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Monitoring Forest Cover Change of Margalla Hills Over a Period of Two Decades (1992-2011): A Spatiotemporal Perspective

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Abstract

Forests play a critical role in the provision of the ecological interconnectedness, and essential ecosystem services. Deforestation is a serious environmental problem throughout the world including Pakistan where a striking depletion of forest reserves has been an ecological concern for quite some time. Remote sensing techniques have been used to monitor land use and forest cover changes. The present study aims at visualizing the potential impacts of climate change and declining forest reserves on Margalla Hills National Park (MHNP). ERDAS Imagine 9.1 and ArcGIS 10.2 softwares were employed for the spatial and temporal analysis and visualization of over the past two decades. Our analysis revealed a great increase in the built-up area, barren soil and agricultural land, whereas diminishing trend is shown by the classes such as water body, lower vegetation, scrub and conifer forest. The conditions of the region are unsatisfactory and require conservation practices to be carried out in order to avoid susceptibility against ecological and socio-economic disturbances.

Keywords: Forest change; Hybrid classification; Margalla Hills, Remote sensing; Climate change

Introduction

The world's forests are under strain due to escalating natural and anthropogenic disturbances which adversely affect the ecosystem services. Despite various proposals to stop deforestation, the world continues to drop 15 million hectares of forests every year. This alarming situation has led researchers to conduct studies on the decline of forest reserves all over the world. Various researches clearly verify the potential of integrating high resolution remote sensing digital data and aerial photography for understanding changes in land-cover patterns. Temporal and spatial analysis of the forest cover has been carried out in Nepal over a period of fourteen years [1]. Management-induced changes in the forest structure have been quantified in Changbai Mountains of China using Landsat TM imagery [2]. GIS techniques have been employed and choropleth maps have been generated using ArcGIS software to draw attention to the threatened Conifer forests in Pakistan and their consequent reduction in area during the last two decades [3]. Data obtained by the analysis of the vulnerability of forests in Kenya indicating reduction in forests with a consequent increase in agriculture land are very useful to the forest department for conservation practices [4]. Primarily this study focuses on the application of Landsat TM data to monitor the forest cover and density on the hills of Margalla and to assess the changes over the last two decades. The other primary objectives were to generate and digitize cover maps of forests employing geographical information systems (GIS) and to detect the decline observed in the two main types of forests in the study area (deciduous scrub forest and coniferous pine forest) from 1992 to 2011 by using a hybrid classification-maximum likelihood algorithm. At the same time, identification and delineation of different land use categories and detection of conversions among the land use classes over two decades were also achieved. This study also provides baseline data to highlight the impacts of climate change on cover value of forests and ascertain the impacts in order to forecast the future trends. The final target was to devise a conservation strategy on the basis of results obtained.

Study area

In the present study, zone III of Islamabad was studied which covers Margalla Hills and the Rawal Lake. The Margalla Range spreads over 173.9 square kilometers of zone III which covers an area of 203 square kilometers. Margalla Hills National Park (MHNP) is located in the north of Islamabad between 33°40'01" to 33°42'43" N latitude, 72°45'01" to 72°52'32"E longitude. MHNP was first affirmed as the National Park under Islamabad Wild Life Ordinance in the year 1980 [5]. The topography of the area is rocky and furrowed, varying in elevation, where the structure of the rock is basically limestone [6]. The area falls in the far end of monsoon zone and the mean monthly 254 mm of monsoon precipitation occurs in July and August. The recorded average relative humidity for the same period varies between 59 and 67% [7]. The hottest months are May and June as the temperature then rises up to 42°C and the coldest months are December and January when temperature falls below zero [8]. MHNP is rich in 616 diverse species of flora. Although the two ecological zones are subtropical deciduous scrub forests and subtropical evergreen coniferous pine forests. The park inhabits 238 bird species, 30 mammal species, 21 amphibians and reptiles' species, 27 fish species and 39 butterflies and numerous other invertebrate species [9]. Margalla Hills are divided into three main parts being the Margalla reserve forests, military farms and area acquired by CDA [10]. MHNP populates 92,000-100,000 people living in 37 small hamlets and villages. More than half of the population (about 60%) living in the park area are practicing agriculture, animal production and marketing. They are engaged in subsistence, rain-fed agriculture yielding low supply. Wheat and Corn are the chief crops other than Sorghum (Figure 1).

