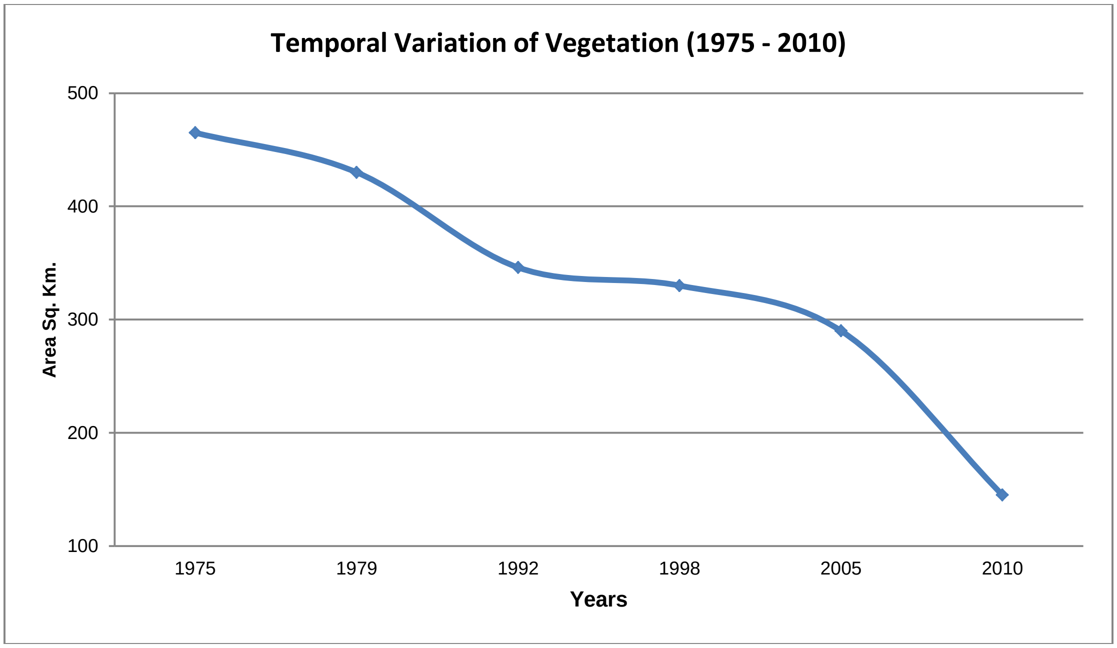


Figure-5.Temporal variation in vegetation landcover of Islamabad.

