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Geo-Environmental Consequences of River Sand and Stone Mining: A Case Study of Narnaul Block, Haryana

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Abstract

Accelerated developmental activities during the past few decades have imposed immense pressure on rivers which functions as life support systems. As a result, many river channels in the world have been altered drastically to the level beyond their natural resilience capacity. Among various types of human interventions, indiscriminate extraction of sand and gravel is most disastrous one, as it threatens the very existence of the riverine ecosystem. The present study examines the impact of sand and stone extraction on land and groundwater resources in the Narnaul Block of Haryana. For this purpose, areal expansion of sand and stone quarries and their impacts on local ecology in the study area have been examined using geo-spatial techniques. Images captured by Landsat 1 MSS and Landsat 7 ETM+ satellites between 1975 and 2009 have been used for the analysis. Changes in the natural vegetation as a function of the production level in the quarries have been computed using the normalized difference vegetation index. It is revealed that the vegetated areas have decreased rapidly between 1975 and 2009 following an upsurge in sand and stone mining activity in the region. In addition, excessive extraction of construction material has accelerated the decline in the groundwater level, particularly in the Dohan river catchment part of the study area in recent years. The construction boom has fueled the demand whereas weak governance and rampant corruption have facilitated hysterical and illegal mining of construction material from the dry river channels threatening ecology.

Keywords: *Geo-environmental, Sand extraction, Stone mining, Groundwater, Remote Sensing and GIS.*

Introduction

There has been a distinct progress in built-up area and infrastructure development world over. These advancements however, are contributing to lopsided increase in demand for resources such construction material (Hemalatha et al., 2005). In the past few decades, the demand for construction material has been increasing in many parts of the world due to high rise group housing and commercial complexes, growth of new private townships, adding more lanes to highways, flyovers, modernization of airports, metro railways and other subsequent growth in infrastructure projects (Singh et al., 2007; Leeuw et al., 2010). The contributory factors for this rapid pace of development is rise in foreign remittances and liberalized housing schemes for building constructions mainly from banking sector (Padmalal et al., 2008). To meet this ever growing demand for housing and infrastructure, construction materials such as sand, stone and clay are needed in large quantities (Tepordei, 1995; Marh and Pathania, 2008; Padmalal et al., 2008; Leeuw et al., 2010). Large size materials such as boulders are used for road sloping and wall construction and medium and smaller grades (gravels and sands) are quarried for construction purpose (Padmalal and Arun, 1998; Padmalal, 2006). It is estimated that some 13 billion tons of stone, 10 billion tons of sand and gravel, and 500 million tons of clay are used as construction material worldwide annually (Monforton and Windsor, 2010). Sand and gravel (natural or crushed) account for more than 90 percent of the total volume of concrete used in a wide variety of construction (Kim, 2005).

Due to rapid economic development, growing world population and mounting mega infrastructure projects, the demand for construction material is expected to increase while land-based resources from quarries are not in great supply. Being a valuable nonfuel natural mineral commodity, it is almost impossible to build infrastructure without sand and gravels in any area (Drew et al., 2002; Kim, 2005). However, in today's society the location of extraction operations, regulations, environmental effects, and aesthetic concerns regarding mining are issues of local as well as global concern (Drew et al., 2002; Arun et al., 2006; Apaydm, 2012).

It has been observed in many studies that indiscriminate mining of sand from riverbed and floodplain areas lead to severe damages to the river basin environment. In recent studies the adverse environmental impacts of the extraction of construction material have been recognized and understood by many scholars (Kim, 2005; Arun et al., 2006; Marh and Pathania, 2008; Padmalal et al., 2008; Leeuw et al., 2010; Apaydm, 2012; Tamang, 2013). Various studies (Kondolf, 1994, 1997; Poulin et al., 1994; Padmalal and Arun, 1998; Santo and Sanchez, 2002; Hemalatha et al., 2005; Sonak et al., 2006; Marquez et al., 2007; Navarro and Carbonel, 2007; Singh et al., 2007; Peckenham et al., 2009; Leeuw et al., 2010) reveal that sand mining is taking place at a much faster rate than natural replenishments, which in turn has led to severe ecological disorders. Excessive sand mining causes erosion and deposition in riverbeds which leads to alteration in the topography of the riverbeds and affects the ecosystem of the river (Tamang, 2013). Mining activities lead to changes in forms of channels, physical habitats and food webs (Starnes, 1983; Rivier and Seguier, 1985; Thomas, 1985; Sandecki, 1989; Kitetu and Rowan, 1997), engineering structures associated with river channels (Harvey and Smith, 1998; Padmalal et al., 2008; Tamang, 2013), coastal and near shore environments (Jenkins et al., 1988; Gaillot and Piegay, 1999) agricultural lands (Hemalatha et al., 2005; Govindaraj et al., 2013) and social conditions (Yadav, 2007).

Mining of sand and gravels cause alteration in fluvial characteristics of river channels (Welhan, 2001). One of the effect is modification of groundwater in the channel due to formation of depressions (recharge areas) and change in the pathway of river. Such changes may increase or decrease groundwater recharge whereas shorter flow paths may increase susceptibility to contamination while deflection in river paths may lead to drying up of wells (Kondolf, 1994, 1997; Sonak et al., 2006; Marquez et al., 2007; Navarro and Carbonel, 2007; Peckenham et al., 2009). This often causes reduction of the aquifer volume as well (Apaydin et al., 1996; Welhan, 2001; Apaydm, 2012).

