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Land use change detection in the limestone exploitation area of Margalla Hills National Park (MHNP), Islamabad, Pakistan using geo-spatial techniques

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Abstract

The aim of the study is to assess the limestone (LS) exploitation area and its negative impacts on natural resources using geo-spatial techniques. LS is an important constituent of cement manufacturing which is extensively used in the construction of infrastructure such as roads and buildings. The Margalla Hills National Park (MHNP) is situated around Islamabad and contains a large amount of LS reserves. However, the exploitation of LS from the MHNP is causing harmful environmental impacts on the surrounding areas. Geographic Information System (GIS) and Remote Sensing (RS) have been proved as powerful tools for LS exploitation assessment. Four Landsat Thematic Mapper (TM)/Enhanced Thematic Mapper (ETM+) satellite images have been acquired over a span of 17 years (1992-2009). The temporal changes in the study area were detected by performing the digital image processing techniques of image enhancement and supervised classification. The classification accuracy has been verified with high resolution Google Earth images and by using error matrix. Advanced Space borne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation (GDEM) has been used for topographic information extraction. It was observed that LS exploitation area increased from 0.35% to 5.72% from 1992-2009, whereas, the vegetation was decreased from 23.46% to 12.12%. Urban development also increased rapidly. The results showed that LS exploitation is deteriorating the ecosystem, biodiversity, landscape and vegetation of the MHNP which was established in 1980 to protect, conserve and manage the biodiversity and ecosystem in this region. We conclude that the LS exploitation in the MHNP should be managed properly to secure the water, soil, air quality in the federal capital. Initiatives should be taken for the rehabilitation of the LS exploited areas and then, to suggest alternative LS exploitation sites in the near periphery of study area with EIA restrictions.

*Keywords***:** Limestone exploitation; Landsat satellite; Remote Sensing; Land use; Change detection

1. Introduction

Limestone (LS) exploitation is carried out for the cement production which is obtained by grinding clinker with Gypsum and used for construction purposes (Akinbile, 2007). Stone crushing and cement production is one of the significant industrial activities that exists all over the world. This sector is an important industrial segment for infrastructural development and construction of roads, bridges, canals, dams, building and housing projects. However, during the process of crushing a considerable amount of dust is emitted at almost every stage (Akinbile, 2007). This process not only effects the local environment but also the human health in the surrounding areas. Furthermore, the removal of vegetation exposes soil surface and thereby enhances the chances of land erosion (Ibrahim, 2002). Therefore, LS exploitation must involve planning, conflict resolution, construction, operation and close down (FMSMD, 1999).

Margalla hills contain high quality of Limestone (LS including sand-stone and shale, which is considered as best for construction purposes (Nawaz et al., 2004). Increasing trend of LS exploitation is harmful for vegetation, natural ecosystem, biodiversity and human health. Thus, environmental impact assessment (EIA) is required before the execution of any project to mitigate the harmful environmental impacts. Conventional surveying and mapping techniques consume a lot of time and are expensive as well for the assessment of LS exploitation area while such information is not readily available, especially in developing countries. Satellite Remote Sensing (SRS) and GIS have been widely applied in identifying and analyzing for LS exploitation assessment, environmental impact assessment, geo-morphological analysis, land use mapping and planning (Treitz et al., 1992; Harris and Ventura, 1995). Usually, remotely sensed data is used to provide information on terrain surface whereas on the other hand, GIS is a supporting tool to RS and has the capability to manipulate and store data in digital forms (Shaban, 2010). Using GIS, Wandahwa and van (1996) implemented land suitability evaluation and mapped climate, altitude, soil type, and ecosystem. The topography of the land surface is one of the most essential characteristic of the earth used in GIS analysis (Reuter et al., 2009).

Space-borne sensors have shown a great potential for delivering reliable estimates of the extent and changes occurring in the LS exploitation area along with mapping urban growth and forest cover estimation (Foody et al., 1996). Multi-temporal and multi-spectral satellite images are used for characterizing land use and land cover (LULC) change and deforestation rates (Lu et al., 2004). SRS is a growing technology and is being used as a fundamental component of conservation planning and biodiversity assessment (Sesnie et al., 2008; Stickler and Southworth, 2008). LS exploitation area assessment from satellite data is executed using either supervised and/or unsupervised classification method. The spectral complexity of predefined classes has further led to numerous suggestions for procedures and techniques to improve classifications including topographic normalization, spatial filtering, image segmentation, object-oriented classifications (Foody et al., 1996), vegetation indices and multi-temporal image data (Lucas et al., 1993).

