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ASSESSMENT OF SAND MINING INDUCED ECOLOGICAL IMPACTS IN DOHAN RIVER OF MAHENDRAGARH DISTRICT, HARYANA

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Abstract

The present study attempts to assess the ecological impacts of sand mining in Dohan watershed of Mahendragarh district of Haryana. For this purpose, areal expansion of sand mining sites and their impacts on local environment have been examined using geo-spatial techniques. Images captured by LANDSAT 5 TM and LANDSAT 7 ETM+ satellites for the year 1989 and 2009 have been used in this study. Both natural (vegetative index and moisture index) and anthropogenic (land use/cover change) parameters have been computed to assess the sand mining induced environmental degradation. The study reveals that sand mining has adversely affected the vegetation cover and moisture content in the study area. Thus, uncontrolled sand mining activities during 1989 and 2009 have significantly affected the environmental health of the study area. In addition, excessive mining of sand has also contributed in the decline of groundwater table in recent years.

Introduction

Rivers have been the source of variety of resources for humankind since time immemorial. For centuries, humans have been enjoying the natural benefits provided by rivers without understanding much as to how the river ecosystem functions and maintains its vitality (Naiman and Bilby, 1998). Indiscriminate extraction of non-living resources like sand and gravel from riverbed is the most disastrous activity being carried out in the river beds as it threatens the very existence of the river ecosystem (Kondolf, 1994). River sand is one of the most plentiful resources as it comprises of about 20 per cent of the Earth's crust (Nair, 2005).

In India, rivers are the major sources and suppliers of sand as this resource naturally replenishes in the process of erosion and deposition every year during four months of Monsoon season (Nair, 2009). Sand aggregates constitute bulk of the material used in construction industry. Demand of sand as construction material in India has increased manifold since the initiation of economic liberalization (Padmalal et al., 2008). During first decade of 21st century, the demand of sand further increased at an alarming rate due to booming real estate sector in the country (Singh et al., 2007; Sreebha and Padmalal, 2011). Excavation of sand and gravel contribute about 4 per cent of the total national gross domestic product in the country. It occupies about 36 lakh ha land area and provides an employment to 1.1 million people in the country (Saviour, 2012). However, there is indiscriminate mining in river beds to meet the increasing demand of sand resulting, severe damage to its ecology. As a result, the channels of many rivers have been drastically altered to the extent of exhaustion of their natural resilience capacity (Kondolf, 1994; Arun et al., 2006).

Environmental degradation caused by sand mining has become a serious ecological hazard. However, the degree of on-site and off-site ecological impacts of sand mining would vary depending on the geologic and geomorphic settings of the areas. Excessive sand mining accelerates the process of erosion and deposition in riverbeds leading to alteration in the topography of the riverbeds and adverse effects on the ecosystem of the river (Tamang, 2013). The mining of sand from the river beds results changes in the forms of channels, physical habitats and food webs (Kondolf, 2006), engineering structures associated with river channels (Tamang, 2013), agricultural lands (Hemalatha et al., 2005; Govindaraj et al., 2013) and social conditions (Yadav, 2007). Indiscriminate sand mining also alters groundwater regime in the vicinity of channels due to formation of depressions (recharge areas) and change in the pathway of river. Such changes may increase or decrease groundwater recharge and this often causes change in aquifer volume as well (Welhan, 2001; Peckenham et al., 2009; Apaydm, 2012). Environmental impact of excessive sand mining in the river beds and flood plains has been studied and analyzed by many researchers worldwide (Kim, 2005; Rovira et al., 2005; Arun et al., 2006; Lu et al., 2007; Padmalal et al., 2008; Leeuw et al., 2010; Sreebha and Padmalal, 2011). In addition, location of sand extraction operations, its regulations, environmental effects, and aesthetic concerns regarding mining have emerged as the issues of local as well as global concern (Sonak et al., 2006; Apaydm, 2012). But very little attention is paid by researchers to such issues in developing countries. The situation is alarming in small rivers like those draining the arid or semi-arid areas of India.

Since economic liberalization period, the construction boom in National Capital Region (NCR) has generated tremendous demand of sand as a construction material (Singh et al., 2007). Sand mined from various river courses of the region is the main source of this construction material because sand obtained through crushing of boulders is quite expensive. Therefore, courses of surrounding rivers were triggered for quarrying of sand. This, off-course, has led to legal as well as illegal mining of sand and degradation of environment in the vicinity of mining areas in general and in Dohan river of Mahendragarh district of Haryana in particular. The present study, therefore, is a modest attempt to evaluate the negative impacts of indiscriminate sand mining in Dohan river of Mahendragarh district in Haryana so that adequate measures may be taken to check it.

Objectives of the study

Major objectives of the study are:

- to examine and evaluate the environmental health of study area over time and space; and
- to assess the impacts of sand mining on groundwater resources of the study area.

Study Area

The study area has been selected on the basis of the location and concentration of sand mining activities. For this, a circle of 10 km radius has been drawn around the core sand mining area (Fig. 1). The study site (10 km radius) is located in Narnaul Block of Mahendragarh district in south-western Haryana. It has a geographical extension between 28° 00' 30" to 28° 11' 26" North latitude and 75° 56' 24" to 76° 08' 34" East longitude. The actual area under sand mining in Dohan watershed is about 1.80 km^2; however, the area affected by it is much larger. Dohan River originates from the Wast Dokan protected forest area of Sikar district of Rajasthan. This is a seasonal stream which gradually shrinks and disappears in sandy tract after flowing in Mahendragarh district. The study site consists of flat and level plain

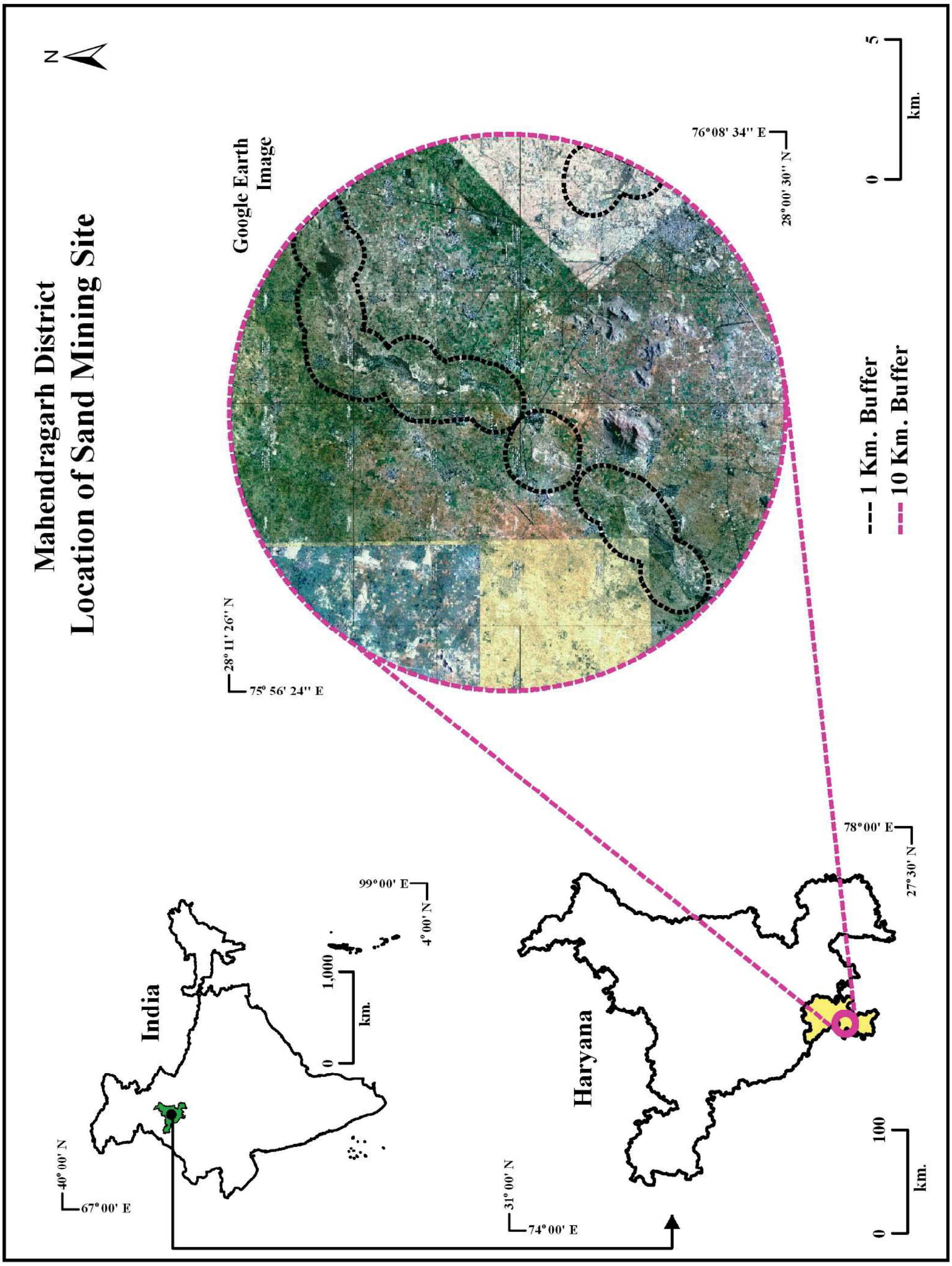
Mahendragarh District
Location of Sand Mining Site
Google Earth Image
N
28° 11' 26'' N
75° 56' 24'' E
76° 08' 34'' E
28° 00' 30'' N
0
5
km.
1 Km. Buffer
10 Km. Buffer
India
40° 00' N
67° 00' E
99° 00' E
4° 00' N
0
1,000
km.
Haryana
31° 00' N
74° 00' E
78° 00' E
27° 30' N
0
100
km.