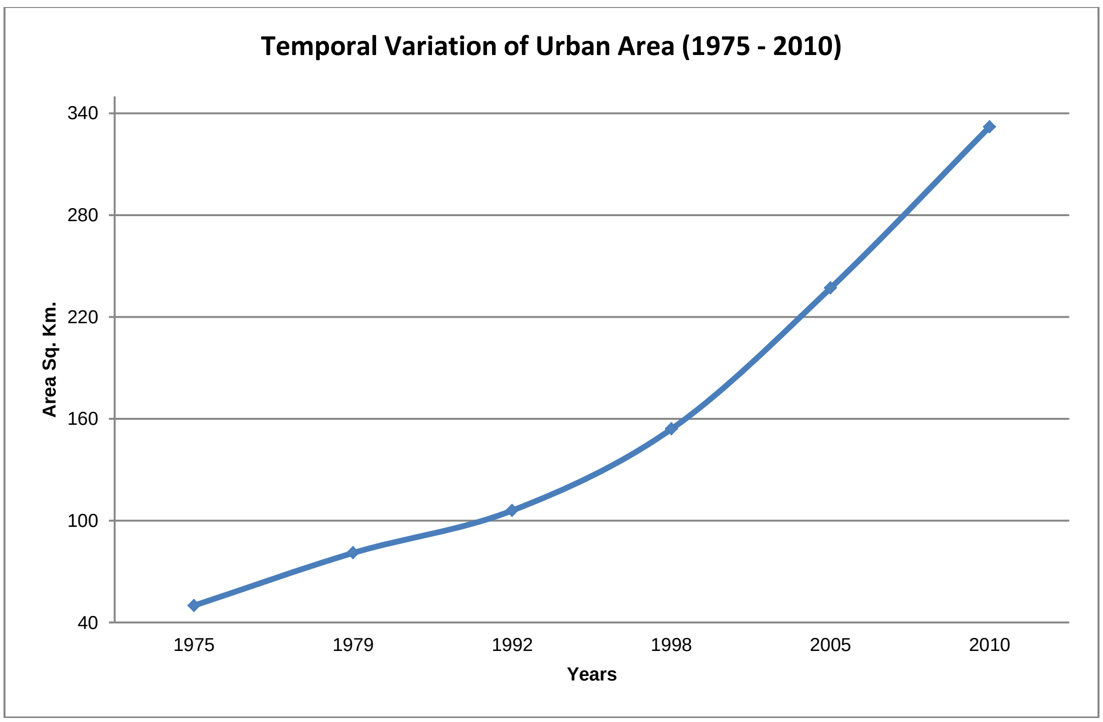


Figure-6. Temporal variation in urban area landcover of Islamabad.

Soil: Fluctuation was found in the trend of soil of Islamabad during the temporal window of 35 years from 1975 to 2010. The area of soil evaluated was 380 Sq. Km. in 1975 and it reached to its extremity in 1992 with an aggregate of 440 Sq. Km. and a decline was noticed in the next 13 years with the shrinkage in area of about 69 Sq. Km. and reached to 371 Sq. Km. in the year 2005. The area of soil decreased to 414 Sq. km. after the decline in 2005. However an increasing trend was observed during the last 5 years as shown in figure-7. The reason could be sectors development at Islamabad has been highlighted (Butt *et al.*,2015).

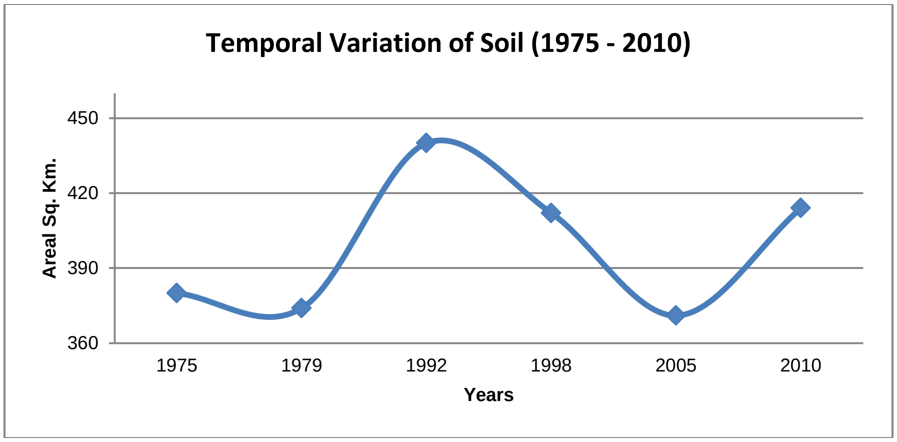


Figure-7. Temporal variation in soil landcover of Islamabad.

Water: Crest and trough was observed in the pattern of land cover water on which the lives of people were dependent. Water does not follow the linear pattern. The total area was 11 Sq. Km. in 1975 and an increase of approximately 21 Sq. Km. was found during the last 35 years. After that it followed a downward trend decreasing to about 8 Sq. Km. This trend of water can be related to the anomaly of precipitation and temperature variations of upper Indus where the precipitation was high and the temperature was too low so the water from snow melt could not reach to water reservoirs. There was an increasing trend in the water after 2005 and extended to 15 Sq. Km. area in 2010 as is shown in figure-8. This increase could be associated with the heavy rainfall in year 2010 across whole Pakistan (Lau*et al.*,2012 and Atif *et al.*,2016).

