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Spatio-Temporal Analysis of Land Cover/Land Use Changes Using Geoinformatics (A Case Study of Margallah Hills National Park)

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Abstract

In order to make any strategy for management of National Park, it is necessary to understand the dynamics of land use/ land cover changes .Remote Sensing and GIS have significant magnitude for analysis of spatial extent and temporal changes of land cover/land use in urban and regional planning studies. The objective of the present research is to identify the nature, extent and spatial pattern of land cover changes during 1997-2008 in MHNP Islamabad through high resolution satellite imagery .The Normalized Difference Vegetation Index (NDVI) and Maximum Likelihood Classification (MLC) algorithms are used to determine the vegetation cover and spatial extent of different land use/ land cover classes of the study area respectively. The second objective of this research is to find the spatial distribution of exotic species based on different environmental factors through decision tree classification method. Results show that vegetation cover declines during 1997-2008 and vegetation health is affected by the presence of these exotic species, because these species are not suitable to local ecosystem. About 2.5% area of the NP is occupied by Paper Mulberry (Broussonetia papyrifera) and 9.4% by Punch Phali (Lantana camara).The results provides the effective analysis of land cover of National park which might be helpful in efforts towards the conservation of this ecological heritage site.

Keywords: National Park, NDVI, Supervised Classification, Decision Tree Classification, Landcover, Landuse

1. Introduction

"The environmentalists have urged the federal government to announce a comprehensive plan for future sustainability of the Margalla Hills National Park with an aim to convert it up to the level of world-class national parks". (The News, 14th Oct, 2013). Margallah Hills National Park Islamabad consists of natural resources that highly contribute to its ecology. Its environment make a pleasant place with its own unique beauty to admire, may be scenic, waterfalls, mountains and wildlife[1]. Islamabad, the capital has witnessed a remarkable expansion, growth and development activities such as buildings, road constructions, deforestation and many other similar anthropogenic activities in last decade, resulted in increased land consumption. Without any appropriate management, this protected area can be deteriorated. Prime objective of this research is the interpretation of land cover/land use changes in Margallah Hills National Park during ten years (1997-2008) through Remote Sensing and GIS. Conventional methods of land use/land cover mapping are time consuming, labor intensive and are done relatively infrequent [2]. In recent times, the dynamics of land cover and particularly settlement expansion in the area requires a more powerful and sophisticated system such as GIS and remote sensing data

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which provides a general extensive synoptic coverage of an area than survey methods. Remote sensing is helpful in providing up-to-date information and GIS assists in making spatial database and its management +. Supervised classification method using maximum likelihood algorithm is used for landcover classification. This algorithm assumes all the pixels of same values in the image and makes them one class. Spectral signatures are taken for each class and then classification is performed on the basis of these signatures [4]. In recent years forest is the main land cover class which is affected the most as result of urbanization and other land use practices. Vegetation cover has been decreasing rapidly due to change in land covers / land use [5]. One of the methods which is used to determine the vegetation cover is NDVI (Normalized Difference Vegetation Index), measures the reflectance in red and infra-red bands of electromagnetic spectrum for vegetation +. Presence of invasive species in Margallah Hills National Park is an important factor that has been taken into consideration in this research while determining its vegetation cover. These species grow vigorously as they get favorable condition and ultimately affect indigenous ecology. Spatial distribution of plant species is now possible with high spatial and spectral resolution image in very short time and with accurate results [6].

1.1 Study Area

Study Area is Margallah Hills National Park, Islamabad (Figure 1). It comprises of hill ranges, north of the Federal Capital of Islamabad at 33°48'N longitude and 73°10'E latitude. Area of national park is 19,386 hectares. Its elevation ranges between 456m and 1,580m.

2. Materials & Methods

SPOT-5 pan sharpener image (2.5m resolution) is used to identify the spatial distribution of invasive species while multispectral images (20m resolution) of three different time periods i.e.1997, 2003, 2008 are used for determining the nature, extent and spatial patter of changes occurred in land cover/land use of MHNP Islamabad. Digital Elevation model (DEM) of the study area having 15m resolution is generated from stereo pairs of ASTER image, thus obtained data for slope, aspect and elevation. Spatial distribution of two invasive species is determined by recording 10 Ground Control Points (GCPs) for each species in the study area through Global Positioning System (GPS). Software used in this study is ERDAS IMAGINE 9.1, Arc GIS 9.2, Microsoft Excel, Microsoft Access database.