The construction boom in Delhi and surrounding National Capital Region (NCR) in Haryana has generated huge demand of concrete (Singh et al., 2007). This triggered the quarrying of construction materials directly from the beds of the surrounding rivers and adjoining terraces in Haryana. The state has experienced large scale legal as well as illegal mining of construction material heeding to increasing demand of construction resources but not caring for the provisions made in several central legislations for conservation of environment and mineral resources. The illegal extraction of these resources, with generous help of political and bureaucratic big wigs, is so unbridle that not only are the region's precious natural resources being pilfered in a big way, its forests are being clean-felled, land degraded and its rivers threatened with extinction (Yadav, 2002). People dependent upon such activities seem to be least concerned about its environmental impacts, illegal quarrying was a common practice and rampant till the Supreme Court order that banned it in October, 2009. The lack of sufficient information regarding the negative effects of extraction activities has also been an important factor for laying strategies for the conservation and management of the small catchment rivers in the region. Therefore, the present study is a modest attempt to evaluate the impacts of mining of sand and gravels on landuse/land cover, vegetation and groundwater resources around the channel of river Dohan in Narnaul Block of district Mahendergarh in Haryana.

Study Area

Narnaul Block is a part of Mahendergarh district in southwestern Haryana. It shares boundary with four districts of Rajasthan namely Alwar, Jaipur, Sikar and Jhunjhunu. It has a geographical extension between 27° 53′ 58′′ to 28° 11′ 6′′ North latitude and 75° 56′ 2′′ to 76° 9′ 55′′ East longitude (Fig. 1). The total area of the block is about 321 km^2 and the area under sand mining is about 1.90 km^2. But its natural topography is affected by sand extraction and stone mining activities at much larger scale. Dohan is the main river of the study area. The elevation varies from 276 m to 642 m. The study area is mainly occupied by alluvial and sandy plains dotted with flat topped Aravalli ridges. About 80 percent area of the block is less than 350 m. Aravalli hills in the region rise up to 650 m (Fig. 1). The study area has semi-arid climatic conditions with hot summer and cool conditions during winter. The normal annual rainfall is about 422 mm. The southwest monsoon that sets in the last week of June and withdrawal by mid September contributes about 80 percent of the annual rainfall. July and August are the wet months. Remaining 20 percent of the annual rainfall occurs during the non-monsoon months on account of thunder storms and western disturbances. There is significant inter-annual variation in the rainfall. During 1975-2009 highest rainfall of 817 mm was experienced in 1996 while the lowest rainfall of 145 mm was recorded in 2002. Annual rainfall in the area is unreliable as co-efficient of variation of rainfall is 42 percent.

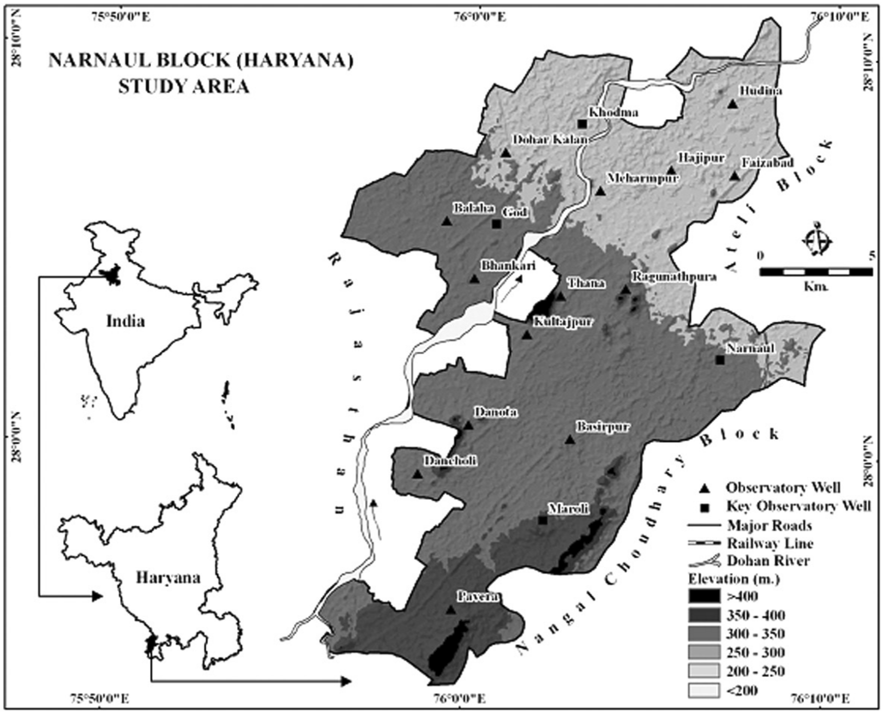

Fig. 1

Objectives

The study mainly focuses on geo-environmental impacts of mining of construction material. It aims to realize following objectives:

1. To study the changes in pattern of landuse/ land cover induced by extraction of construction material.
2. To assess the consequences of sand and gravel mining in terms of impact on groundwater resources and local ecology of the region.