Fig. 1

interrupted by cluster of sand dunes, isolated hillocks and rocky ridges. Its elevation varies from 278 m to 642 m above the mean sea level. It experiences a hot summer, a cold winter season, scanty rainfall and persistent soil moisture deficit regime except during monsoon season. The normal annual rainfall is about 418 mm and there is significant inter-annual variation which leads to variations in stream flow and sand deposited on the river bed (Fig. 2). Geologically, the study area belongs to the Alwar series, Ajabgarh series and Rialo series of Delhi Super group and is of recent origin. The litho units in the river bed and surrounding areas are the river born sediments brought and deposited in the flood plains by the seasonal streams. These sediments are of recent geological origin. The size of the sediments towards the source i.e. host rock is coarse and at the tail end of the river the grain size is reduced to smaller sizes resulting in the formation of clay beds. Sand and silt are deposited in the middle of the river bed whereas fine sand and clay are found deposited at the fringe.

Material and Methods

(i) Sources of Data

The present study utilizes the United States Geological Survey (USGS) satellite data of LANDSAT 5 TM and LANDSAT 7 ETM+ sensor with a spatial resolution of 30 m to assess the sand mining induced ecological impacts. The data were downloaded from Global Land Cover Facility (GLCF) website (https://earthexplorer.usgs.gov/). LANDSAT 5 (Path: 147 Row: 40 and 41) TM (dated October 6, 1989) and LANDSAT 7 (Path: 147 Row: 40 and 41) ETM+ (dated October 10, 2009) imageries covering the study area are assembled and analyzed to determine environmental change over two decades in terms of land use/land cover, biomass and moisture content. Moreover, about 120 m high resolution Digital Globe Image tiles of the study area have also been downloaded from Google Earth using the Map Grabber 3.2 software. Ancillary data like Survey of India (SOI) topographic maps (1:50,000) have been procured from SOI regional office, Chandigarh to prepare the base map of the study area. The elevation data at 30 m resolution have been obtained from Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Digital Elevation Model (DEM). The data related to groundwater depth have been collected from Central Ground Water Board (northern region), Chandigarh and Groundwater Cell, Department of Agriculture, Panchkula, Haryana. Rainfall data have been procured from India Meteorological Department, Chandigarh.

It is worthwhile to mention here that LANDSAT sensor has been chosen primarily due to the availability of data since 1984 in several spectral bands which are very crucial for calculating various indices. Additionally, October month has been selected on the presumption that there is sufficient vegetation cover around river bed so the vegetation removal due to sand mining activities can be easily identified. The year 1989 has been taken on account of the beginning of liberalization period in India, which provided impetus to large scale sand mining for infrastructure development in the NCR. Conversely, the year 2009 has been selected on the basis of the fact that in May 2009 Supreme Court of India banned all the mining activities in the study area.

(ii) Methods

To demarcate the study area, a circle of 10 km radius has been drawn around the sand mining sites for assessing the environmental conditions. Furthermore, a buffer of 1 km has been delineated along the sand mining sites to assess the impact of mining in vicinity. A comparison of environmental conditions in these delineated areas will bring out the impact of sand mining on ecological conditions. In addition, the ArcGIS 9.3 and ERDAS IMAGINE 9.2 softwares have been used for thematic database generation, integration of the

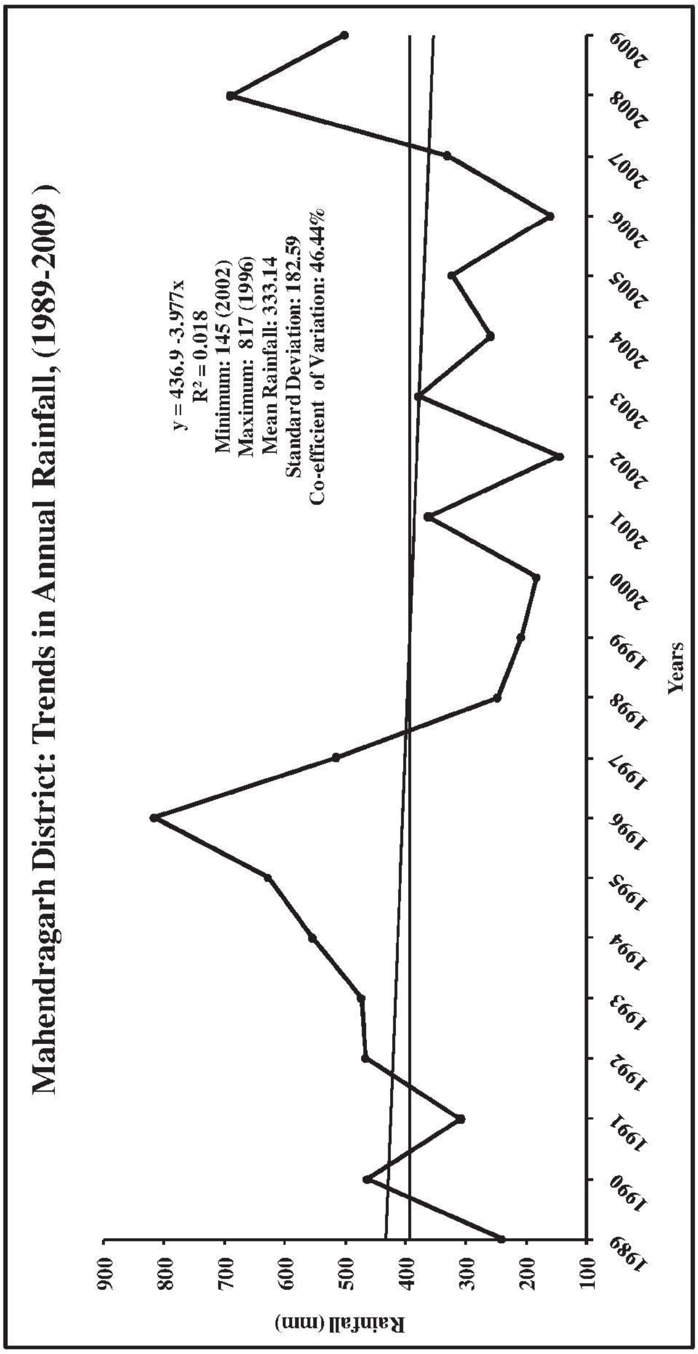
Mahendragarh District: Trends in Annual Rainfall, (1989-2009)
y = 436.9 -3.977x
R² = 0.018
Minimum: 145 (2002)
Maximum: 817 (1996)
Mean Rainfall: 333.14
Standard Deviation: 182.59
Co-efficient of Variation: 46.44%
Rainfall (mm)
900
800
700
600
500
400
300
200
100
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Years

Fig. 2

spatial and non-spatial data for land use/land cover, change detection and preparation of the results. The standard image-processing techniques have been employed in conjunction with a temporal decision tree and track changes through time. The band ratio indices used in this study, are Normalized Difference Vegetation Index (NDVI); Normalized Difference Moisture Index (NDMI); Normalized Difference Water Index (NDWI) and Normalized Difference Bare Land Index (NDBaI) to identify the vegetation cover, moisture content, bare land and water bodies. The LANDSAT 5 TM, LANDSAT 7 ETM+ bands Red, Green, Blue, NIR, MIR and SWIR have been used to derive the selected indices such as:

- NDVI: It is the difference between the red and near-infrared band combination divided by the sum of the red and near-infrared band combination (Rouse et al., 1973) or:

  NDVI = (NIR-Red)/ (NIR+Red)

- NDMI: This index contrasts the near-infrared (NIR), which is sensitive to the reflectance of leaf chlorophyll content to the mid-infrared (MIR), sensitive to the absorbance of leaf moisture (Wilson and Sader, 2002):

  NDMI = (NIR-MIR)/ (NIR+MIR)

- NDWI: It is developed to delineate open water feature as:

  NDWI = (Green-NIR)/ (Green+NIR)

- NDBaI: It has been used to retrieve bare land from the LANDSAT imagery advocated by Jamalabad and Abkar (2004) as

  NDBaI = (SWIR-Red)-(NIR-Blue)/ (SWIR+Red)+(NIR+Blue)+1

where Red, Green, Blue, NIR, MIR and SWIR represent the spectral bands of the LANDSAT TM and ETM+ images.