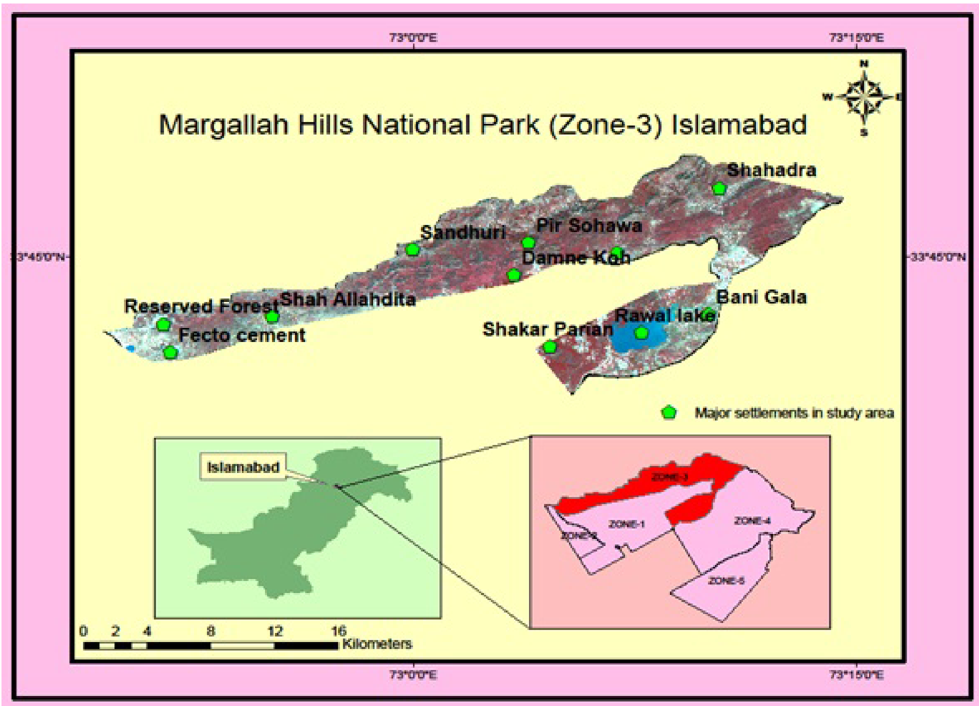

Figure 1. Map of study area (Margallah Hills National Park-Zone 3, Islamabad).

2.1 Land Cover Classification

For vegetation recognition, false color composite is generated by combing near infrared, red and green bands of SPOT-5satellite images[8]. Supervised classification using maximum likelihood algorithm is performed on images of 1997, 2003 and 2008 and six resultant classes are produced namely: dense shrubs, less dense shrubs, cropland/ grassland, built-up area, bare surface and water body. NDVI is calculated as a ratio of red and near infrared bands of a sensor system as in Eq.1.[9]

$$NDVI= (NIR- R) / (NIR+ R) \quad (1)$$

NDVI values range from -1.0 to 1.0. NDVI values between -1.0 and 0 represents non- vegetative features such as bare surface, built- up area and water body. Conversely, greater than 0 displays vegetation cover. NDVI of three images are crossed in Arc GIS environment to find out the changing pattern of vegetation during 1997-2008.

2.2 Spatial Distribution of Invasive Species

Ground Control Points (GCPs) are collected with the help of GPS (Global Positioning System) in the field. Signature files are made from these GPS points, obtained spectra of each tree species [10]. The spectral points now called as signatures, are used to train the computer to recognize the both species on SPOT image. The signature file contains mean and standard deviation of each sample [11]. A decision tree is a multistage classifier that can be applied to a single image or a stack of images. It is made up of a series of binary decisions that are used to determine the correct category for each pixel. The decisions can be based on any available characteristic of the dataset e.g. NDVI values, slope, elevation, aspect and spectral range etc. (Decision Tree Classification, ENVI Tutorial). The following datasets are used for identification of two species and their criteria are given in Table 1.