Data Base and Methodology

The assessment of geo-environmental impact of mining activities on local ecology is the prime focus of this study. Though the data on area under different mining activities is not supplied by the Department of Mining and Geology, Haryana, frontier technology i.e. Remote Sensing and GIS has been used for the present study. The satellite data of LANDSAT 1 MSS image for 1975 (Path 158, Row 41 for March 2) and LANDSAT 7 ETM+ for 2009 (Path 147, Row 41 for March 9) have been used to determine the extension and direction of sand extraction and landuse/ land cover changes in the study area. Ancillary data such as Toposheets from Survey of India on 1:50000 scale are obtained to prepare the base map and relief map of the study area. The data related to groundwater depth has been collected from Central Ground Water Board (Northern

Region), Chandigarh and Ground Water Cell (GWC), Department of Agriculture, Panchkula, Haryana whereas rainfall data have been procured from Deputy Director General Office, India Meteorological Department, Northern Region, Chandigarh. Data related to mines revenue has been obtained from the Department of Mines and Geology, Haryana, Chandigarh. The standard image-processing techniques have been employed in conjunction with a temporal decision tree and track changes through time. Hence, the spatial resolution of the satellite imageries restricts the source of information up to some extent. It is not possible to demarcate individual mining site because of their small size, limitations of the technology and non availability of vegetation on the bare hills. Due to moisture content in river bed, grass and shrubs are found and resultant change easily recorded. Field survey was done in the study region for validating the landuse classification in October, 2012 and further related analysis and ground photographs were also taken. The ArcGIS 9.3 and ERDAS IMAGINE 9.1 softwares have been used for database generation, integration of the spatial and non-spatial data for landuse/ land cover, change detection and preparation the results. The detailed methodological process for analysis has been presented in Fig. 2.

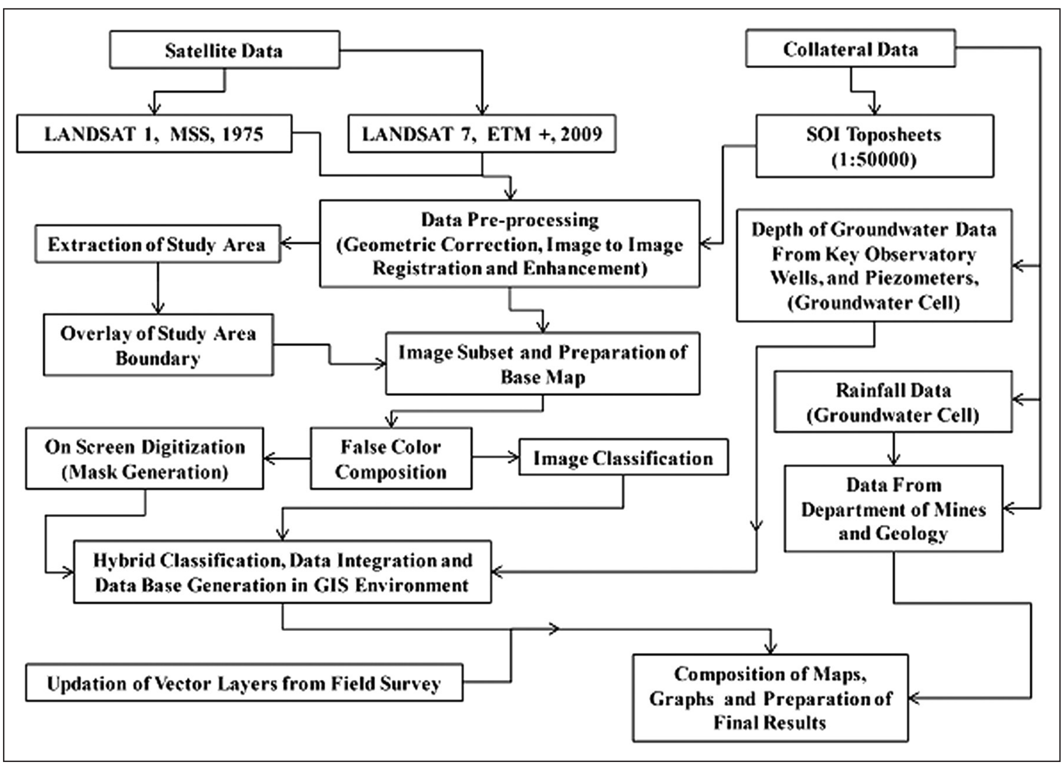

Fig. 2

Results and Discussions

1. Mining of Construction Material

There has always been a competition to exploit the mineral deposits, mining of construction material and pumping of groundwater. Material like stones, sand and gravels are necessary for infrastructure but the various degrees of environmental deterioration caused by mining cannot be disregarded. To have the assessment of mining activities in study area the data related to the number of stone crusher units, number of stone and slate mining contracts, number of sand extraction lease, area under stone, slate and sand mining and revenue from these activities was requisitioned under Right to Information Act, 2005, from Department of Mining and Geology, Haryana, Chandigarh, for the period 1975-2010. But the department refused to provide the data up to the year 2000 due to the absence of record. It provided data for only four aspects, i.e. number of stone crusher units, stone mining contracts, revenue from stone mining and sand extraction. The data provided by mining authorities pertained to Mahendergarh district of which Narnaul community development block is a part. It is to be noted that most of mining activities of Mahendergarh district are concentrated in the Narnaul Block. Hence, the district figures are taken as indicators of status of mining in the study area. Notably, a ban was imposed on mining activities in Haryana by Honorable Supreme Court of India in November, 2009, but it is surprising that the Department of Mining and Geology has provided data for the year 2010 for above mentioned four aspects of mining.