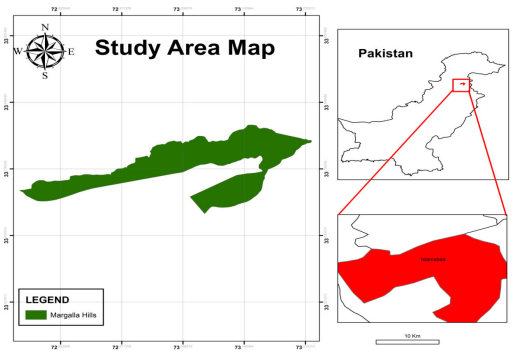

Figure 1: Location Map of the Study area.

Methodology

The data used for the study comprised of the satellite data as well as the ancillary data. The monthly meteorological data for precipitation, temperature, relative humidity and sunshine hours were acquired for the two decades from 1992 to 2011. Multi-spectral data from Landsat 4-5 TM for the years 1992, 2000 and 2011 were also retrieved. The images were first processed in ERDAS IMAGINE 9.1 software starting with stacking and reprojection. The Area of Interest (AOI) of the images was defined on the basis of the shapefile, followed by subsetting of the images to extract the AOI and elimination of areas outside the study area. For the current study the forest cover was assessed using Hybrid classification of Landsat TM data which offered the most satisfactory results. It is the type of image classification which makes use of both unsupervised and supervised approaches, thus called the hybrid classification. Subset image was allowed to pass through the unsupervised classification for self-organization of spectral clusters. If a significant cluster was absent it was added as signature file during the supervised classification. All the signatures were then appended together to form one signature file which was used to classify the complete image. Seven different land cover classes were delineated, which were water, agriculture, barren soil, conifer forest, deciduous scrub forest, other lower vegetation and settlements. Comparison between the classified data and reference data was made in the accuracy assessment and kappa statistics were computed. Post-classification processing including reprojection, vectorization and extraction, merging and area calculation of classes was done in ArcGIS 10.2. Land-use maps for the three years and overlay maps of each class were generated to detect the change that has occurred in the land-use classes. The last step was post-classification comparison in order to calculate the shift in the classes that has taken place over the years.

Result

Table 1 shows the area of the land covers in both hectares and percentages. In the year 1992 lower vegetation class covering 5700 ha (29%) was the major class. This class included grasslands, rangelands and herbs etc. Next major class was that of coniferous pine forest with a total area of 5007 ha (25%). Followed by the scrub forest (16%), agriculture (11%), settlements (10%) and barren soil (6%). While the remaining 594 hectares area was covered by water body (3%). However the land-use map of year 2000 revealed that major land cover class was lower vegetation with an area of 4398 ha (22%). The second major class covering 3524 ha of area was the class of settlements (18%). Followed by scrub forest (17 %), barren soil (16%), agriculture (13%), pine forest (12%) and water class remained the smallest class covering only 316 ha (2%) of the total land area. In 2011 the lower vegetation class remained the major class covering a total area of 4131 ha i.e. 21% of the total area. Followed by the settlements (19%) and the scrub forest (17%) which were next in covering a large area (Figures 2-4).

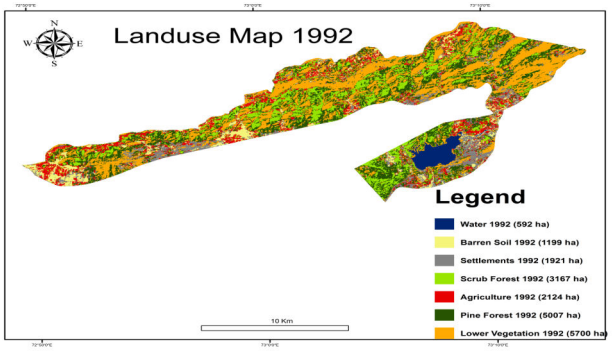

Figure 2: Land cover/ Land use map of Margalla Hills in 1992.