- Digital Number value range of each band found from the overlapping of GPS field data on SPOT image for every tree species selected for the study.
- NDVI value range of each
- Slope of the area derived from DEM
- Aspect of the study area for delineating aspects at which particular species lie, derivedfrom GPS field data and forestry knowledge.
- Elevation of the study area and knowledge of tree species and their occurrence at certain elevations

Criteria set by author for recording GPS points of both invasive species are as following:

- 10 GCPs for each species is recorded.
- The site selected for taking GCPs must have a minimum width of 5m having same species (covering a single pixel of SPOT 2.5m).
- Surrounding area should be preferably of the same species area.

These points are overlaid on image and decision tree classification is adopted to determine the spatial location of invasive species in MHNP.

3. Results & Discussion

3.1 Land Use/ Land Cover Distribution

Results of supervised classification using maximum likelihood algorithm of three images of 1997, 2003 and 2008 are shown. (Figure 2, 3, 4)

It can be seen that in year 1997, dense vegetation is the dominating class and occupied 56% , less dense vegetation 23%, cropland/grassland 9.3%, built-up area 5.84%, bare surface 3% and water 2.22% of total area of national park.

Figure 3 shows that dense vegetation is also dominating class in 2003 and occupied 54%, less dense vegetation 21.1%, bare surface 8.5%, built-up area 7.3%, grassland/ cropland 5.8% and water inhabit 1.4%.

In 2008 percentage area occupied by each land cover/ land use class is as following: vegetation 42.4%, less dense vegetation 20.9%, bare surface 19%, built- up area 9.62%, cropland/grassland 4.65% and water 2.51%.

Table 1. Criteria for Decision Tree Classification

Species	Elevation	Slope	Aspect	NDVI	Band 1	Band 2	Band 3	Band 4
Lantana camara	360-782	>26%	NE,E,SE,S	0.15-0.30	26-42	9-27	16-36	17-36
Paper Mulberry	360-624	>26%	SE,S,SW	0.27-0.40	26-32	8-12	14-19	18-32

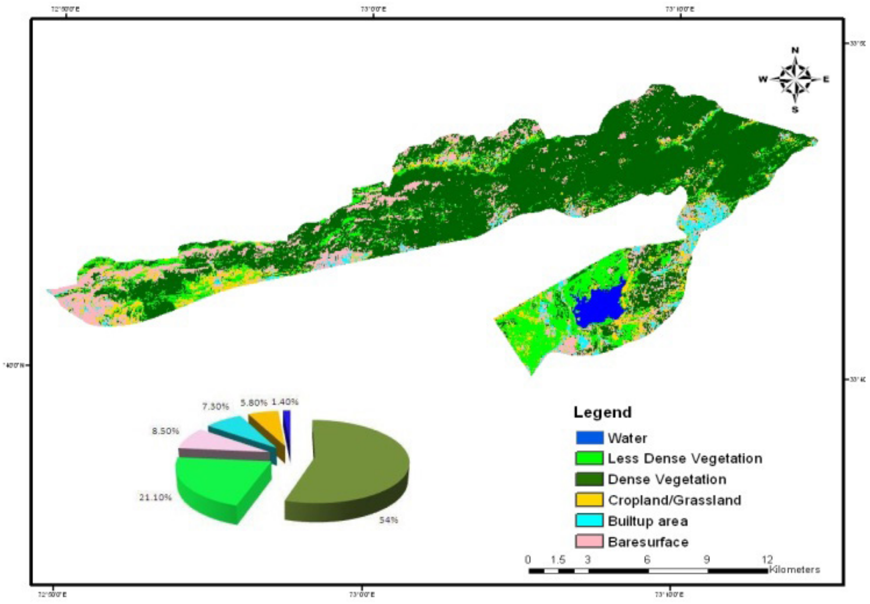

Figure 2. Supervised Classification Map of MHNP in 1997.