The hybrid classification method (supervised and un-supervised classification based on radiometry and on screen digitized mask) and NDVI, NDWI and NDBaI have been employed for evaluating the land use/land cover classification. The spatial distribution of various land use types has been compared to identify the positive and negative changes in terms of optimal land use. For change detection various categories of land use have been identified and scores have been assigned taking into account the quality of land use. In change detection analysis, each pixel of 2009 data has been compared with 1989 data. If the difference in scores of 2009 and 1989 is positive, it suggests improvement in the quality of land use but if the difference is negative, the land use is considered to be degrading. Similarly, for classification of vegetation cover and moisture content, increasing scores have been given from very low to very high vegetation cover and moisture content and change detected as mentioned above.

(a) Preparation of Environmental Health Index

The methodology adopted for computing environmental health index of the study site has been summarized in flow chart (Fig. 3). Three parameters namely NDVI, NDMI and land use/land cover have been used to study the environmental health of the study site. Comparative weightage has been given to each class of land use/land cover, vegetation cover, and moisture cover maps to have a comprehensive idea about the degradation caused by the sand mining over the years. Based on possible negative impacts on land, a rating has been done to assess land use changes. Water bodies have been put under highest weightage category followed by cultivated land, dense vegetation cover, sparse vegetation cover, settlements and fallow land being on the lowest side. Higher sum of score indicates good environmental health of the study site and vice versa. All the thematic maps (NDVI and NDMI) have been reclassified into five categories using the suitable threshold value for both the time periods for assessing the environmental change. Outputs of NDWI and NDBaI maps have not been used for calculating

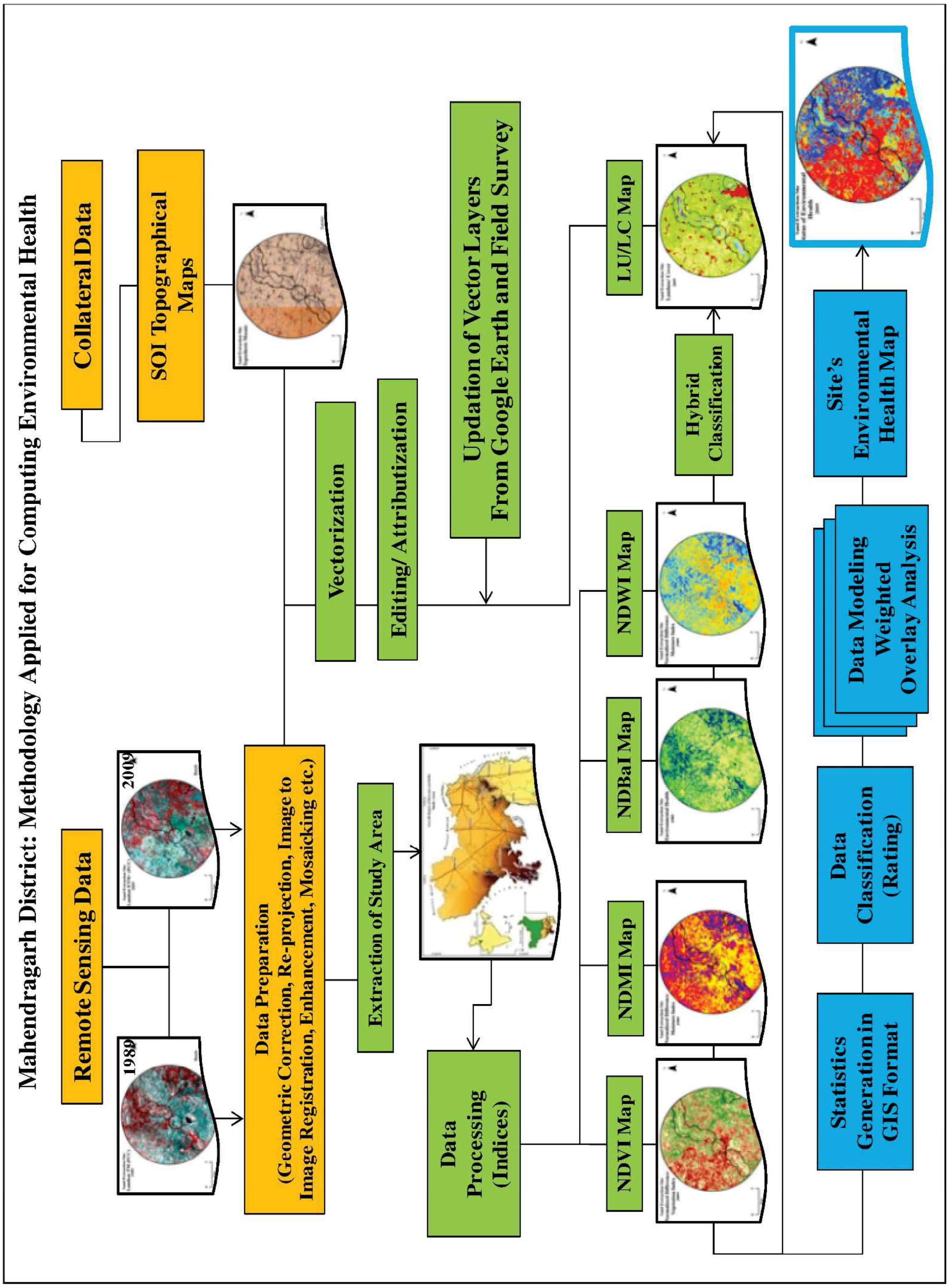
Mahendragarh District: Methodology Applied for Computing Environmental Health
Remote Sensing Data
1989
2009
Collateral Data
SOI Topographical Maps
Data Preparation (Geometric Correction, Re-projection, Image to Image Registration, Enhancement, Mosaicking etc.)
Extraction of Study Area
Vectorization
Editing/ Attributization
Updation of Vector Layers From Google Earth and Field Survey
Data Processing (Indices)
NDVI Map
NDMI Map
NDBaI Map
NDWI Map
Hybrid Classification
LU/LC Map
Statistics Generation in GIS Format
Data Classification (Rating)
Data Modeling Weighted Overlay Analysis
Site's Environmental Health Map

Fig. 3

the weightage value for both the periods. The output of surface water distribution and concentration has been used in land use/land cover map to increase its precision level. This helps in avoiding misinterpretation of land use/land cover classes. All these layers have been integrated using Raster Calculator given in Spatial Analyst extension in Arc/Info 9.3 and finally environmental health index has been derived as under:

EHI $=\sum$ [(Map1× W1/A) × 100 + (Map2× W2/A) ×100……(Mapn × Wn/A) × 100]

where, EHI= Environmental Health Index

Map1 = area under land use type1

W1 = Weight/ score assigned to the type1

A = Total area of the study site

Five categories of environmental health index have been identified to assess the changing pattern of overall environmental health of the site. Furthermore, to obtain the overall positive or negative change in environmental health of the study site ratio of composite value was generated by dividing total weightage value of 2009 with total weightage value of 1989.

The ratio value of more than 1.0 indicates towards the improvement in environmental conditions over the study site and vice-versa.

(b) Interpolation of Groundwater Depth

Spatial pattern of groundwater depth over the study site has been depicted using isopleth technique of mapping. An ordinary kriging estimator has been used to model groundwater table elevation. Changing depth of groundwater over the study site has been plotted for drawing the trend during 1989-2009.

Results and Discussions

(i) Pattern of Vegetation Cover/Vigor

Sand mining from the river beds has a direct impact on vegetation cover/vigor in the vicinity of mines. The change in vegetal cover/vigor (NDVI) as a result of sand mining activities during 1989 to 2009 has been exhibited in Fig. 4 and Table 1. It is evident from Fig. 4 that vegetation cover/vigor is not uniform around the sand mining site selected for the study. The analysis revealed that there is an increase in the very low and low categories of vegetation cover/vigor by about 12 per cent in the vicinity of sand mining site. On the other hand, high and very high vegetation cover/vigor has decreased in 1 km buffer zone of the mining site. There are visible large areas which have no vegetation or very thin vegetation cover. Meanwhile, by the year 2009, the low and high vegetation cover/vigor categories were converted into very low vegetation cover/vigor in north-western, western and southern parts of the study site. On the other hand, the vegetal cover/vigor in the eastern, north-eastern and south-eastern parts has increased probably due to the irrigation facilities available in the study area.

The weightage average value for vegetation map in 10 km radius was observed to be 288.58 in 1989 which increased to 292.38 in the year 2009. Contrary to this, weightage average value decreased from 3.26 in the year 1989 to 2.95 in 2009 in the 1 km buffer zone (Table 2). The unit scale ratio value is observed to be higher in 10 km radius (1.01) as compared to 0.90 in 1 km buffer zone. It indicates that vegetation cover/vigor has improved in 10 km radius zone around the mining site. However, the vegetation cover has deteriorated in the area lying in close proximity to sand mining sites (1 km buffer zone).