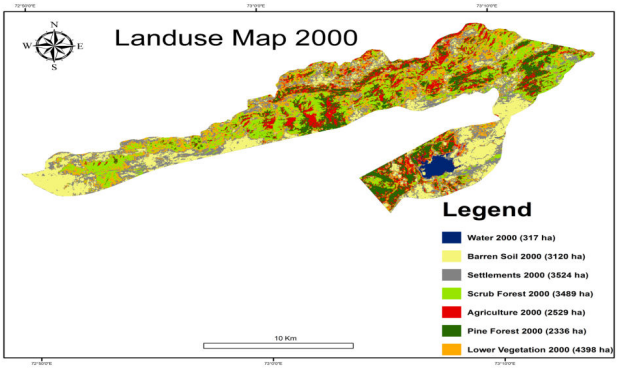

Figure 3: Land use/ Land cover map of Margalla Hills in 2000.

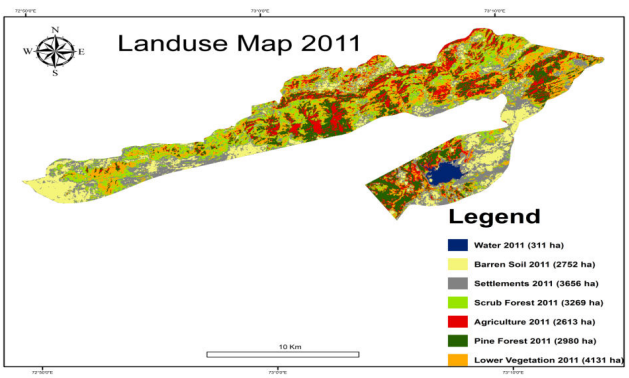

Figure 4: Land use/ land cover map of Margalla Hills in 2011.

Land use/ Cover classes	1992		2000		2011		Percentage Change	
	Area (Ha)	Area (%)	Area (Ha)	Area (%)	Area (Ha)	Area (%)	1992-2000(%)	2000-2011(%)
Water Body	594	3	316	2	311	2	-46	-1.5
Settlements	1921	10	3524	18	3656	18	83	4
Barren soil	1199	6	3120	16	2752	13	160	-11
Agriculture	2124	11	2529	13	2613	14	9	4
Lower vegetation	5700	29	4398	22	4131	21	-22	-6
Scrub forest	3167	16	3489	17	3269	17	10	-6
Pine forest	5007	25	2336	12	3183	15	-53	27
Total	**19712**	**100**	**19712**	**100**	**19712**	**100**		

Note: negative sign shows a decrease and positive sign shows an increase

Table 1: Area statistics and percentage change in area of land-use classes in MHNP from 1992-2000 and 2000-2011.

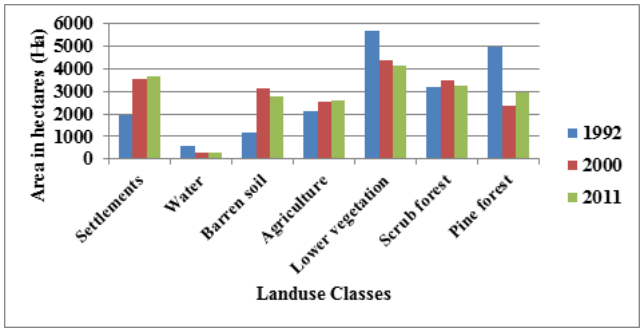

Figure 5: Relative land-cover changes in Margalla Hills from 1992 to 2011.

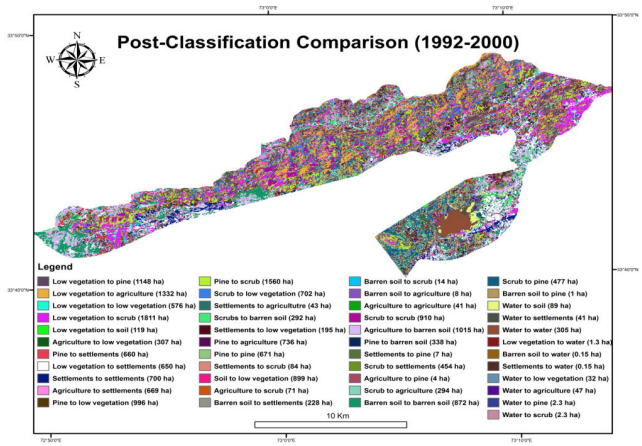

Figure 6: Post Classification Comparison between classified images of 1992 and 2000.