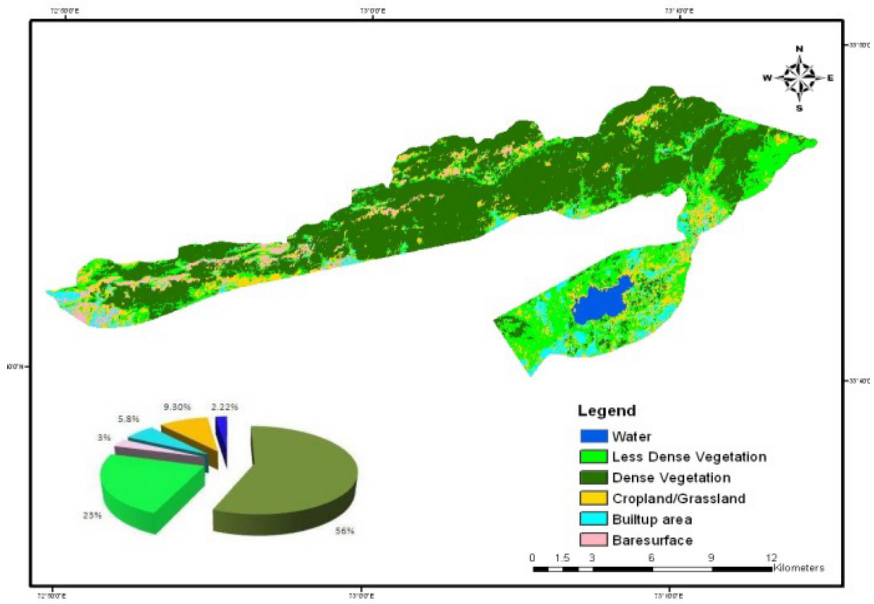

Figure 3. Supervised Classification Map of MHNP in 2003.

3.1.1 Area Calculation

Percentage change in each land cover type during 1997-2008 is calculated by using following formula (Eq.2)

$$\text{Area in percentage} = \text{area of each land cover type} / \text{total area} * 100 \quad (2)$$

This is later used to calculate the trend, rate and magnitude of change in each land cover type. Area under each land cover class and their percentages are presented (Table 2). In obtaining annual rate of change, the percentage change is divided by 100 and multiplied by the number of study years 1997 – 2003 (5years) as shown in Eq. (3).

$$\text{Annual rate of change} = \text{percentage change}/100 * \text{Number of study year} \quad (3)$$

Percentage change with five years interval and annual rate of change is presented in Table 3.

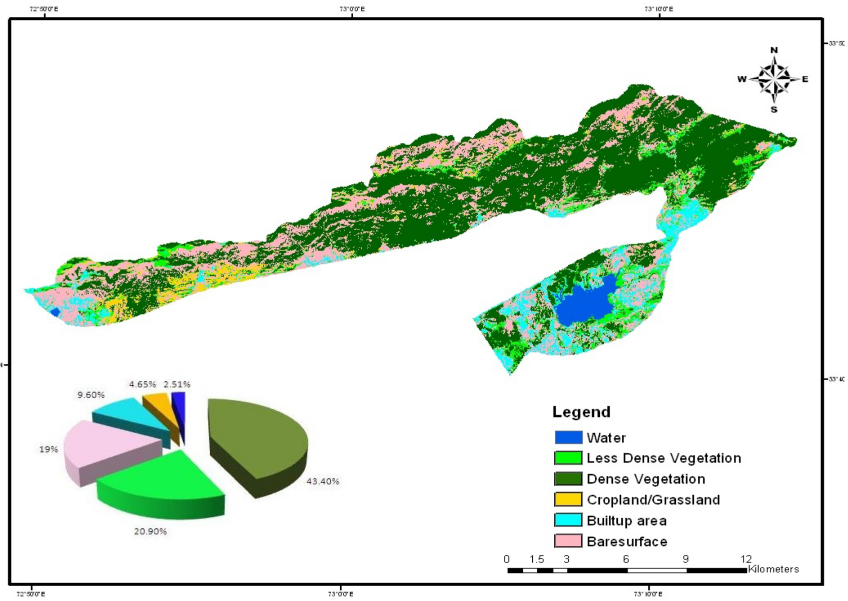

Figure 4. Supervised Classification Map of MHNP in 2008.