(ii) Pattern of Moisture Content

The NDMI computed for the study area indicates that there has been a significant change in the moisture content as a result of sand mining over the period 1989 to 2009 (Fig. 5). It is found that the areas having dominance of moderate to very high moisture content in 1989 experienced very low and low moisture content by 2009 (Table 3). It may be due to the depletion of groundwater adversely affecting the vegetation cover. Such changes are found to

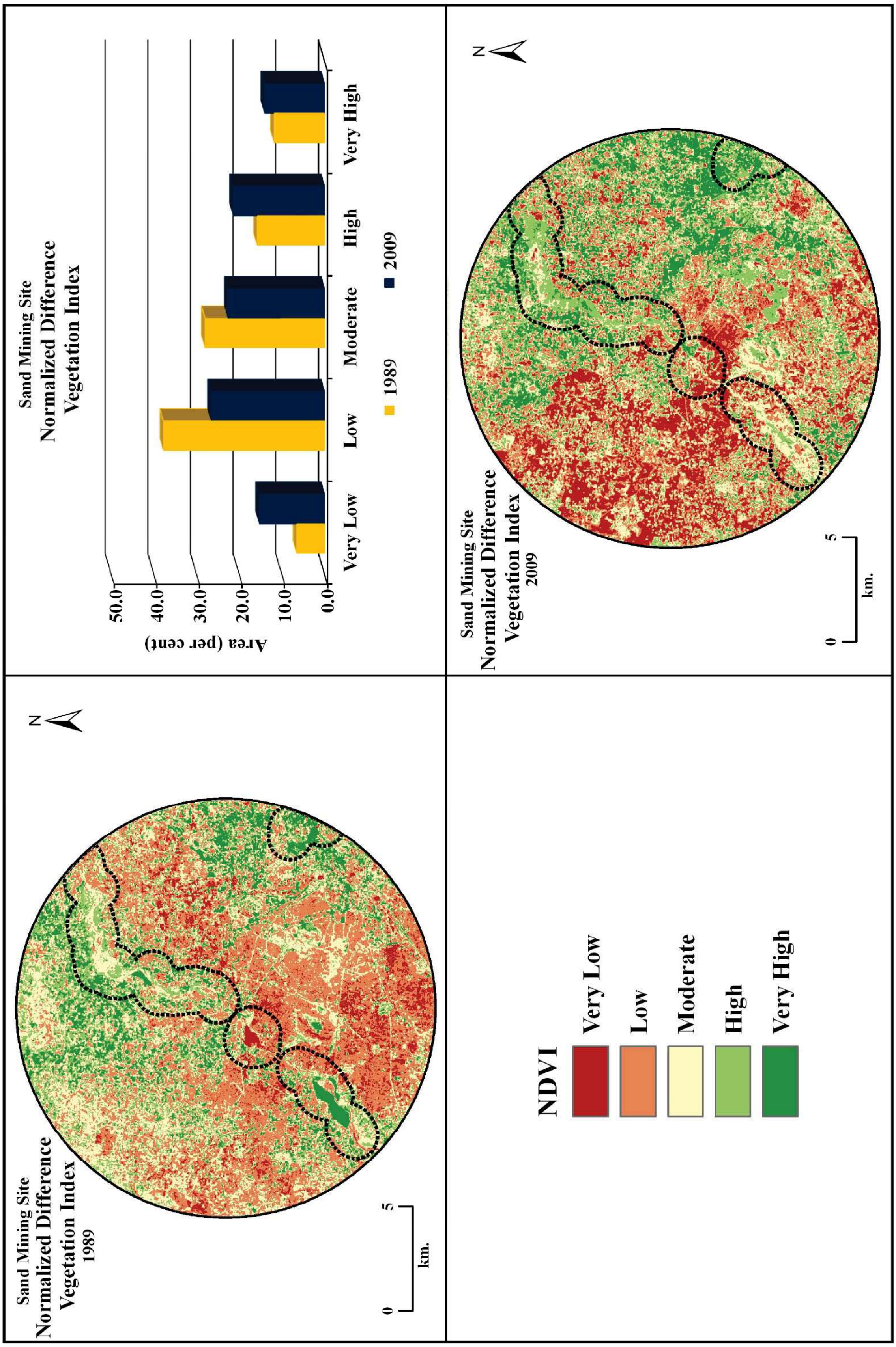
Sand Mining Site
Normalized Difference
Vegetation Index
1989
0
5
km.
N
Sand Mining Site
Normalized Difference
Vegetation Index
Area (per cent)
50.0
40.0
30.0
20.0
10.0
0.0
Very Low
Low
Moderate
High
Very High
1989
2009
Sand Mining Site
Normalized Difference
Vegetation Index
2009
0
5
km.
N
NDVI
Very Low
Low
Moderate
High
Very High

Fig. 4

Table 1
Sand Mining Site in Mahendragarh District: Levels of Vegetation Cover

NDVI	In 10 km Radius				In 1 km Buffer			
	1989		2009		1989		2009	
	Area (km^2)	Area (%)	Area (km^2)	Area (%)	Area (km^2)	Area (%)	Area (km^2)	Area (%)
Very Low	20.57	6.55	48.10	15.31	2.19	4.23	6.08	11.76
Low	118.72	37.79	83.47	26.57	13.23	25.59	15.58	30.14
Moderate	88.01	28.02	71.05	22.62	14.65	28.33	12.72	24.61
High	49.69	15.82	67.34	21.44	12.14	23.48	9.66	18.68
Very High	37.16	11.83	44.20	14.07	9.50	18.37	7.66	14.82
Total	**314.15**	**100.0**	**314.15**	**100.0**	**51.71**	**100.0**	**51.71**	**100.0**

Source: Computed by Authors.

Table 2
Sand Mining Site in Mahendragarh District: Weighted Composite Scores

Parameters	In 10 km Radius			In 1 km Buffer		
	1989	2009	Ratio*	1989	2009	Ratio*
Normalized Difference Vegetation Index	288.58	292.38	1.01	3.26	2.95	0.90
Normalized Difference Moisture Index	288.41	293.27	1.02	3.33	2.96	0.89
Land Use/Land Cover	354.81	293.27	0.83	3.06	2.71	0.86
Environmental Health	252.31	263.10	1.04	3.11	2.78	0.89

Source: Computed by Authors. ** = Index value of 2009/ index value of 1989.*

be more pronounced in western parts of the study site (Fig. 5). It is observed that the area under very low and low moisture content increased from 25 per cent in 1989 to 41 per cent during the year 2009 in 1 km buffer zone along mined river bed (Table 3). On the other hand, the proportion of area under high and very high moisture content categories has declined from about 41 per cent to about 31 per cent over the same period in the vicinity of sand mining sites. As compared to this, the moisture content has increased in 10 km radius zone. In this zone, about one-fourth area had high to very high moisture content in 1989 and the proportion of these categories of moisture content covered about one-third area in 2009, suggesting improvements in moisture contents during the study period.

The calculated weightage average values for NDMI were found to be 288.41 and 293.27 in 1989 and 2009 respectively in 10 km radius zone. Whereas, its values were 3.33 and 2.96 in 1 km buffer zone for the years 1989 and 2009 respectively (Table 2). The ratio value of the moisture content map in 10 km radius zone sand mining sites is 1.02 which clearly

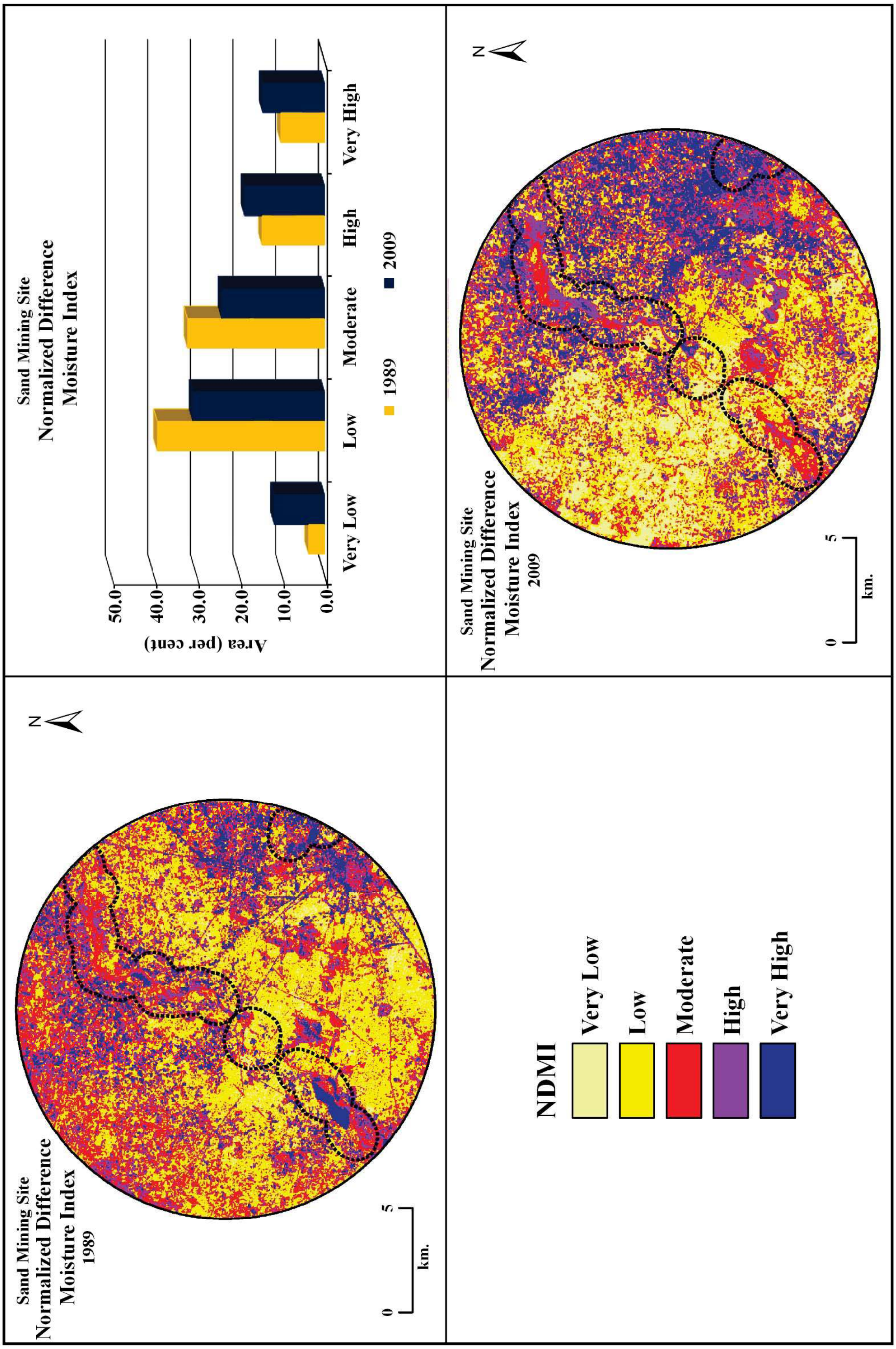
Sand Mining Site
Normalized Difference
Moisture Index
1989
0
5
km.
N
NDMI
Very Low
Low
Moderate
High
Very High
Sand Mining Site
Normalized Difference
Moisture Index
Area (per cent)
50.0
40.0
30.0
20.0
10.0
0.0
Very Low
Low
Moderate
High
Very High
1989
2009
Sand Mining Site
Normalized Difference
Moisture Index
2009
0
5
km.
N