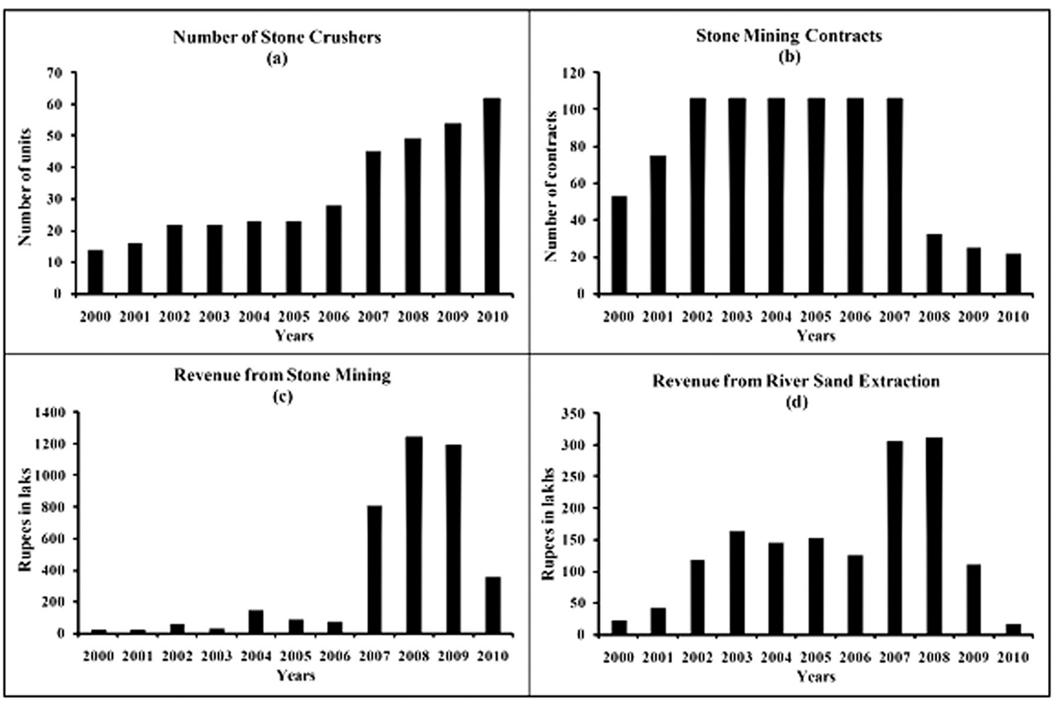

Fig. 3

It is revealed that in study area number of stone crushers units has increased more than four times i.e. 14 to 62 stone crusher units over the period 2000 to 2010 (Fig.3a). Further, there were 53 stone mining contracts in 2001 which increased to 106 in 2002 and continued to be same till 2007 (Fig. 3b). In 2010 these contracts were reduced to 22 because of the ban on mining industry by Supreme Court of India. Till 2006 revenue from stone mining activities was below Rs 1.5 crores, however, after 2007 there was sharp hike in revenue, i.e. more than Rs 12 crores in 2008 (Fig. 3c). Even after the ban on mining activities in 2009, the revenue of state government remained Rs 3.56 crores which was about two and half times higher than that of 2006. This hike in mining revenue is associated with the construction boom in National Capital Region (NCR) and particularly infrastructure development by Delhi Metro Rail Corporation (DMRC) and Commonwealth Games which fueled the demand of construction material. Revenue from river sand extraction also shows continuous increase till 2008 i.e. from Rs 23 lakh in 2000 to 310 lakh in 2008 (Fig. 3d). Broadly speaking, the decision of Supreme Court of India to ban mining activities in Haryana had not been implemented effectively. Even after orders of highest court in India the number of stone crushers increased to 62 in 2010. It has been increase in illegal mining during this period. It is evident from the Plates (Plate-I to Plate-IV) (See page 232). Plate-I shows the extensive river sand extraction in Dohan River and an aerial view has taken from Google Earth. Plate-II and Plate-III show that active and mechanized sand and stone mining activities are mushrooming in the region. These photographs were taken during the field survey in October 2011 and at that time there was blanket ban on mining in Haryana. The curse of mining is evident from Plate-IV as this region is already devoid of vegetal cover and these extraction activities are continuously degrading the natural vegetation.

2. Change in Landuse/ Land cover

Landuse/ land cover changes are very dynamic in nature and needs to be monitored at regular intervals. These changes are the direct and indirect consequences of economic and cultural activities of human beings. A comparative picture of landuse/ land cover pattern of Narnaul Block for 1975 (based on classified LANDSAT 1 MSS image) and 2009 (LANDSAT 7 ETM+ image) has been presented in Fig. 4. The related statistics of area under mining and change detection have been depicted in table 1. As shown in Fig. 4 (See page 231) and Table 1, the sand and gravel extraction has bought about significant transformation in landuse/ land cover of study area during the period 1975 to 2009. Recently, sand and gravel extraction and stone mining activities have also started showing their imprints in the study area. These activities were completely absent in the region in 1975 while in 2009 about 1 percent area was observed under sand extraction and stone mining activities (Table. 1 and Plate-I). Though, the area under extraction activities is very less but their indirect impacts on the local ecology is much broader.