Figure 5 illustrates a graph that represents the change trends in land-use classes in the study area. It clearly depicts that settlements and agriculture area showed an increasing trend. Water body and lower vegetation showed a decreasing trend while other classes showed variance in trend from 1992 to 2000 and then from 2000 to 2011.

As shown in Figures 6 and 7, the post-classification comparison between the years revealed both desirable and undesirable changes as well as the classes that are relatively stable over time. The major land-use classes to which the forests were converted were the settlements, barren soil and agricultural land. However the major land-cover class that contributed to an increase in forests was the lower-vegetation class.

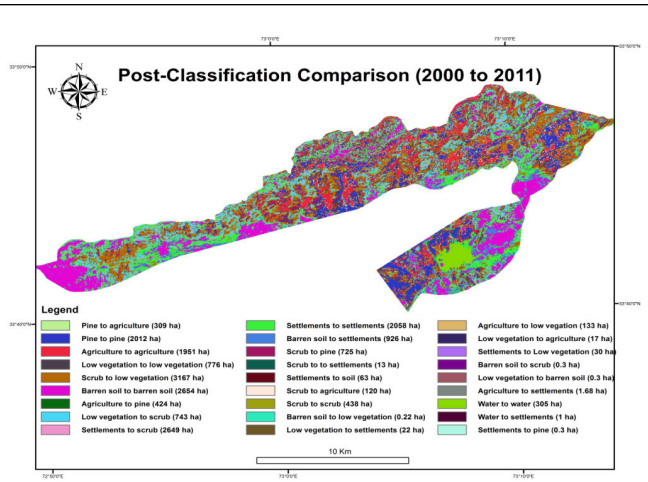

Figure 7: Post Classification Comparison between classified images of 2000 and 2011.

Discussion

Forests occupy approximately 4.6 million hectares of the Pakistan's total land. However, 61,000 hectares of forest region have been

transformed to non-forest use in the country ever since its inception [11,12]. Forests require some important factors like an optimal climate, unrestricted water supply, sufficient sunlight, reduced human interferences, minimal grazing practices by livestock, least wind and soil erosion and an ecological balance to grow in good health. The pressure of meteorological factors on the growth and vegetation process of trees is an obvious phenomenon. The trees that lack the optimal environment are often found in an unhealthy, dried out and stressed conditions. Higher temperature boosts plant water loss via transpiration, causing the plants to shrink the stomatal openings, which in turn diminishes photosynthesis [13]. From cross-tabulation and the application of mathematical operations, the Tables 2 and 3 were formulated for a better comprehension of changes in the land-use classes. From the year 1992 to 2000, 22% of area remained unchanged while 77% of the total land of Margalla Hills changed to the other classes. The unchanged area from 2000 to 2011 was 51% and the changed area was 59%.

Class (1992)	% Unchanged	% Changed	Changed Class in 2000 in Hectares (ha)							Total (1992)
			Agriculture	Water	Soil	Pine Forest	Scrub Forest	Settlements	Low vegetation	
Agriculture	0.2	10	41	-	1015	4	71	669	307	**2107**
Water	1.5	1	47	305	89	2.3	2.3	41	32	**518.6**
Soil	4.4	5.8	8	0.15	872	1	14	228	899	**2022.15**
Pine forest	3.4	21	736	-	338	671	1560	660	996	**4961**
Scrub forest	4.6	11.2	294	-	292	477	910	454	702	**3129**
Settlements	3.5	3	43	0.15	309	7	84	700	195	**1338.15**
Low vegetation	3	25	1332	1.3	119	1148	1811	650	576	**5637**
Total (2000)	22	77	2501	306	3034	2310	4452.3	3402	3707	**19712**

Table 2: Land covers change/ shift summary from 1992 to 2000.

Class (2000)	% Unchanged	% Changed	Changed Class in 2011 in Hectares (ha)							Total (2000)
			Agriculture	Water	Soil	Pine Forest	Scrub Forest	Settlements	Low Vegetation	
Agriculture	9.89	2.8	1951	-	-	424	-	1.68	133	**2509.7**
Water	1.5	0.7	20	305	12.54	-	-	1	8	**346.54**
Soil	13.4	4.68	-	-	2652	-	0.3	926	0.22	**3578.5**
Pine forest	10.2	1.78	309	-	43	2012	-	-	-	**2364**
Scrub forest	2.2	20.4	120	-	-	725	438	13	3167	**4463**
Settlements	10.4	13.9	-	-	63	0.3	2649	2058	30	**4800**
Low vegetation	3.9	3.96	117	-	0.3	-	743	22	776	**1658.3**
Total (2011)	51	49	2517	305	2770.8	3161	3830	3021	4114.2	**19712**

Table 3: Land covers change/ shift summary from 2000 to 2011.