Fig. 5

Table 3
Sand Mining Site in Mahendragarh District: Levels of Moisture Content

NDMI	In 10 km Radius				In 1 km Buffer			
	1989		2009		1989		2009	
	Area (km^2)	Area (%)	Area (km^2)	Area (%)	Area (km^2)	Area (%)	Area (km^2)	Area (%)
Very Low	11.81	3.76	36.98	11.77	1.41	2.73	4.32	8.36
Low	123.19	39.21	97.05	30.89	11.47	22.18	16.75	32.39
Moderate	100.92	32.12	75.74	24.11	17.54	33.91	14.35	27.75
High	46.05	14.66	58.90	18.75	11.37	21.99	9.10	17.60
Very High	32.18	10.24	45.49	14.48	9.92	19.18	7.18	13.89
Total	**314.15**	**100.0**	**314.15**	**100.0**	**51.71**	**100.0**	**51.71**	**100.0**

Source: Computed by Authors.

indicates slight improvement in moisture content during the study period. But in 1 km buffer zone of mining site, the moisture index is found to be 0.89 showing a discernible decline in the moisture content over the study period.

(ii) Pattern of Land Use / Land Cover

There is a perceptible change in the land use/land cover in the areas where sand mining has been activated during the period 1989-2009 (Fig. 6; Table 4). The landscape is marked by shrinkage of river beds and expansion of area under sand mining pits. Though, there is not much appreciable change in agricultural land, but the spatial pattern clearly demonstrates that the agricultural land has been converted into fallow land. Moreover, the areas having good network of canals and good recharge of groundwater have witnessed conversion of fallow lands into agricultural lands (Fig. 6). The area under water bodies has particularly declined in the vicinity of sand mining sites. The shrinking size of water bodies in the study area is directly linked to changes brought out in the river course due to removal of sand and vegetation in the process of sand mining. The study reveals that the area under settlements has increased during the study period in both the zones (Table 4). However, increase is more in the zone of 10 km radius (3.54 percentage points) than in 1km buffer zone (1.84 percentage points) during the study period. Thus, area close to the mining sites is devoid of settlements due to unsuitable environment for the growth of human settlements. Table 4 also suggests that area under degraded shrubs has marginally declined in both the zones, while areas under open shrubs and dense shrubs have marginally improved during the study period suggesting improvements in environment. The choking river bed also indicates that sand mining activity is encroaching other land use/land cover categories over the study site.

The calculated weightage average value for land use/land cover map is found to be 354.81 in 1989 which decreased to 293.27 in 2009 with a ratio of 0.83 in 10 km radius area. Whereas the weightage average value for 1 km buffer zone was 3.06 in 1989 which decreased to 2.71 in 2009 with a ratio value of 0.86 (Table 2). This shows the ecological deterioration in land use/land cover in sand mines as well as its neighboring areas.

(iv) Change in Natural and Anthropogenic Parameters

The changes in vegetation cover/vigor, moisture content and land use/land cover as a

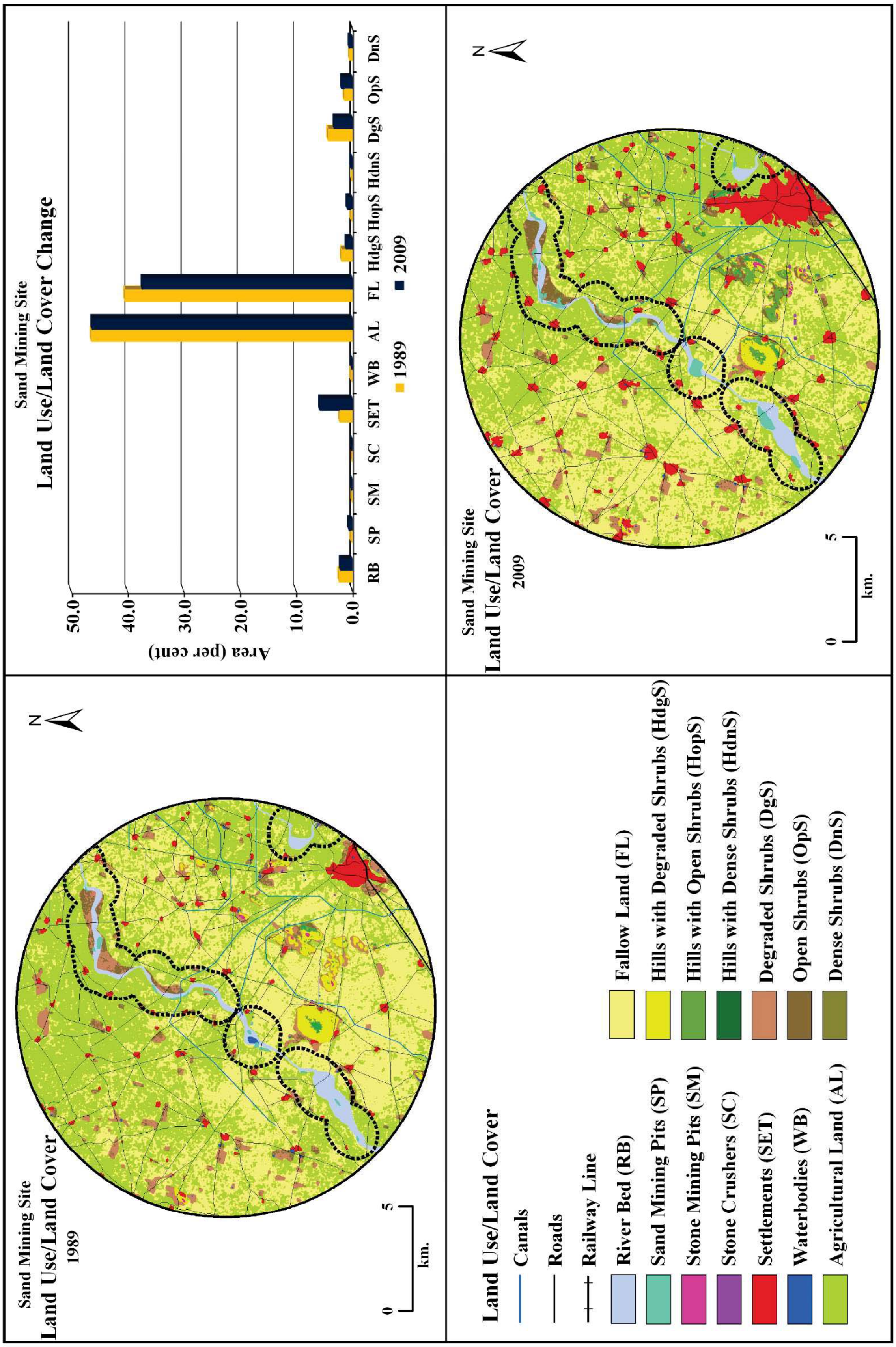
Sand Mining Site
Land Use/Land Cover
1989
0 5 km.
Sand Mining Site
Land Use/Land Cover Change
Area (per cent)
50.0
40.0
30.0
20.0
10.0
0.0
RB SP SM SC SET WB AL FL HdgS HopS HdnS DgS OpS DnS
1989 2009
Land Use/Land Cover
Canals
Roads
Railway Line
River Bed (RB)
Sand Mining Pits (SP)
Stone Mining Pits (SM)
Stone Crushers (SC)
Settlements (SET)
Waterbodies (WB)
Agricultural Land (AL)
Fallow Land (FL)
Hills with Degraded Shrubs (HdgS)
Hills with Open Shrubs (HopS)
Hills with Dense Shrubs (HdnS)
Degraded Shrubs (DgS)
Open Shrubs (OpS)
Dense Shrubs (DnS)
Sand Mining Site
Land Use/Land Cover
2009
0 5 km.