Table 2. Spatial Extent of Each Land cover Class During 1997-2008

Land cover type	1997		2003		2008	
	Area (ha)	Area %	Area (ha)	Area%	Area (ha)	Area%
Dense vegetation	10927	56	10519	54	8469	43.4
Less-dense vegetation	4457	23	4130	21.1	4076	20.9
Bare surface	718	3	1667	8.5	3669	19
Built up area	1140	5.84	1427	7.3	1882	9.6
Grassland/ Cropland	1820	9.3	1471	5.8	907	4.65
Water	433	2.22	281	1.4	492	2.51
Total	19495	100	19495	100	19495	100

Table 3. Annual Rate of Change of Each Land Use/Land Cover Class (1997-2008)

Land use/Land cover type	1997-2003		2003-2008		Annual rate of change (%)	
	Area(Ha) change	% change	Area(Ha) change	% change	1997-2003	2003-2008
Dense vegetation	-408	-2.0	-2050	-10.5	-0.1	-0.52
Less dense vegetation	-327	-1.67	-54	-0.2	-0.08	-0.01
Bare surface	949	4.8	2002	10.2	0.24	0.51
Built up area	287	1.46	455	2.33	0.07	0.1
Grassland/Cropland	-349	-1.8	-564	-2.9	-0.09	-0.14
Water	-152	-0.7	211	1.08	-0.03	0.05

The comparison of all land cover classes showed that dense vegetation, less vegetation and cropland/grassland decreased while bare surface and built-up area increased during the study period. This decline of vegetation is less from 1997 to 2003 as compare to next five years. Bare surface and built up area increased more rapidly from 2003-2008. As the study area consists of national park so dense vegetation class is the dominating class. Water body took up the least percentage among all classes. Built-up area in 1997 is less than built-up in 2003 and 2008. It seems that before 1997 human intervention in National Park area was less although some settlements were there and people had their own fields, cropland and grassland.

Farming seems to be practiced more in 1997 in study area; therefore grassland/cropland occupies an area of 1820 hectares at that time and later on it decreases. After 1997 roads are constructed, anthropogenic activities increases; as a result people migrates from far off places to this zone. Increased human intervention, land clearing, deforestation, grazing pattern, illegal cutting, mining activities are the major factors that results in decreased vegetation cover from 1997 to 2008. Water body shows fluctuation during whole study period. Water body occupies less area in 2003 than in 1997, because 2003 image is taken in June and in summers evaporation rate is high whereas images of 1997 and 2008 are of winter season. Water body decreases in 2008 again because more built up area results in high rate of runoff due to which localized ponds are generated in the study area which can be clearly seen in 2008 image.

3.2 Normalized Difference Vegetation Index (NDVI)

The results of NDVI performed on three images i.e. 1997, 2003& 2008 are shown in Figure 5, 6, 7.

In 1997 area under vegetation cover is 16365 ha while non-vegetation is 2931 ha

In 2003 vegetation cover is reduced to 15697 ha and non-vegetation is expanded to 3598 ha

NDVI map of 2008 shows area under vegetation cover is 15444 ha and under non-vegetation is 3905ha

Comparison of vegetation cover calculated from NDVI and maximum likelihood methods are presented in Table 4.

Comparison shows that there is no major difference between the two methods. The selection of method depends upon the objective of the study. NDVI gives best results when vegetation cover of large area has to be calculated, and it provides synoptic coverage of vegetation. Supervised classification is the best suitable method for detailed study of different vegetation up to species level

3.3 Identification of Invasive Species

Spectral profile gives digital numbers (DN) values of every GCP collected in the field. On the basis of digital number (DN) values of pixels in the image, location of