LULC changes may have negative impacts on environment, water resources, land and vegetation if appropriate measures are not taken in time (Sunday and Ajewole, 2006).The lack of proper rehabilitation of the LS exploitation sites causes serious environmental degradation and spread of diseases (Kaliampakos et al., 1998). This necessitates temporal monitoring of changes occurring in the land use and land cover of an area. The need for low-cost data resource is particularly important for conservation and research in developing countries where funding for mapping is often limited. So research interests are being directed to the mapping and monitoring using RS/GIS techniques (Epstein et al., 2002). Landsat onboard Multispectral Scanner (MSS), Thematic Mapper (TM), and Enhanced Thematic Mapper Plus (ETM+) is archiving and delivering free of costimagesforabout30 years (USGS, 2008). It meets a wide range of information requirements for monitoring the conditions of earth’s land surface (Williams et al., 2006; Chander et al., 2009). The availability of multispectral and high resolution data as well as advanced capabilities of digital image processing techniques, in generating enhanced and interpretable images, has further enlarged the potential use of RS in delineating lithological contacts and geological structure in great detail (Drury, 1987; Yousif and Shedid, 1999; Crippen and Blom, 2001). There are many applications of RS in geology which involve the delineation of structures, discrimination of different rock, soil types and resource exploration (Kruse and Dietz, 1991). Many geological studies have employed TM and ETM+ data to discriminate the various lithologies, lineaments limestone and minerals (Abrams, 1984).

The main objective of the current study is to assess the spatiotemporal changes in the limestone exploitation area and its impacts over the past 17 years, using geospatial technique. Moreover, to identify alternative LS querying sites in an attempt to save the MHNP.

2. Study area

Margalla Hills National Park (MHNP) is located in the north of the Pakistan’s capital city Islamabad, whereas the study area lies between $33^0$40'01" to $33^0$42'43" N latitude, $72^0$45'01" to $72^0$52'32"E longitude as shown in (Fig. 1). MHNP was declared as the National Park under Islamabad Wild Life Ordinance in 1980. The step was taken to conserve the natural resources from injudicious human activities such as over cultivation, grazing, mining and water pollution (Ahmad, 2009). The foothills run approximately from north to northwest direction and are about 40 km in length (Malik and Husain, 2003). The current study focuses on a subpart of MHNP, where limestone exploitation is taken place. MHNP, like the Potwar Plateau and Azad Kashmir, also has a distinct altitudinal range and lies at the junction of Potwar Plateau and northern mountainous region of Pakistan (Masroor, 2011). The soil of the study area is derived from wind, water-laid deposits and sedimentary rocks. Margalla Hills are largely tertiary in age with smaller areas of formation belonging to quartzitic sandstone calcareous shale and limestone (Hijazi, 1984). The topography of the area is rugged, varying in elevation comprising mainly steep slopes and gullies (Fig. 2), where the rock structure is basically limestone (Yasin and Rubina, 1987). Natural springs and rainfall play an important role for streams in the MHNP. The area falls in the far end of monsoon zone and the mean monthly 254 mm of monsoon precipitation occurs in July and August (Maqsood, 1991). The mean relative humidity for the same period varies between 59 and 67% (Masroor, 2011). 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 (Hussain, 1986). MHNP vegetation is largely the result of monsoon and the foothills flora is mostly tropical in origin (Shinwari and Khan, 1998). According to Chandio (1995) the water-table has dropped from 12.5 to 22.9m in Rawalpindi and from 10 to 19.8m in Islamabad.