Margalla Hills mainly have the deciduous type of scrubs which shed their foliage. They require an annual precipitation of about 64-76 cm, which usually occurs in the winters more while summers are dry. This plant community grows well in wetter areas of tropical wet and dry climate. They have adaptations to resist dry climate. While there is adequate rain for trees to nurture, the stretched dry season compels the trees to shed their leaves because of shortage of water. In areas that receive less rainfall, scrub replaces the forest. Scrub forest class of Margalla Hills showed an increase of 10 % from the year 1992 to 2000. Out of the total area of scrub forest in 1992, only 29% remained unchanged while remaining 71% changed to the other classes. While out of the total area of Margalla Hills National Park, 4.6% of the scrub forest area remained unchanged, 11.2% area transformed to other the classes while 17.9% area covered by other classes shifted to scrub forest. In the next decade the decline shown by the scrub forest area was about 6%. 10.4% of the area remained as previous and 13.9% of the area covered by scrub forest changed to the other classes. The spread of settlements, agriculture and urbanization has led to clearance of

forests. The forest fires spread wildly through the forest and caused the loss of vegetation. Overgrazing is another main reason behind this decline.

The Margalla Hills have Sub-tropical pine forests and Sub-tropical deciduous scrub forests. Among the pine forests, chir pine (*Pinus roxburghii*) is very commonly found. The growing conditions for chir pine forests are good soil-drainage, acid or calcareous soils and an optimal climate. The foremost trigger of the pine trees decline is the changing climate conditions. Due to global warming, at elevations up to 1000 m the temperature becomes too warm for the pine populations. Forests present in high-temperatures are expected to be most exposed to danger posed by climate change. By the year 2050, temperature in several of these forests will increase beyond the resistance ability of the species, with highest temperatures to be above 36°C, a temperature that will destroy adult trees of this species according to FAO [14]. Pine forest class covered a total area of 5007 hectares in 1992 that reduced massively to 2336 hectares area in 2000. This substantial change in the pine forest class was calculated to be 53%. 3.4% land out of the total area of MHNP continued as pine forest class, while 21% changed to the other classes. The increase in the pine forest class in 2011 was calculated to be 27%. It was estimated that, 10.2% of the pine forest remained unchanged, while 1.78% changed to the other classes. The decline can be associated with the climate when there is no rain for months and temperature rises up to 45°C and hundreds of hectares turn to cinders. Conversion of dense forests to agricultural land is also practiced greatly in MHNP by the illegal timber cutting. Extensive cattle grazing and fuel wood cutting by the local communities have deformed the plants to bushes [15].

Agricultural class of Margalla Hills shows an increase by 9% from 1992 to 2000. In 2011, there was a 4% increase in agriculture area after 11 years. As stated by [16] about 60% of the residents living in the park are involved in agricultural practices. Development of roads is one of the many reasons for the increase in agriculture which provides easy access to farmers to make encroachments and remove strips of forests to use the fertile soil for crop production.

Urbanization has impacts on the environment, these may be positive or negative but unplanned urban growth always has negative impacts. Problems of environment associated with urbanization tend to be similar in both developing and developed countries. Population in the MHNP is about 92,000 settled in 37 villages. Developments include road networks, recreational spots and sit outs etc. Settlements class covered a total area of 1921 hectares in 1992 that shot to 3524 hectares area in 2000. This increase in the settlements class was calculated to be 83%. It was also calculated that out of the total area of MHNP, 3.5% remained as settlements class, while 3% changed to other classes. Settlements class had been a major land use class in the year 2000 which increased further to an area of 3656 hectares in the year 2011 again being a significant land use class. The increase shown by the built-up area was about 4% due to the ever-increasing population and urbanization, which led to the establishment of housing schemes and colonies to facilitate accommodation by establishing many housing schemes and colonies [17]. Other developments include road networks, residential colonies, recreational pursuits i.e Monal, Pir Suhawa, Daman-e-Koh, Said-pur village and Lake View park are among the most popular recreational and tourist spots. But the increase in such developments needs to be compensated by the decline of forests, barren soil and water bodies. Numerous industrial and commercial units have been in service, clearly violating the environmental laws in the capital and defacing the Margalla Hills National Park for a long time now. The four residential colonies are Margalla Meadows, North Ridge Society, Al-Reyan Housing Society and Ali Model Town [17]. Margalla View Housing society is also being developed as D-17 sector of Islamabad near Margalla Hills terrain. Islamabad Chalets is a society first of its kind in the Margalla Hills and is endangering the ecology of the area due to increase in traffic. At first, in the 1980's the ISI developed a housing scheme for its employees within the boundaries of the national park [18]. The inclination and degree of urban change is likely to persist with the speedy development of infrastructure.