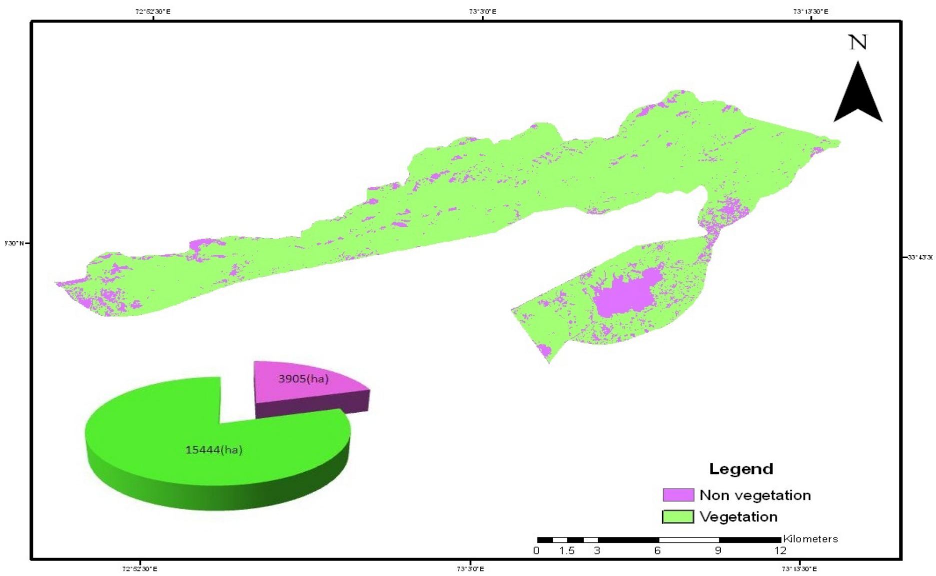

Figure 5. NDVI Map Derived from SPOT Image 1997.

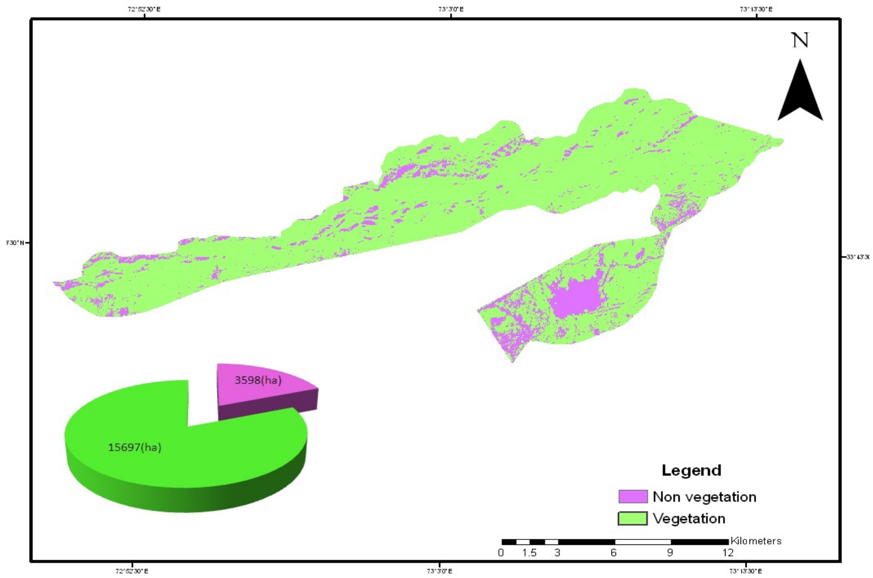

Figure 6. NDVI Map Derived from SPOT Image 2003.

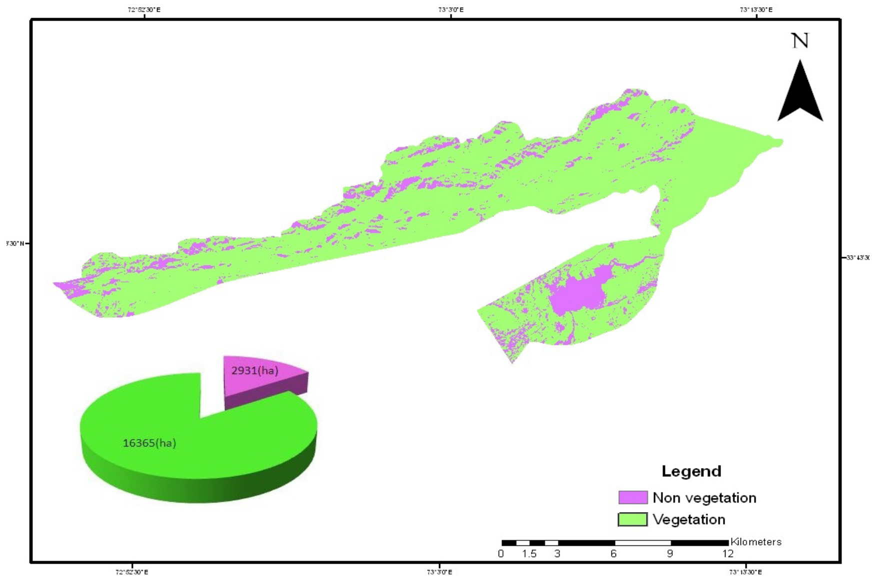

Figure 7. NDVI Map Derived from SPOT Image 2008.