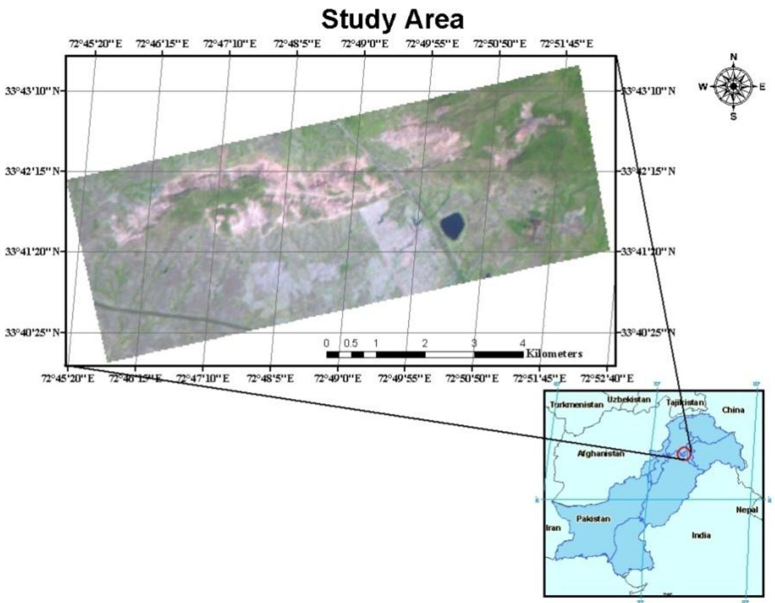


Fig. 1. The location of the study area in the Margalla Hills National Park, Islamabad (Pakistan)

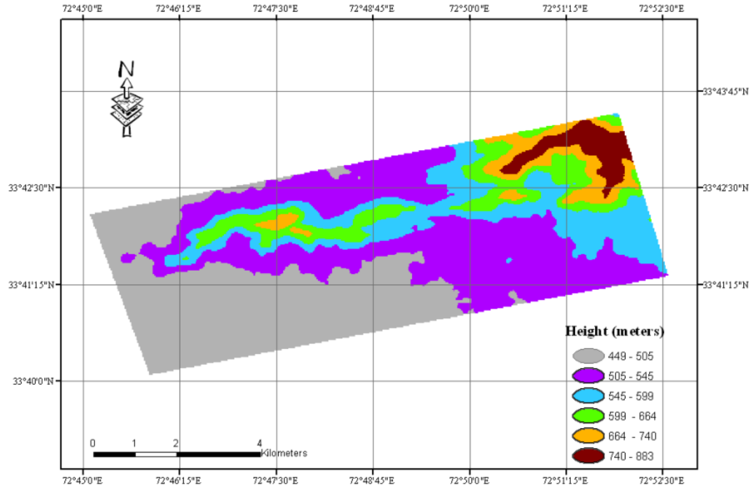


Fig.2. Digital Elevation Model (DEM) generated and extracted for topographic analysis, where study area is divided into six zones with different elevations ranging from 449 to 883 meters.

3. Data and Methodology

Two types of data have been used in the study. Elevation data is used for topographic information extraction and multi-temporal Landsat satellite images were used for Limestone exploitation area assessment. Other LULC classes i.e. bare land, vegetation, water, road network and urban development were derived to observe the impact of limestone exploitation on them. Advanced Space borne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model (GDEM) have been released with a 1 arc second and provided much extended coverage. ASTER GDEM is an easy-to-use, covering all the land on earth, and available to all users regardless of size or location of the study areas to extract topographic information. The ASTER GDEM with 30 meter resolution is expected to meet the requirements of many users, for global topographic information (Reuter et al., 2009).

Landsat data is a precious resource for monitoring global changes and is a primary source of medium spatial resolution used in decision-making (Goward et al., 2006; Masek et al., 2008; Vogelmann et al., 2008). Remote sensing classification approaches such as supervised, unsupervised and knowledge-based expert system approaches (Sugumaran et al., 2003; Mundia and Aniya, 2005; Lu and Weng, 2005), have been used and are still being used for the land cover change detection. The supervised classification is a time consuming, however, an accurate system used to extract surface features manually from remote sensing images (Butt et al., 2011).