Fig. 6

result of sand mining activities have been summed up in Fig. 7 and Table 5. High negative changes in vegetation cover/vigor have been noticed in about 51 per cent area in the vicinity of sand mining sites (within 1 km buffer zone) (Fig. 7). Likewise, about 35 per cent area within 10 km radius has shown negative changes in vegetation cover/vigor. Similarly, about half of the area in 1 km buffer zone has experienced negative changes in the moisture content. In comparison to this, about 35 per cent area in 10 km radius zone has also recorded decline in the moisture content. A very small area in both the cases has recorded very high positive change in the moisture index.

Furthermore, sand mining has brought about significant transformation in land use/land cover. A close analysis of data reveals that low and high positive changes in land use/land cover were experienced in only 24.36 per cent area in 1 km buffer as compared to 20.17 per cent area in 10 km radius zone. However, low to high negative changes in land use/cover are more pronounced in 1 km buffer zone of the sand mining sites (Table 5). In addition, sand mining has scarred the landscape resulting in loss of ambience and increase in land not suitable for any productive purpose.

(v) Status of Environmental Health

Environmental health of the land has deteriorated in the vicinity of sand mining sites as compared to 10 km radius during the study

Table 4
Sand Mining Site in Mahendragarh District: Pattern of Land Use/Land Cover

Land Use/ Land Cover Classes	In 10 km Radius				In 1 km Buffer			
	1989		2009		1989		2009	
	Area (km^2)	Area (%)	Area (km^2)	Area (%)	Area (km^2)	Area (%)	Area (km^2)	Area (%)
River Bed (RB)	7.27	2.31	6.47	2.06	7.04	13.61	6.24	12.06
Sand Extraction Pits (SP)	0.58	0.18	1.80	0.57	0.58	1.12	1.80	3.49
Stone Mining Pits (SM)	0.18	0.06	0.29	0.09	0.02	0.03	0	0.00
Stone Crushers (SC)	0.02	0.01	0.20	0.06	0.00	0.00	0	0.00
Settlements (SET)	7.01	2.23	18.12	5.77	0.56	1.09	1.51	2.93
Waterbodies (WB)	0.50	0.16	0.40	0.13	0.17	0.34	0.05	0.10
Agricultural Land (AL)	145.68	46.37	145.35	46.27	25.14	48.61	25.13	48.60
Fallow Land (FL)	126.77	40.35	117.29	37.34	13.93	26.93	12.97	25.08
Hills with Degraded Shrubs (HdgS)	5.99	1.91	3.28	1.04	0.10	0.20	0.04	0.08
Hills with Open Shrubs (HopS)	0.57	0.18	2.72	0.87	0.02	0.05	0.05	0.10
Hills with Dense Shrubs (HdnS)	0.27	0.09	0.68	0.22	0.01	0.02	0.03	0.06
Degraded Shrubs (DgS)	13.48	4.29	9.98	3.18	2.14	4.15	1.18	2.29
Open Shrubs (OpS)	4.36	1.39	5.95	1.89	1.72	3.33	2.36	4.56
Dense Shrubs (DnS)	1.47	0.47	1.63	0.52	0.27	0.53	0.34	0.66
Total	**314.15**	**100.0**	**314.15**	**100.0**	**51.71**	**100.0**	**51.71**	**100.0**

Source: Computed by Authors.

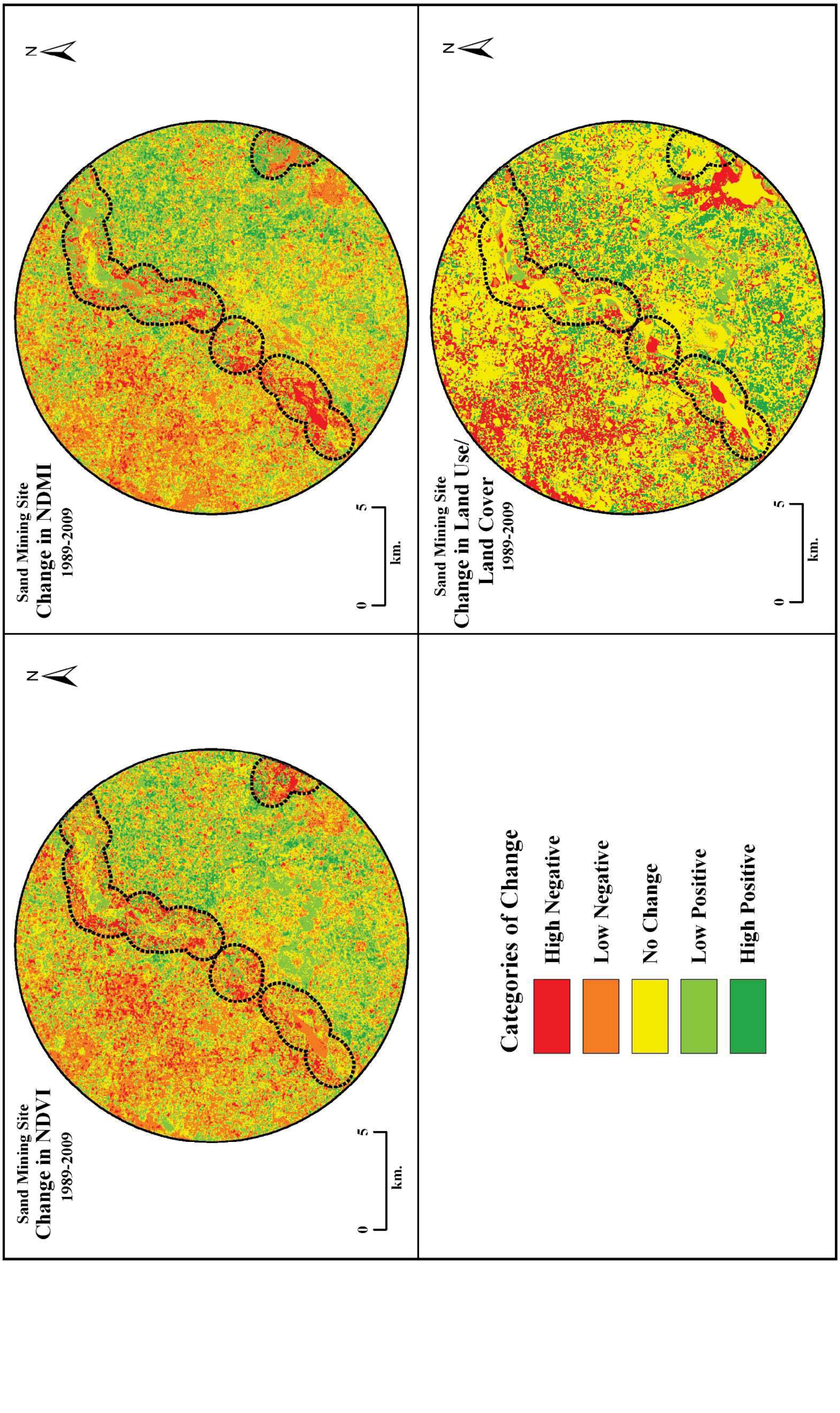
Sand Mining Site
Change in NDVI
1989-2009
0
5
km.
N
Sand Mining Site
Change in NDMI
1989-2009
0
5
km.
N
Sand Mining Site
Change in Land Use/
Land Cover
1989-2009
0
5
km.
N
Categories of Change
High Negative
Low Negative
No Change
Low Positive
High Positive

Fig. 7

Table 5
Sand Mining Site in Mahendragarh District: Change in Areas under Vegetation Cover, Moisture Content and Land Use/Land Cover

Type of Change	In 10 km Radius						In 1 km Buffer					
	Normalized Differentiate Vegetation Index		Normalized Difference Moisture Index		Land Use/ Land Cover		Normalized Differentiate Vegetation Index		Normalized Difference Moisture Index		Land Use/ Land Cover	
	Area (km^2)	Area (%)	Area (km^2)	Area (%)	Area (km^2)	Area (%)	Area (km^2)	Area (%)	Area (km^2)	Area (%)	Area (km^2)	Area (%)
High Negative	12.2	3.88	9.87	3.14	56.97	18.13	8.25	15.96	8.10	15.66	8.35	16.15
Low Negative	99.29	31.61	100.11	31.87	5.07	1.61	18.74	36.23	18.02	34.85	6.48	12.53
No Change	92.27	29.37	96.62	30.76	188.75	60.08	12.19	23.58	10.44	20.18	24.28	46.95
Low Positive	94.45	30.07	91.51	29.13	7.79	2.48	10.48	20.28	13.01	25.16	5.71	11.03
High Positive	15.95	5.08	16.05	5.11	55.57	17.69	2.04	3.95	2.14	4.15	6.89	13.33
Total	**314.15**	**100.0**	**314.15**	**100.0**	**314.15**	**100.0**	**51.71**	**100.0**	**51.71**	**100.0**	**51.71**	**100.0**

Source: Computed by Authors.