Table 4. Comparison of Vegetation Cover Calculated from Two Methods

Year	Vegetation area(ha)		Difference between two methods
	NDVI	Maximum likelihood	
1997	16804	17204	3%
2003	15697	16120	3%
2008	14390	13452	6%

species were identified. The range of DN values for both species are presented (Figure 8 & Figure 9).

Location of GCPs for both paper mulberry and lantana camara are shown (Figure 10).

Figure 11 shows spatial distribution of these two species after decision tree classification method. Area covered by paper mulberry was approximately 492 ha and by Lantana Camara was 1836 ha

Results show that both the invasive species are found at lower elevation ranging from 360-624 and from 624-782m. Species have almost same habitat. Both are found on low slopes. Paper mulberry is found on southeast, south, southwest ward aspect while lantana camara is on northeast, east, southeast and south faced aspect. Area covered by paper mulberry is approximately 492 ha (2.54%) and by Lantana camara is 1836 ha (9.4%).

3.3.1 Accuracy Assessment

Accuracy assessment is carried out for decision tree classification method by taking half of the GPS point data of tree species collected in field survey. This data is used as reference for checking the accuracy results of the decision tree classification method applied by using ERDAS imagine software. All the points are taken as an input by making an Excel file and importing it into ERDAS imagine as user defined points. The Excel file consists of geographic locations in meters along with the tree species. The overall accuracy and Kappa report of decision tree classification method is 75% and 0.79%.

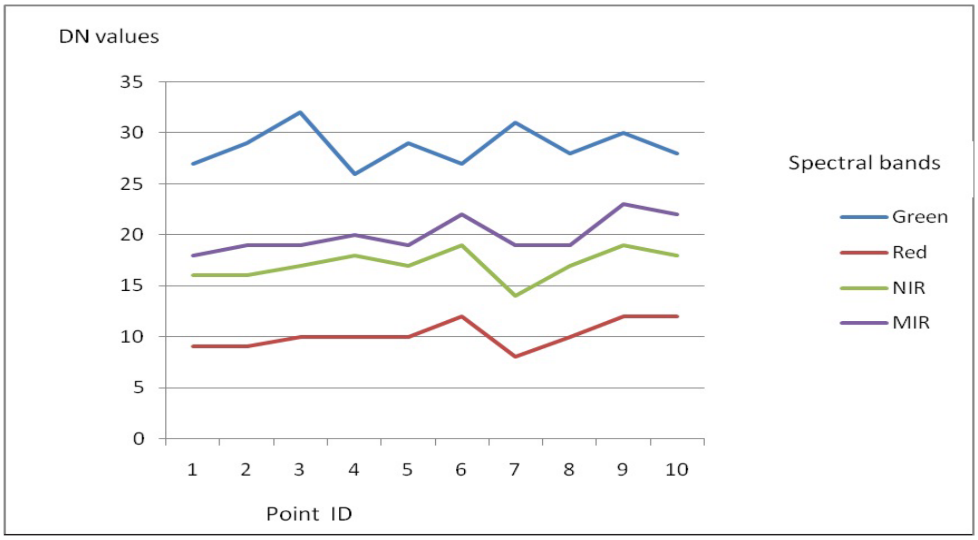

Figure 8. Variation of Mean DN Values of Paper Mulberry with Four Spectral Bands of SPOT image.

Figure 9. Variation of Mean DN Values of Punch Phali with Four Spectral Bands of SPOT image.