Heavy LS exploitation started in the study area in 1980’s. This study is based on land cover classification of four multi-temporal cloud free images. The acquisition dates are 20 September 1992, 08 September 1998, 21 May 2002 and 30 May 2009 with having path 150 and row 37. ERDAS Imagine 9.0 software was used to carry out all image processing tasks while Arc GIS 9.1 was used for analysis and map development. To minimize radiometric distortion due to different atmospheric conditions and different acquisition dates, a basic radiometric and image-based atmospheric correction according to Chavez (1996) was applied. Radiometric correction was performed on all the four images due to variations in scene illumination and sensor irregularities, viewing geometry, atmospheric conditions and sensor noise. The images have been geometrically corrected using the UTM map projection (Zone 43N, datum WGS84). In order to geometrically correct the original distorted image, the resampling technique of nearest neighbor method is used to determine the digital values, for placing in the new pixel locations of the corrected output image. This method uses the digital value from the pixel in the original image which is average of four nearest to the new pixel location in the corrected image with RMS error of less than one pixel. Our methodology is based on the Principal Component Analysis (PCA) and supervised classification methods. PCA are used to extract specific training sites and finally, the Maximum Likelihood (MLA) supervised classification algorithmis used to produce satellite-derived maps (Butt et al., 2012). PCA is used to convert raw remote sensing data of multi-spectral imageries into a new principal component image, which is more easily interpretable (Singh and Harrison, 1985; Weng, 1993). Digital image processing techniques are used to define unique training sites for classification of the study area. The image classification procedure is applied to automatically categorize all pixels into land cover classes or themes on the basis of training sites defined in an image. In this study 40 training sites are identified on the basis of filed survey and image interpretation. The Maximum Likelihood (MLH) classification algorithm is applied in the current study, because it can be more effective than the often used Minimum Distance Algorithm (MDA) and Mahalanobis Distance Algorithm (MDA) when the number of training sites per class is larger (Jensen, 1996). As for as the spectral reflectance concerns, water bodies generally reflect high in the visible spectrum. For vegetation, the spectral reflectance is based on the chlorophyll and water absorption in the leaf. For man-made materials, concrete and asphalt, both display spectral curves generally increase from the visible through the Near IR and Mid-IR regions. Bare land decreases as organic matter increases (Iqbal et al., 2009).

The classification accuracy was verified using high resolution Google Earth images which are available and quite conveniently help to recognize the studied natural objects. The study area shape file was converted into KML layer which was then imported to Google Earth. The classified images and Google Earth images, all were displayed simultaneously to cross refer the classification. The areas that indicated limestone, vegetation, urban development, water and bare land on the classified images were zoomed in the Google Earth images covered by KML layer and the classification accuracy was checked. Accuracy assessment was also performed by using the original satellite images to avoid errors in the reference data using Error matrix. Error matrices were developed on all the four images to check the accuracy as shown in Table 1. The classification accuracy using error matrix was found to be more than 98%. The higher level of accuracy was obtained in the data of TM 1992 and less accuracy was found in the data of TM 2009.

With the help of field survey and literature review alternative sites would be identified and their quantity and quality would be examined. Few alternative querying sites have also been recommended by the (Nawaz et al., 2004) other than MHNP.

Table 1. Accuracy analysis (percentage) of all the classes derived from Landsat data.

Classes	Limestone Exploitation	Vegetation	Water	Bare land	Urban Development	Road Network
Landsat (1992) classification accuracy: 98%)						
Limestone Exploitation	98.25	0	0	0.67	0	0
Vegetation	0	99.46	0	0	0	0
Water	0	0	100	0	0	0
Bare land	1.09	0	0	99.33	0.32	0
Urban Development	0.66	0.54	0	0	99.68	0.07
Road Network	0	0	0	0	0	99.93
Landsat (1998) classification accuracy: 98%)						
Limestone Exploitation	99.53	0	0	0.47	0.88	0
Vegetation	0	99.82	0	0	0	0
Water	0	0	100	0	0	0
Bare Land	0.47	0	0	99.01	1.23	0
Urban Development	0	0.18	0	0.52	97.89	0
Road Network	0	0	0	0	0	100
Landsat (2002) classification accuracy: 98%)						
Limestone Exploitation	98.95	0	0	0	0	0
Vegetation	0	99.73	0.48	0	0	0.99
Water	0	0	99.52	0	0	0
Bare land	1.05	0	0	98.01	0	0
Urban Development	0	0.04	0	1.51	100	0
Road Network	0	0.23	0	0.48	0	99.01
Landsat (2009) classification accuracy: 99%)						
Limestone Exploitation	99.29	0	0	0	1.27	0
Vegetation	0	99.02	0	0.02	0	0
Water	0	0	100	0	0	0
Bare Land	0.71	0	0	99.95	0	0
Urban Development	0	0	0	0.03	98.73	0
Road Network	0	0.98	0	0	0	100