Table 6
Sand Mining Site in Mahendragarh District: Status of Environmental Health

Environmental Health Status	Composite Score	In 10 km Radius				In 1 km Buffer			
		1989		2009		1989		2009	
		Area (km^2)	Area (%)	Area (km^2)	Area (%)	Area (km^2)	Area (%)	Area (km^2)	Area (%)
Very Poor	5.0 and less	106.96	34.05	110.99	35.33	10.31	19.94	13.24	25.60
Poor	5.01-7.50	63.50	20.21	50.60	16.11	9.14	17.68	10.94	21.16
Moderate	7.51-10.00	54.37	17.31	43.90	13.97	9.21	17.81	10.37	20.06
Good	10.01-12.50	51.03	16.24	60.65	19.31	10.64	20.57	8.20	15.86
Very Good	More than 12.50	38.29	12.19	48.01	15.28	12.41	24.00	8.96	17.34
Total	-	**314.15**	**100.0**	**314.15**	**100.0**	**51.71**	**100.0**	**51.71**	**100.0**

Source: Computed by Authors.

period (Fig. 8 and Table 6). Besides, about half of the area in 10 km radius area has very poor to poor environmental health. However, there is some improvement in good and very good categories of environmental health during the period 1989 to 2009. An increase in area under very poor and poor environmental health categories have been observed leading to a substantial decline in area under very good and good categories in the vicinity of mining sites (Table 6).

Table 2 shows that the computed weightage average value for environmental health was 252.31 and 263.10 in 1989 and 2009 respectively in 10 km radius area whereas, the index value was found to be 3.11 and 2.78 in 1 km buffer zone which suggests towards the deteriorating environmental health. Overall unit value of ratio for 10 km buffer zone was 1.04 and its value for 1 km buffer zone was 0.89. The values of these ratios clearly reveal that environmental health has slightly improved in 10 km radius of the study site but it has deteriorated in the vicinity of the sand mining sites.

(vi) Impact on Depth of Groundwater Table

It is evident from Table 7 that there is a drastic decline in depth of groundwater table near the sand mining sites. Fig. 9 reveals that both during pre-and post-monsoon seasons, the groundwater table have declined consistently at a steeper rate during the period 1989 to 2009. The slight fluctuations during this period and seasonal gaps may be attributed to inter annual variations in rainfall. Due to increasing trends of annual rainfall, ground water recharge was higher till 1996. However, afterwards till 2006 annual recharge was low due to declining trends of rainfall. Again after 2006 there was a rising trend in the annual rainfall suggesting improvement in annual recharge in the study area (Fig. 2). Associated with variations in annual rainfall and recharge; expected fluctuations in groundwater table are not noticeable in the study area due to large scale withdrawal of groundwater for irrigation. The average depth of the groundwater table during this period of 35 years has declined from 30 m to about 55 m at the rate of 1.19 m/year (Fig. 9). Fig. 10 shows that in 1989, most parts of the study site, except the north-western and western parts, the groundwater table depth was more than 30 m. However, in 2009, entire study area had groundwater table deeper than 40 m. Similarly, Table 7 reveals that about 64 per cent of the study area has groundwater table depth of more than 60 m. The gradient of fall of groundwater table is steep in north-western and southern parts of the study area. Sand mining activities are not the major cause for this sharp and large scale decline in groundwater table. Deep bore wells for irrigation and check in the seasonal flow of Dohan river due to watershed management practices in the upper catchment areas of Rajasthan state can be important factors in deepening of groundwater table, however the role of sand mining activities cannot be ignored (Tejpal, 2014).

Conclusions

Mining of sand from the bed of Dohan river in Mahendergarh district has accelerated due to mounting demand of construction material in the NCR region during post liberalization period. At the study site, area under sand mining has increased by more than three times over the period 1989 to 2009. Although, the area under sand mining is small, yet direct and indirect ecological impacts of sand mining have much wider spatial dimensions. The study revealed that sand mining has led to various ecological hazards reflected in terms of depletion and degradation of vegetation cover/vigor, moisture content, groundwater level and land use/land cover. The vegetation cover/vigor has significantly degraded in close proximity (1 km buffer zone) of the sand mining sites, whereas, it has improved considerably in 10 km radius zone during the study period. Similarly, low moisture content is found in the vicinity of sand mines in comparison to the areas away from

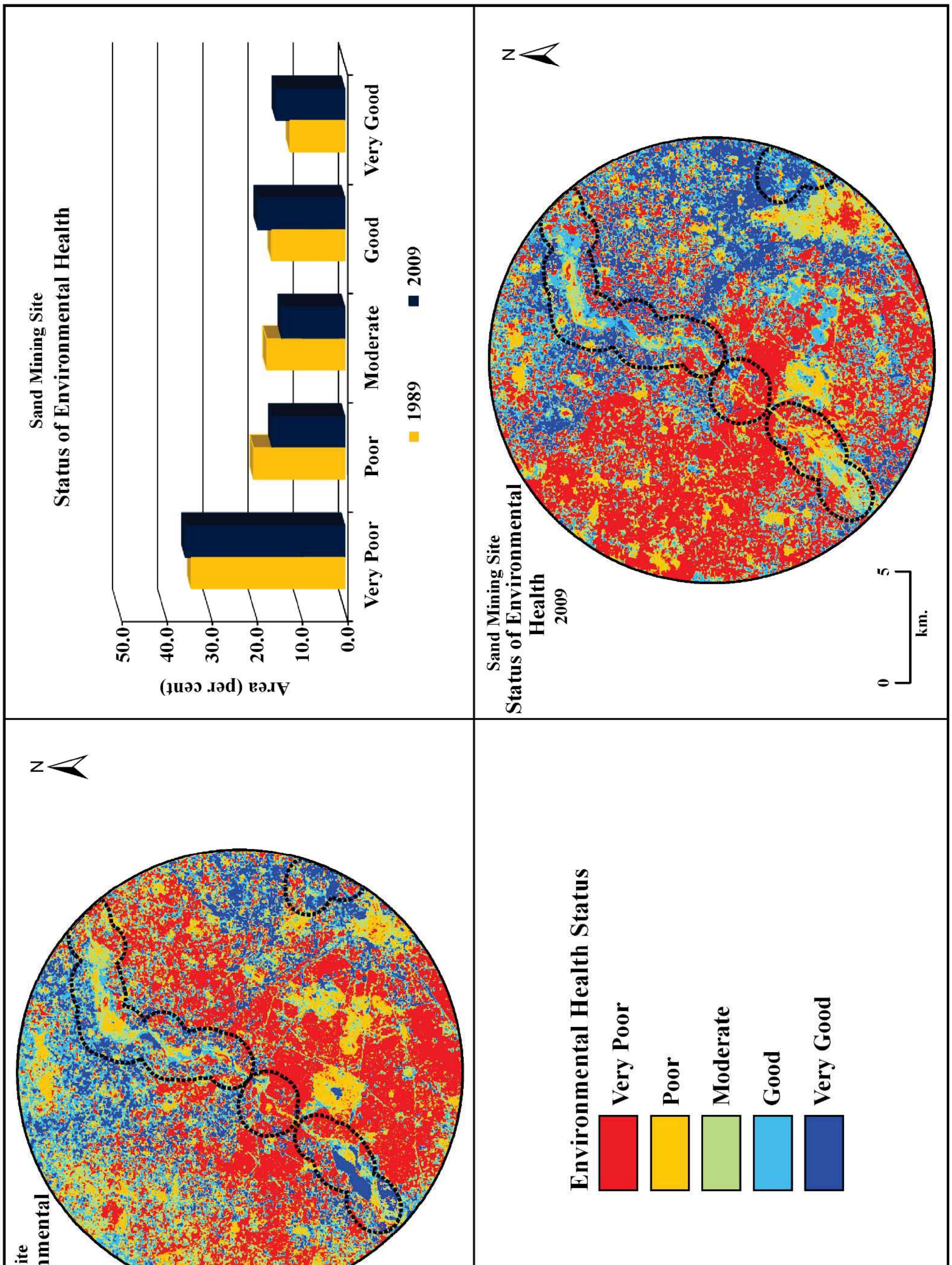
Sand Mining Site
Status of Environmental Health
1989
0
5
km.
N
Sand Mining Site
Status of Environmental Health
Area (per cent)
50.0
40.0
30.0
20.0
10.0
0.0
Very Poor
Poor
Moderate
Good
Very Good
1989
2009
Sand Mining Site
Status of Environmental
Health
2009
0
5
km.
N
Environmental Health Status
Very Poor
Poor
Moderate
Good
Very Good