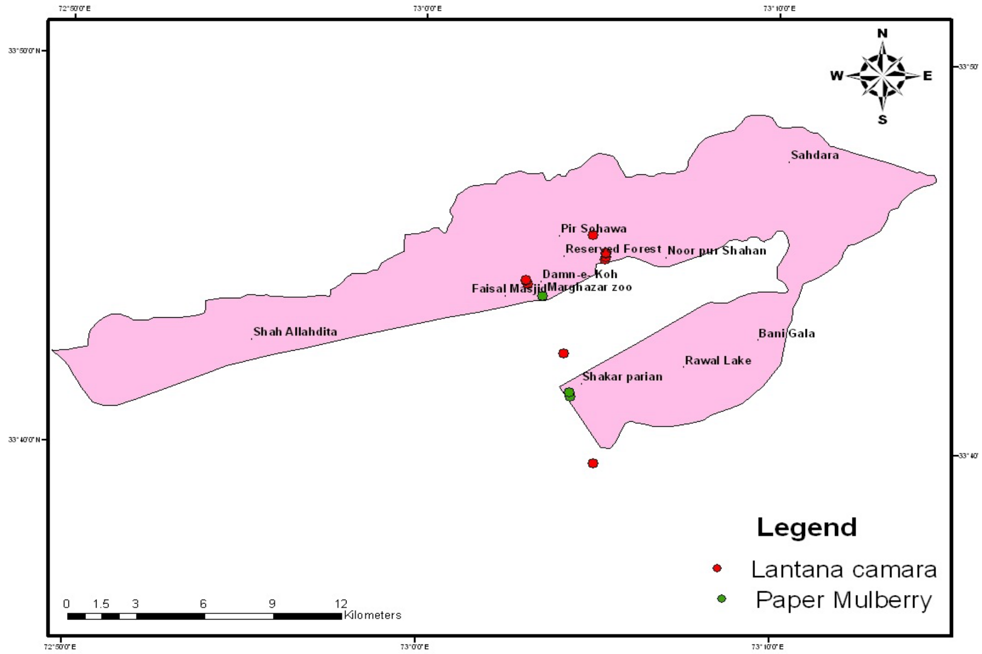

Figure 10. Ground Control Points of Invasive Species in Study Area.

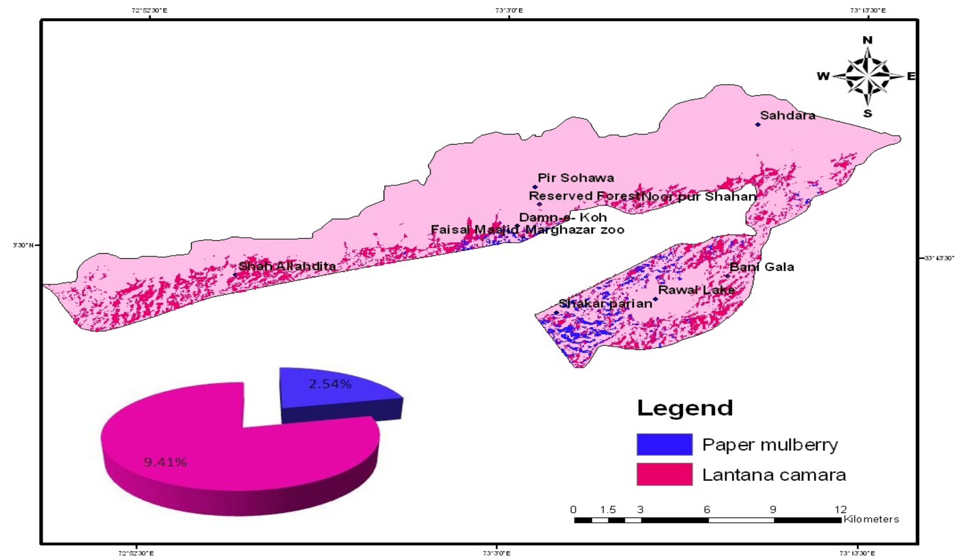

Figure 11. Spatial Distribution of Invasive Species in MHNP.

4. Conclusion

Study shows that land cover of Margallah Hills National Park zone-3 of Islamabad has been altered during ten years (1997-2008). This change can be seen more during the period of 2003-2008. LC/LU classes of built-up area and bare surface are increased during 1997-2008 while vegetation including dense vegetation, less dense vegetation and cropland/grassland are declined. NDVI results also show the reduction in vegetation cover from 1997 to 2008.Invasive species are threat for indigenous ecosystem and also affects human health. Total area of National Park is 19495 ha, out of which 13452 ha is under vegetation cover. The area covered by both species is 2328 ha. If this area is subtracted from 13452 ha (total vegetation cover) the remaining is 11124 ha which is actual vegetation cover in National Park. Vegetation covers in study area although looks good but vegetation health is being deteriorating due to these exotic species. The spatial distribution of invasive species is further used in management zoning of MHNP in the study. There is a need to develop a management plan by considering the outcome of research to conserve the national park.

5. Acknowledgement

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