4. Results and discussion

Landsat TM and ETM+ satellite data was classified using MLH algorithm to investigate the LS exploitation area. Results of this classification are shown in Table 2 and Figure3. Results show that the LS exploitation area is increasing rapidly from the past two decades. It can be deduced from the results that in a short span of six years from September 1992 to September 1998, the LS exploitation area was increased by 1.47% (Fig. 4) whereas, LS exploitation area increased by 3.08% from September 1998 to May 2000. From May 2000 to May 2009 the increase observed 5.72%. From the past two decades, we observed a continuous increase in the LS exploitation area and if it continues with the same rate in the coming years, then some part of the Margalla Hills can be disappeared. Prominent agencies of the country including Environmental Protection Agency (EPA) and Natural Resource Monitoring (NRM) can be benefitted with such studies in order to make plans for better management of the limestone exploitation. The rapidly occurring LS exploitation is in turn severely destroying the natural ecosystem and vegetation as the results shows that the vegetation is decreasing rapidly in the study area. Total vegetation-covered area; either sparse or dense decreased by about 12% from September 1992 to 2009 (Table 2). The obvious effect of LS exploitation would be on vegetation and decreasing trend of vegetation would result in bare land. Urban development increased very rapidly in the study area from 1992 to 2009 as in September 1992 it was recorded to be 0.44%, and finally in May 2009 urbanization was estimated to be 3.86%. We monitored increasing and decreasing trend of bare land in various years due to other factors including vegetation, limestone exploitation area, urbanization and water. Increasing and decreasing trend of road network has been found to be due to the condition of the road. If the road would be repaired, then it would not have been reflected as road and considered as bare land. In this study, only surface water was considered as water class and changing in the water is due to the over consumption of water. Water is directly related to the rainfall. If there would have been rainfall prior to taking of image, then we could have been observed more water-covered area. Maps of the study area after classification process are shown in Figures 5.

Table 2. Area in square kilometer (km^2) obtained from Landsat satellite of the classes including Limestone Exploitation, Bare Land, Vegetation, Water, Road network and Urban development. A comparison was made between every two years to find the changes annually.

Class	1992	1998	Annual changes (1992-1998)	2002	Annual changes (1998-2002)	2009	Annual changes (2002-2009)
Limestone Exploitation	00.35	01.47	00.19	03.08	00.40	05.72	00.38
Bare Land	18.26	26.90	01.44	21.31	-01.40	20.18	-00.16
Vegetation	23.46	12.57	-10.89	15.10	00.63	12.12	-00.43
Water	00.33	00.75	00.07	00.17	-00.15	00.18	00.01
Road Network	00.45	00.09	-00.06	00.45	00.09	01.10	00.09
Urban Development	00.44	01.39	00.16	02.96	00.39	03.86	00.13