Sr. No.	Years	No. of Fire	Area Burnt In Acres
1	2002	20	88
2	2003	71	131
3	2004	62	548
4	2005	09	07
5	2006	41	347
6	2007	37	409
7	2008	38	345
8	2009	16	76
9	2010	14	9.25
10	2011	12	6

Table 4: List of forest fires occurred from 2002 to 2011 on Margalla Hills, Source: CDA, 2012.

Lower vegetation class of Margalla Hills shows a decrease of 22% from the year 1992 to 2000. 3% of the lower vegetation area remains unaffected, 25% area changed to other land use classes while 15.8% area covered by other classes in 1992 changed to lower vegetation in 2000. Further 6% area dropped in 2011. The cause of this decline may have been over grazing practices by livestock, urbanization and built-up area and increase in the crop production within the MHNP. Forest fires also cause rapid desertification of grass lands to barren soil. Periodic forest fires are responsible for the limited under growth of Chir pine and scrub forests in Margalla Hills [19]. In Pakistan, forest fires take place mostly in dry hot season both in scrub and in the tropical chir forests. These fires cause incredible loss to the forest areas and require constant checking for their sensing, reporting, mobilization, fighting and control [20]. Forest fires cause harmful effects like conversion of vegetation to ashes, scenery and wildlife habitat destruction, damage to watershed values of forests and air pollution. The cones of the trees act like fire balls. Table 4 shows a list of forest fires occurred in Margalla Hills from 2002 to 2011 while Figure 8 shows the duration of each forest fire.

75% of forest fires last or lasted for 1-4 hours, 15% of fires in MHNP prolonged for 4-8 hours. Very few forest fires of only 1% of carried on for a day or more than 24 hours.

The boost in the Barren soil class was calculated to be 160% which can be attributed to human activities like indiscriminate bush burning, over grazing of pastures, forest fires, stone crushing and fuel wood extraction. Much of the vacant land was then converted to settlements

after year 2000. The class thus, showed a decrease of 11% from 2000 to 2011.

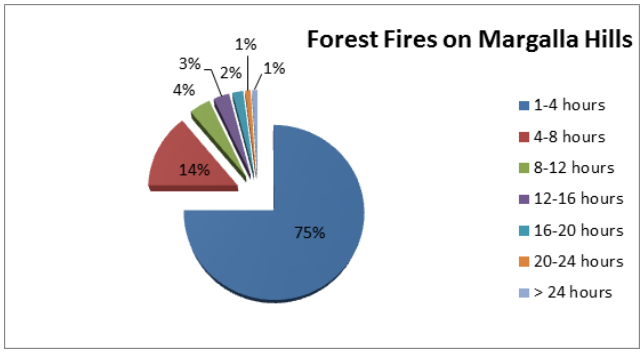

Figure 8: The duration of forest fires on Margalla Hills with the percentage.

According to this research, the water body class covered 594 hectares in the year 1992 which transformed into a body covering 316 hectares in the year 2000. The class dropped to 311 hectares in 2011. Rawal dam supplies 23 MGD of water for drinking and other domestic purposes to Rawalpindi city and a limited amount of water to Islamabad for irrigation. The catchment is facing problems of rapid urban growth and deforestation due to which the regime of water is altering. The use of herbicides and pesticides for agriculture causes high toxicity level in water. The construction of roads, pavements and other structures reduce the infiltration area that ultimately affects the recharging of the aquifer of the twin cities. The storage capacity of Rawal Lake that used to be 47230 hectares in 1960 has been reduced to about 35% due to sedimentation [21].