Comparison of Land Cover Dynamics: Areal change of land covers of Islamabad was analysed during different periods of time i.e. from 1975 to 1992 and from1992 to 2010 to observe the overall land cover dynamics during the time span of 35 years. Soil and water showed a fluctuating pattern of rise and fall in coverage of soil over different time periods. The analysis done during 1992 to 2010 gave downwards trendin soil, the same pattern was observed by water. The urban area and vegetation also followed the same trend. Overall an increase in urban area and decrease in vegetation was responsible for this trend. Summary statistics of the correlation of each land cover ispresented in table-3

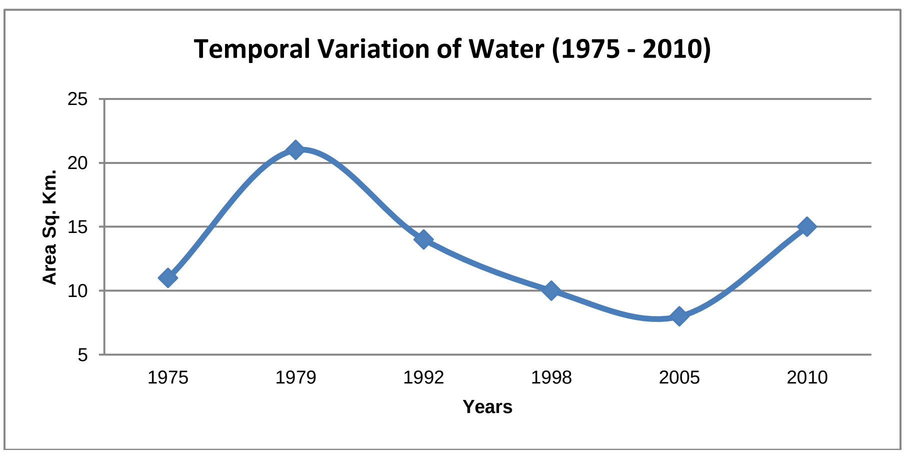


Figure-8.Temporal variation in water landcover of Islamabad.

Table-3. Correlation between all landcover classes of Islamabad.

Land Covers	Soil	Urban Area	Vegetation	Water
Soil	1			
Urban Area	0.149	1		
Vegetation	-0.385	-0.969	1	
Water	0.016	-0.198	0.142	1

Significant relation was found between vegetation and urban area. An increase in urban area resulted in the decrease in the vegetation. Graphical representation of each land cover with the other is shown in figure-9. All the land covers were very low correlation with each except for the urban area and vegetation.