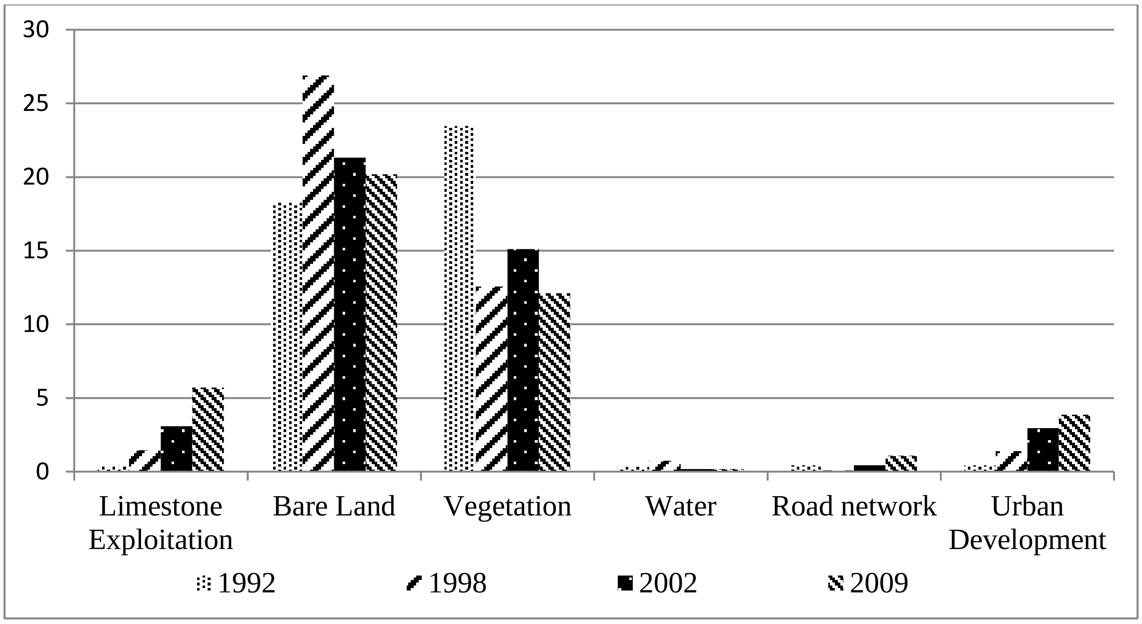


Fig. 3. Increasing and decreasing trend of all the six classes from 1992 to 2009, where limestone exploitation area is increasing rapidly with the increasing speed of urbanization.