The cultivated area has witnessed major changes in landuse indirectly because of sand extraction and stone mining activities. Cultivated area is progressively being converted either in open area or in residential area. Area under cultivation has experienced reduction of 37.13 km^2 from 1975 (172.36 km^2) to 2009 (135.23 km^2). On the other hand, the open area has notably increased by about 30.47 km^2. In 1975, the open area accounted for about 93.84 km^2 (29.25 percent) area which increased 124.31 km^2 (38.75 percent) in 2009. The desertification is more pronounced in highlighted red circle area of the block which is fertile alluvial plain of Dohan River. It was agricultural land in 1975 which was converted into open area probably due to scarcity of water resources in the region in 2009. The expansion in area under settlements is also significant in the block which is more around Narnaul city because of being a district headquarter. In 1975, the area under settlements was 2.10 percent which increased to 6 percent by the closer of first decade of 21st century. Sand and gravel extraction and stone mining activities have also started showing their imprints in the study area. There is also significant change in area under scrubs. This landuse category has lost its 5.64 sq km area between 1975 and 2009. The squeezing river bed and receding hill slopes also indicate that sand and gravel extraction and stone mining activities are encroaching rapidly on other land use categories in the study area.

3. Depletion of Groundwater Resources

Aravalli ranges are the oldest land formation of the country and cover about 3.7 percent area of Narnaul Block. There are various minerals mined from the Aravallis, which include limestone, dolomite, iron ore, silica sand, china-clay, quartz and slate. But most of the mining activities in the study area pertain to extracting the minerals used as construction material. This includes road material and masonry stone boulder mined from hills and ordinary sand and gravels extracted from the channel of Dohan River (Government of Haryana, 2006). The sand and gravel extraction and stone mining activities in the study area have increased during last decade due to increasing demand of construction material in the surrounding region. Large scale sand and stone mining in this area started during early 1980s which resulted in damage to fragile ecology and groundwater resources. Fig. 5 presents the average depth of groundwater in Narnaul

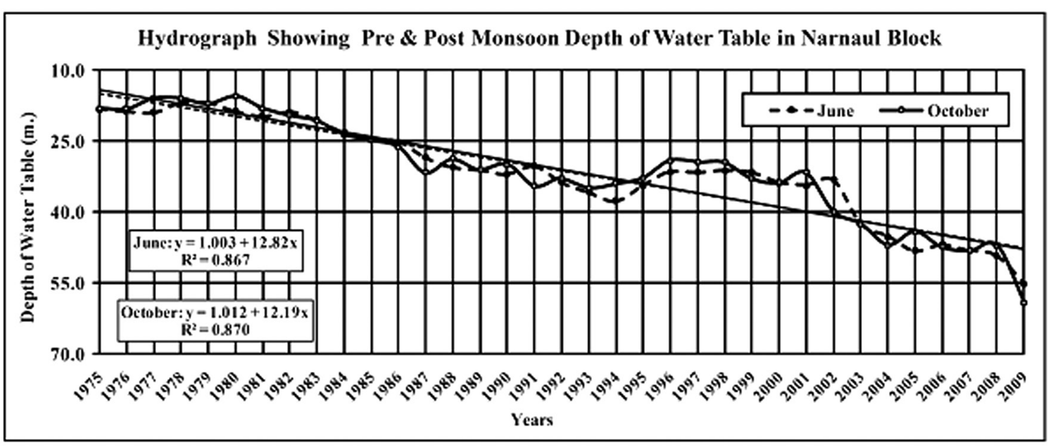

Fig. 5

Block. The information reveals that the study area has experienced drastic decline in depth of ground water during both pre and post monsoon seasons.

The average depth of water table in Narnaul Block has declined from 18.4 m in 1975 to 55.2 m in 2009. It indicates that the water table has declined with an average rate of 1.05 m/year. The late 1970s and 1995 to 1998 are exception to this when depth of water table has risen due to exceptionally good monsoon rainfall. Overall, the area under tube well irrigation has expended very fast since 1980s (Tejpal and Jaglan, 2013). The over withdrawal of ground water for various uses and intensive sand extraction are largely responsible for sharp decline in depth of water table. Fig. 6 (See page 231) depicts notable variations in depth of ground water before and after mining in the block. The spatial pattern shows that the depth of ground water has declined from 10 m to 80 m across the region over a period of 35 years. In 1975, almost entire area except northwestern region had water table at the depth of 10 m to 20 m. But by 2009 entire Narnaul Block had faced critical situation as far as groundwater availability is concerned. The northwestern and central parts of the study area has experienced sharpest decline (65 to 80 m) in ground water depth. The gradient of water table fall is steeper in northwestern and southern parts of the study area (Fig. 6). This is the area where both sand and stone mining activities are carried out intensively and illegally. The long-term ground water fluctuation (1975 to 2009) indicates that average ground water table declined by about 58 m in the study area (Fig. 7).