Fig. 8

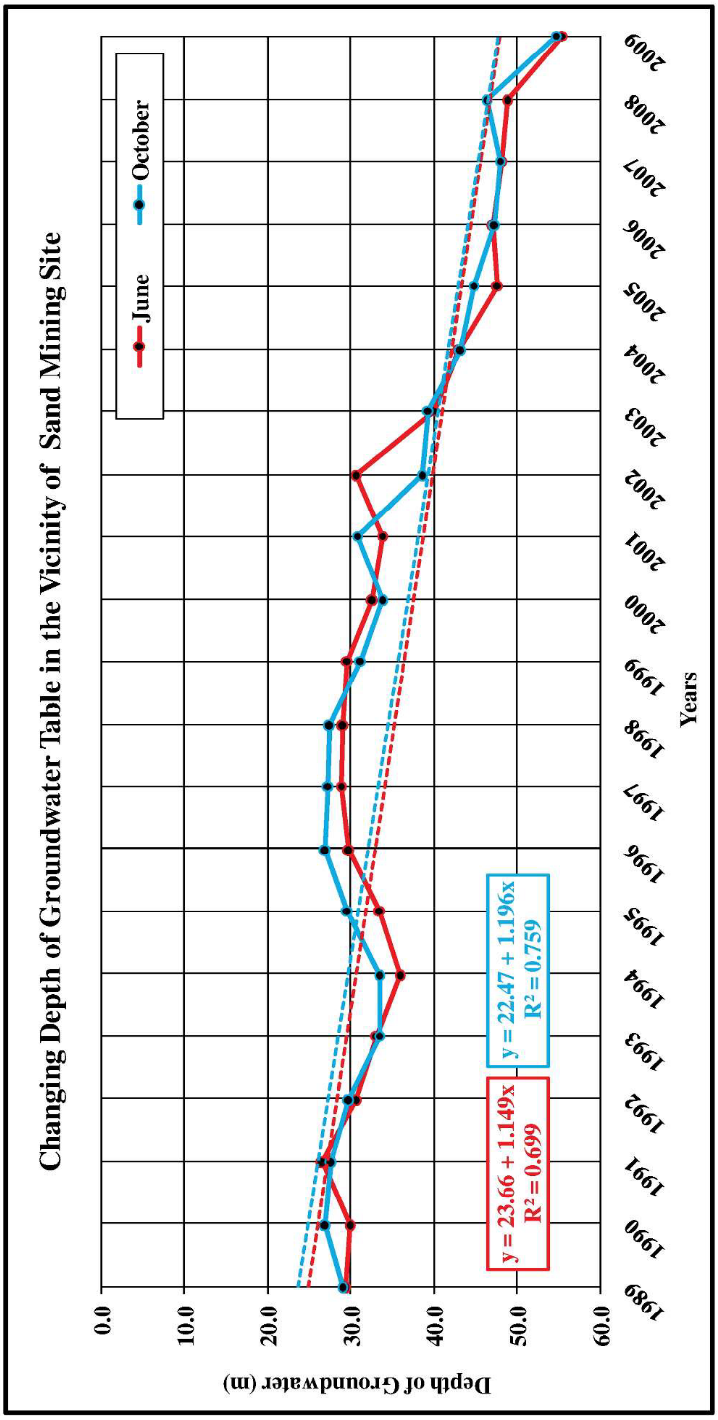
Changing Depth of Groundwater Table in the Vicinity of Sand Mining Site
June
October
y = 23.66 + 1.149x
R² = 0.699
y = 22.47 + 1.196x
R² = 0.759
Depth of Groundwater (m)
0.0
10.0
20.0
30.0
40.0
50.0
60.0
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
Years

Fig. 9

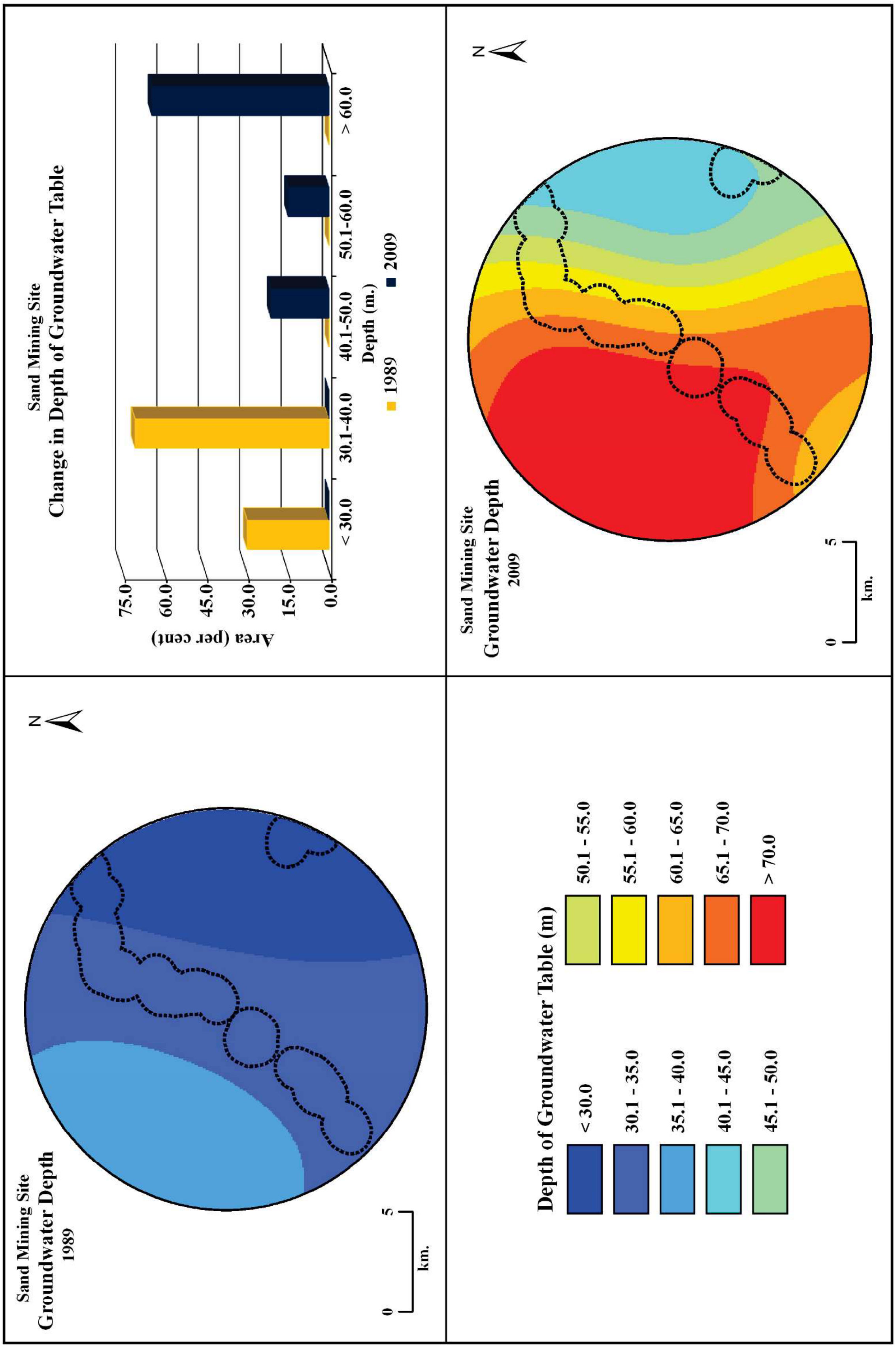
Sand Mining Site
Groundwater Depth
1989
0
5
km.
N
Sand Mining Site
Change in Depth of Groundwater Table
Area (per cent)
75.0
60.0
45.0
30.0
15.0
0.0
< 30.0
30.1-40.0
40.1-50.0
50.1-60.0
> 60.0
Depth (m.)
1989
2009
Depth of Groundwater Table (m)
< 30.0
30.1 - 35.0
35.1 - 40.0
40.1 - 45.0
45.1 - 50.0
50.1 - 55.0
55.1 - 60.0
60.1 - 65.0
65.1 - 70.0
> 70.0
Sand Mining Site
Groundwater Depth
2009
0
5
km.
N

Fig. 10

Table 7
Sand Mining Site in Mahendragarh District: Area under Different Categories of Groundwater Depth

Depth (m)	1989		2009		Change
	Area (km^2)	Area (%)	Area (km^2)	Area (%)	Area (km^2)
Less than 30	93.19	29.66	0.00	0.00	-93.19
31 - 40	220.96	70.34	0.00	0.00	-220.96
41 - 50	0.00	0.00	66.02	21.02	+66.02
51- 60	0.00	0.00	46.29	14.73	+46.29
More than 60	0.00	0.00	201.84	64.25	+201.84
Total	**314.15**	**100.0**	**314.15**	**100.0**	**0.00**

Source: Computed by Authors.

these sites. Shrinking of river bed, depleting water bodies and removal of shrubs also indicate towards adverse ecological impacts. In addition, sand mining has scarred the landscape with pits and trenches resulting in loss of ambience and an increase in land not suitable for productive purposes. This study also highlights that the groundwater table has declined by about 25 m at the rate of 1.19 m per annum in the study area.

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