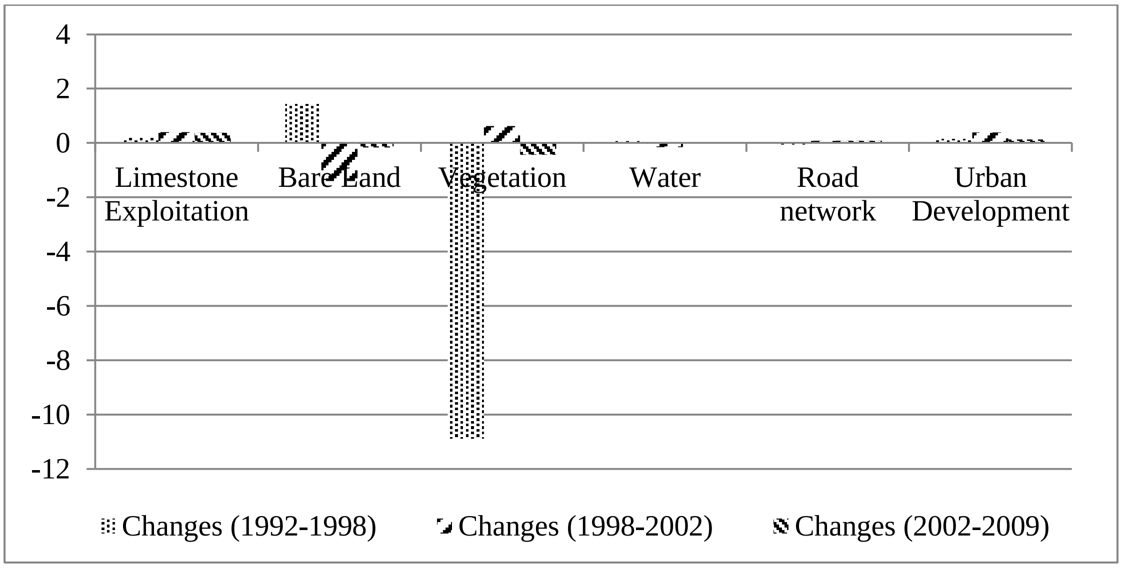
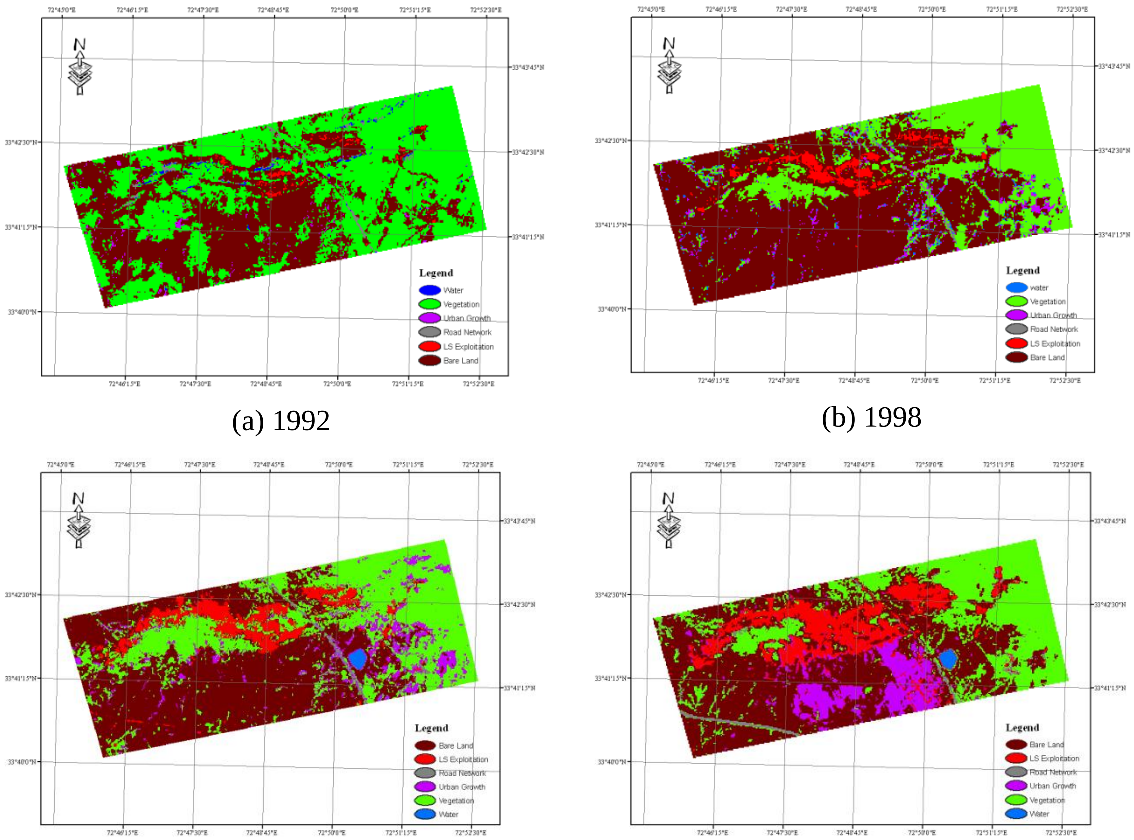


Fig. 4. Change detection of all the classes in percentage from 1992 and 2009.



(a) 1992 (b) 1998

(c) 2002 (d) 2009

Fig. 5. Classified maps of satellite image from the year 1992 to 2009 (a-d).

Results show overall 98% average classification accuracy using error matrices and these results were also verified through high resolution Google Earth images that are available and quite conveniently help to recognize the studied objects in the study area.

We have also identified various LS querying sites other than the MHNP. These sites have been identified using field survey and comprehensive literature review. The alternative LS querying sites are Khairi Murat, Kala ChittaDhar, Pathargarh, Khanpur and Ganghar Ranges. It has been analyzed that the recommended sites are sufficient for not only present needs but also for future requirements. These alternatives sites are not far away from Islamabad and Rawalpindi and enough for present and future requirements. Alternative recommend sites would be beneficial to save the biodiversity and ecosystem of MHNP and also support the Government to collect the revenue.

5. Conclusion

On the basis of our results, we conclude that

i. Limestone exploitation is directly affecting the vegetation-covered area that might accelerate erosion.
ii. Due to excessive LS exploitation, environment is also getting polluted and as a result it is also infecting the surrounding areas other than study area.
iii. LS exploitation is altering the natural ecosystem and biodiversity.
iv. Geospatial techniques can be used to assist the policy makers to identify alternate sites for LS exploitation.
v. If both the LS exploitation and urbanization keep on increasing with the same rate, then environment of the study area would be rigorously polluted.

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