For present study, some observatory wells are selected for which continuous water level data are available from Groundwater Cell, Panchkula. These are Khodma and God villages (within 2 km distance of Dohan River channel), Narnaul city and Maroli village 5 km away from Dohan River bed (Fig. 1). The selection of these observatory wells has been done for analysis of water table depth with the premises that the area near the river has more possibilities of

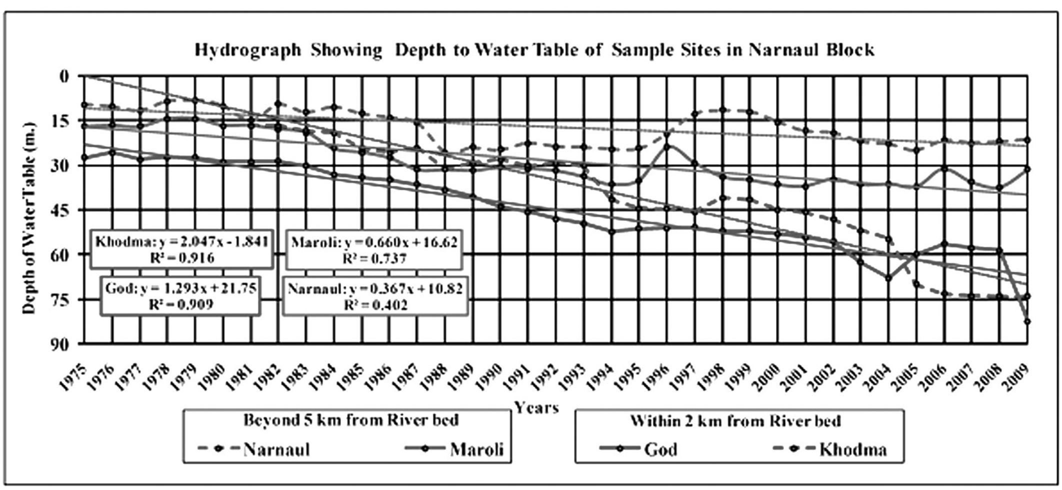

Fig. 7

ground water recharge as compared to those which are situated far away. The scenario of fluctuation in water table depth has been depicted in Fig. 8. It shows that there is constant decline in water table depth at all places. The graphs for Khodma and God villages reveal that in these areas the depth of water table has declined at the rate of 2.0 m/year and 1.3 m/year respectively and the trend value of R^2 explains more than 90 percent variations. These observatory wells are located in the areas that are severely affected by sand mining activities. Though these wells are located very close to river bed, most potential recharge zone of ground water still they exhibit sharp decline in water table.

Compared to Khodma and God villages, the trends of the graphs are at variance for level of water table in tubewells located in Narnaul city and Maroli village. They indicate the 0.3 m and 0.6 m annual decline in ground water depth respectively (Fig. 8). However, the extraction of ground water is more in Narnaul city due to higher demand of drinking.

It has been observed that sand acts as a sponge which helps in recharging the water table and once this layer is removed, the hydrodynamics of the riverbed gets disturbed as sand takes several years for deposition. As sand is extracted rapidly through mining (Plate-I, II and III), the riverbed loses its ability to hold water and this leads to reduction in groundwater recharge.

Conclusions and Policy Recommendations

Indiscriminate sand and stone mining for construction purpose over the years has done irreparable damages to the local ecosystems in southwestern Haryana. The present study reveals that the basin of small and seasonal river Dohan draining in Narnaul Block of Mahendergarh district of Haryana has degraded significantly on account of sand and stone mining over the past few decades.

The mining of sand and stone in the study area has increased due to escalating demand of construction material in the surrounding areas. Over the period 2000-2010 the number of stone crushers has increased by four times while stone mining contracts have doubled. Though, the area under extraction activities is very small (about 1 percent) but the indirect ecological impact of these activities is much broader. The squeezing river bed and receding hill slopes also indicate that extraction activities are encroaching rapidly on other land use categories in the study area. There is a considerable change in land use/land cover signifying a shift from agricultural to non-agricultural uses in the study area. The cultivated area is shrinking because of scarcity of water resources in the region which may be attributed to sand extraction and stone mining activities. This is a prima facie indicator of the effect of mining activities on groundwater recharge. In Dohan River basin the depletion of groundwater resources at a very fast rate is a matter of great concern. It is evident that the study area has experienced constant and drastic decline in depth of ground water during both pre and post monsoon seasons at all places. It has been found that in Narnaul Block the water table has declined at the rate 1.05 m/year. Over the period 1975 to 2009 the ground water table has declined by about 58 m in the study area. The entire Narnaul Block faces critical situation as far as groundwater availability is concerned.

The wells located close to the sites of sand mining in the river channel have experienced exceptionally sharp decline in water table as compare to other areas. This underlines the role of extraction activities in depletion of ground water resources in the region.

There is an urgent need to check and regulate mining activities and associated geo-environmental impacts in the region. For this the district authorities have issued prohibitory orders/circulars after the intervention of Honorary Supreme Court of India. However, the orders have not been properly implemented. Keeping the above finding in view, following policy recommendations are suggested for minimizing the extent of geo-environmental impacts caused by mining in the region.