One of the chief reasons for deforestation is a burgeoning and competitive world economy, although the forest resources of Pakistan are meager but they add considerably to its economy. People rely on forests of Margalla Hills for fodder, timber and wood for fuel. In addition, people living in the vicinity of these forests collect various non-timber forest products (NTFPs) for use at the domestic level and for cash income [22].

Removal of strips of forest to grow crops by farmers is a common practice in MHNP. Other events causing clearance of land are increase of urbanization, establishment of buildings and residential colonies, road constructions, dependence of rural residents on wood for fuel, overgrazing of land by livestock and the activities of the timber mafia have converted forest regions to barren soil and deserts. Therefore, governments as well as environmentalists have some challenges to overcome. People harvest forests to meet their own household needs and mostly they do so without being thoughtful about the effects it has on environment [23,24].

Margalla Hills contain sandstone and shale which is very suitable for the construction of bridges and buildings. Fecto cement industry involved in limestone exploitation is present towards the west of MHNP. Other quarrying and stone crushing companies are named as Chaudhry M. Asif, Chaudhry Irfan, Chaudhry Naveed and Akhter Mehmood. Crushing and mining activities also have adverse effects on the plants present there besides destroying the natural landscape, air and noise pollution and environmental degradation [25,26].

With the help of correlation analysis the inter link between climate variables and parameters of land-use change was highlighted. The correlation analysis of land use parameters in relation to the climate parameters helped strengthen the result of the study by giving a c ear representation of variations in terms of positive and negative change. It shows a strong correlation between land use parameters and the climate conditions of Margalla Hills.

Pearson's Product Moment Correlation tells us how well are two data sets related. The digit 1 shows the maximum level of significance between two variables, while the sign '+' and '-' show total positive and total negative correlations respectively. 0 shows that no correlation is present.

The Pearson's correlation result obtained for agriculture with climate (Table 5) shows that, agriculture is most significantly co-related with temperature and relative humidity having values of over 0.9. But with temperature it has a positive correlation and with relative humidity it has a negative correlation. Water is positively correlated with precipitation and humidity i.e. when rainfall increases water increases and when humidity rises, dryness decreases and water level increases. While water gives a negative correlation with sunshine hours and temperature. Pine forests have low significant relation with temperature and sunshine hours and a moderately significant correlation with rain and humidity. Scrub forests have trees that adapt themselves to the hot climate with the help of their thick and spiny barks, so they have a moderately significant but positive correlation with temperature and a highly significant positive relation with sunshine. Lower vegetation has a high 0.924 correlation with humidity, a moderate 0.775 correlation with precipitation and significant negative correlations with temperature and sunshine hours i.e. when temperature and sunshine increases, lower vegetation decrease.

In terms of co-relation between the land use parameters and the climate data, climate change has been claimed to have the most significant influence on the vegetation class whether it is the grass land, wood land, forest, range land, herb or agriculture. It is postulated to affect the forest nutrient cycles, crop productivity, soil fertility, biodiversity and other processes of ecological importance. For instance, the variations in the precipitation patterns causes the hydrological fluxes of nutrients to change also affecting the decomposition, productivity and nutrient uptake. Likewise, another signification climate variable, the temperature fluctuations can also result in modifications of hydrological fluxes, decomposition, accelerated physiological development, resulting in hastened maturation and a reduced yield [27-29]. Rainfall is the most significant factor in the destruction of forests and agricultural lands. Higher rainfalls could enhance growing period duration. In some areas of Pakistan, high degree of precipitation was beneficial for forests, production and water availability. However, contrary consequences were observed in other parts of the country due to loss of fertile soils with intense flooding caused by high average rainfalls. It has also been claimed that the declining rate of woody biomass is the second highest in the world ranging from 4-6% [30]. This decline in forest area has been linked to the ever changing climatic conditions that have been intensified over the years as a consequence of natural and man-made processes.

According to the IPCC, an increase in the average global temperature is very likely to lead to changes in the global trends of precipitation and atmospheric moisture. Increased temperature cause the evaporation and water vapor level to rise which changes the atmospheric circulations, resulting in increased precipitations. The more is the precipitation, the more are the chances of storms and sea level rise. The impacts of the rising temperature have already been witnessed globally and at national scale. These include: the drying of the rivers when the season is dry which were previously perennial rivers, unpredictable weather conditions, rigorous rainfalls, low water levels in the dams, recurrent episodes of drought, flood, catastrophic inundations, storms and other natural calamities such as devastation caused by the flood in 2010 in Pakistan that caused 1800 above casualties affecting over 21 million, which was in large partially because of the hap-hazard deforestation taking place along our river banks and mountains.