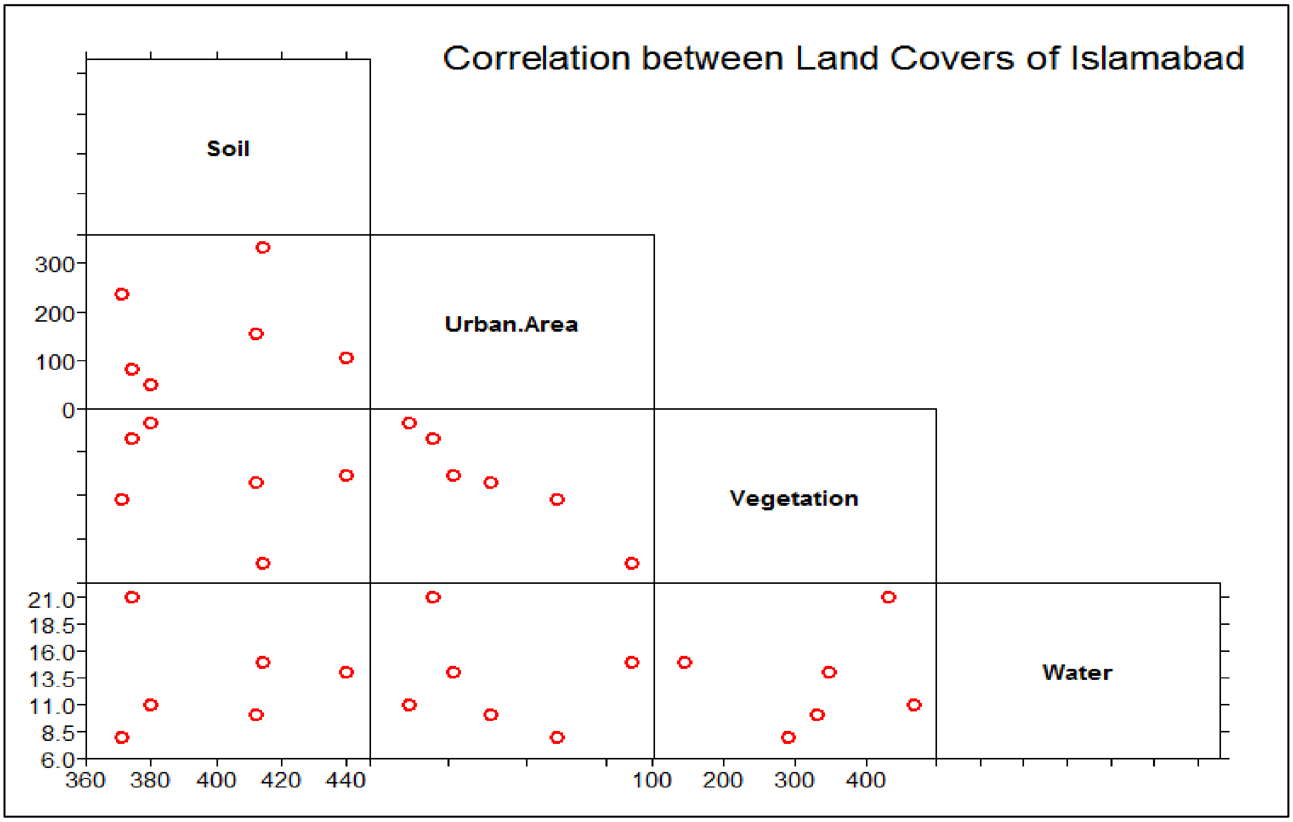


Figure-9. Summary statistics of landcover of Islamabad.

Conclusion: Vegetation cover in Islamabad is decreasing as the urbanization is increasing at alarming rate. There is a general association between vegetation and urban area of Islamabad with each other, the increase in urbanization due to over population lessens the natural resources. In Islamabad the opposite trend was observed during the temporal window from 1975 to 2010 for the urban growth and important land cover vegetation whose importance could not be ignored in any age in any community as in figure-10. The census records shows that the population of Islamabad has grown from 95,940 in the year 1951 to 1.70 million in 2011.

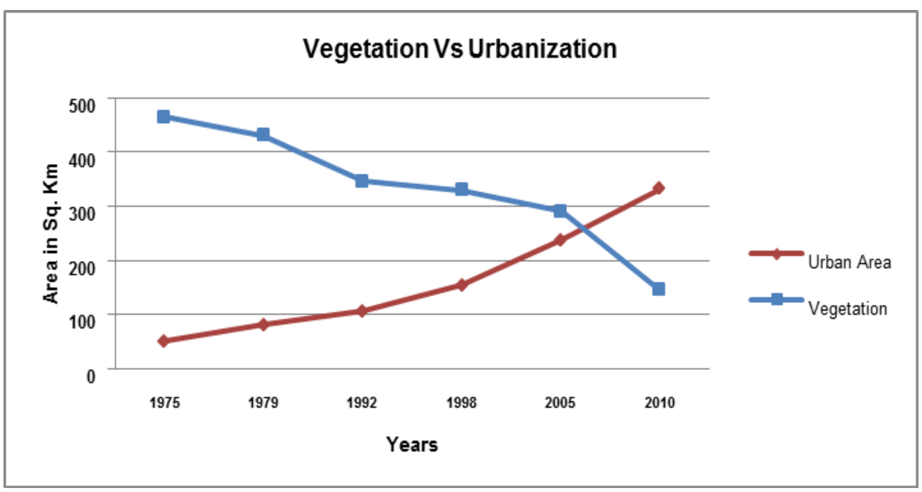


Figure-10.Trend of Vegetation and Urbanization in Islamabad.

In 1975 the area of vegetation was found to be 465 sq. km. while the urban area was about 50 sq. km. An increasing trend was noticed in the urbanization with the decrease in the vegetation from 1957 to 2010. The areal extent of vegetation was found to decline with the amount of 320 sq. km. whereas the expansion of urbanization was about 282 sq. km. during the time span of 35 years from 1975 to 2010.

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