- The decision of Supreme Court of India to ban mining activities in Haryana had not been implemented effectively because of the fact that the enterprises are still thriving due to increasing demand of construction material and lack of political will. However, a complete ban on mining may lead to unaffordable price rise of construction material which may severely hurt infrastructure projects. Hence, there is a need to evolve comprehensive policy to make these activities ecologically tolerable.
- There should be regular monitoring of these activities and related environmental damages. Mitigation progremmes against these damages should be performed and regular inspections should be carried out to keep these activities under control within ecological permissible limits. Department of Mines and Geology must limit the extraction of sand and gravel mining to meet the indigenous demand alone. The suitable sites for extraction of construction material may be identified to minimize the large ecological impacts in the region.
- Groundwater is a crucial source of irrigation for the farmers in Narnaul Block to eke out the living since there is no other perennial source of irrigation in the region. Since the aquifer recharge and depletion of groundwater in the region is linked to sand mining there is a need of monitoring the sand extraction activities from the river bed in the region. Effort should be made to increase ground water recharge efficiency through the rain water harvesting technologies and the reclamation of abandoned mine pits which left after mining activities.
- People dependent upon such activities seem to be least concerned about its environmental impact. Therefore, awareness campaign should be carried out at various levels among people about the impacts of mining with immediate need for control measures.

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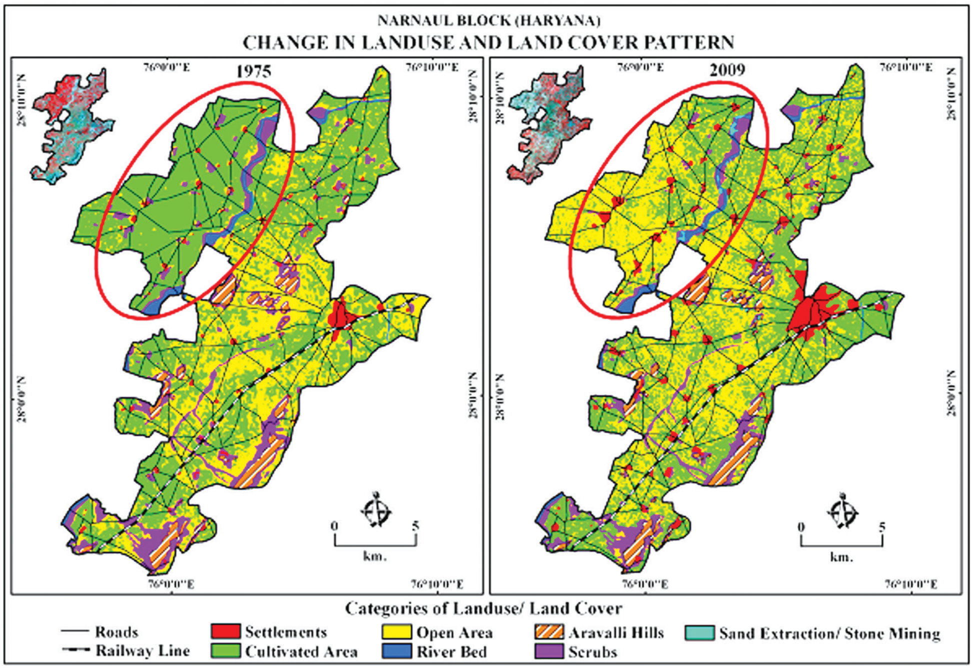

Fig. 4 (For text see page 223)

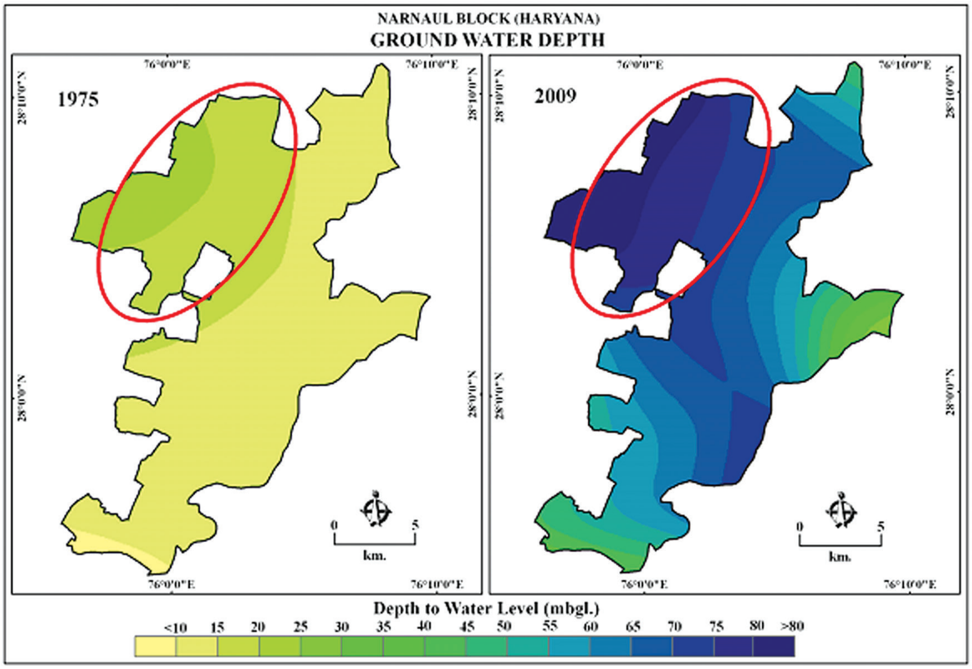

Fig. 6 (For text see page 225)

Plate-I: Sand and gravel extraction site (Reproduced from Google Earth, October 26, 2010).