As discussed earlier the climate change may have both positive and negative effects. There have been rare incidences of snow fall on Margalla Hills. There was one reported in 2006 and after a period of six years the hills were snow-blanketed again in 2012. Heavy snow fall in the months of winter can raise the water and catchment dam levels. But hails accompanied by intense snow fall can also have a devastating effect on the vegetation. The monsoon precipitations are quite intense by nature and can be responsible for severe flooding if they get a chance to intermingle with the westerly waves. Excessive exposure of the soil to wind and water can cause erosion. Heavy rainfall or flood can cause the loss of top soil and soil erosion minimizing the soil fertility and health. Grave winds also blow in the area occasionally. High wind velocity can cause evapo-transpiration at a higher rate that leads to breaking and uprooting of trees, dislodging of crops and damage to habitation. Chilly winds in winter can also cause frost.

Variables		Agriculture	Water	Barren soil	Pine forest	Scrub forest	Lower vegetation	Settlement	Temperature	Precipitation	Relative humidity	Sun shine hours
Agriculture	*r*		-0.989*	0.942	-0.888	0.627	-1.000**	0.996*	0.999*	-0.776	-0.925	0.727
	p		0.046	0.109	0.152	0.284	0.001	0.030	0.013	0.217	0.124	0.241
Water	*r*			-0.981	-0.946	-0.733	0.990*	-0.999*	-0.983	0.676	0.859	-0.819
	p			0.063	0.105	0.238	0.046	0.017	0.059	0.264	0.171	0.195
Barren soil	*r*				-0.991*	0.852	-0.942	0.969	0.928	-0.519	-0.749	0.915
	p				0.043	0.175	0.109	0.080	0.122	0.326	0.234	0.132
Pine forest	*r*					-0.914	0.889	-0.927	-0.869	0.400	0.647	-0.961
	p					0.133	0.151	0.122	0.165	0.369	0.276	0.089
Scrub forest	*r*						-0.628	0.696	0.595	0.005	-0.282	0.991*
	p						0.284	0.255	0.297	0.499	0.409	0.043
Lower vegetation	*r*							-0.996*	-0.999*	0.775	0.924	-0.728
	p							0.029	0.013	0.218	0.125	0.241
Settlement	*r*								0.991*	-0.715	-0.885	0.787
	p								0.042	0.247	0.154	0.212
Temperature	*r*									-0.801	-0.939	0.698
	p									0.204	0.112	0.254
Precipitation	*r*										0.958	-0.131
	p										0.093	0.458
Relative humidity	*r*											-0.410
	p											0.366
Sunshine hours	*r*											
	p											

*. Correlation is significant at the 0.05 level (1-tailed). **. Correlation is significant at the 0.01 level (1-tailed).

Table 5: Pearson's Correlation Analysis of land use parameters with climate variables.

All these are indications of the impact of climate change on Margalla Hills. Planning authorities will have to tackle the challenges that climate change brings with it. They will likely indulge in supervision of the effects of climate change and other anthropogenic activities on natural resources and take on a variety of adaptations to exercise better sustainable efforts, designed to conserve the forest reserves, agricultural land and water supply and devise alternative strategies for their management and protection.

Conclusion

The present study conducted on Margalla Hills National Park revealed that over the period of last two decades the land use and land cover practices have changed significantly. The spatial pattern and change detection in land use/land cover could serve as a guiding tool in biodiversity conservation and environmental development. This research may also prove to be a fine contribution in sustainable land use/land covers planning and forest reserves restoration in the study area. The spatial and temporal analysis of the forest cover has provided an accurate account of the condition of the study site during the period of 1992 to 2011. The study concluded that the forest cover is declining while agriculture and built-up area is heightening. This spreading out of settlements and agriculture is due to the lack in proper planning, urbanization, population boost, poverty and negligence in land use management. The amplification in these classes has consequently affected the vegetation and water bodies leading to deforestation and water body loss. The need of the hour is to take immediate action to sustain our forest resources.

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