(For text see page 225)

Plate-II: Illegal sand extraction from Dohan river bed.

(For text see page 225)

Plate-III: Mechanized and illegal stone mining in Aravalli Hills, near Kultajpur village.

(For text see page 225)

Plate-IV: Degradation of natural vegetation due to sand extraction, near Nangal Katha village.

(For text see page 225)

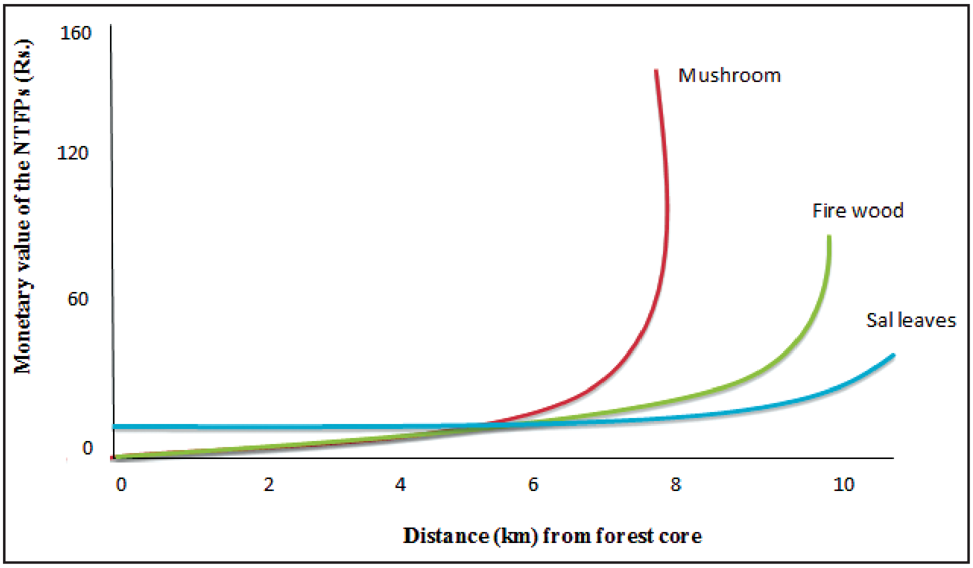

Fig. 4: Increase of monetary value of the NTFPs (Rs.) with increasing distance (km) from forest core (Based on Primary survey) (For text see page 241).

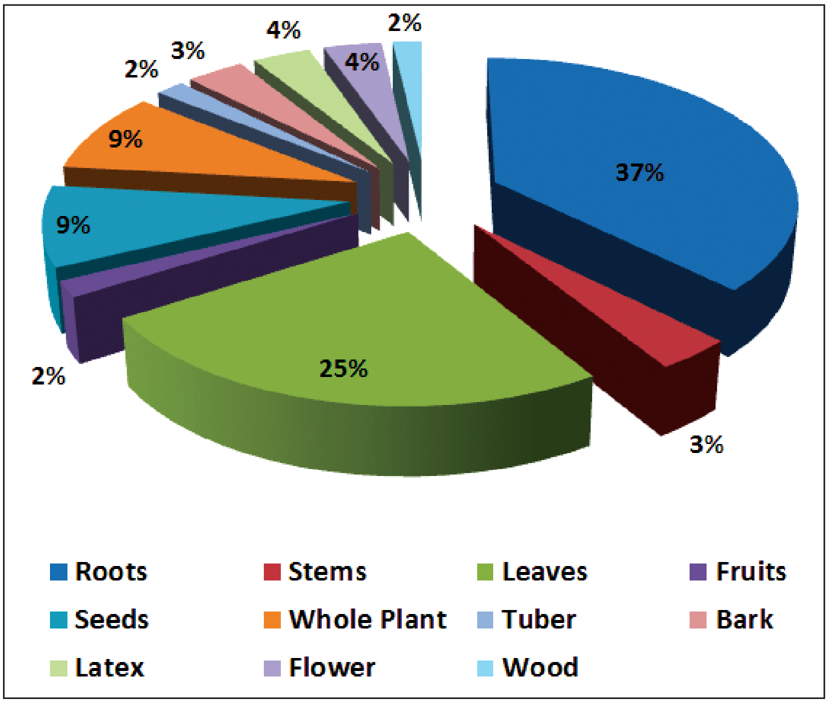

Fig 5: Proportion of plant parts most widely used by the Santals for medicinal purposes (Based on Primary survey) (For text see page 242).

Photograph 1a: Villagers carrying sal leaves for commercial purposes.

(For text see page 240)

Photograph 1b: Head-loading of firewood by Santal women at Jaypur forest.

(For text see page 240)

Photograph 1c: Santal women stitching Sal leaves for making Sia-pata.

(For text see page 240)

Photograph 1d: Santal women collecting green sal leaves.

(For text see page 240)