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Technical Bulletin 5/2007

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CENTRAL SOIL SALINITY RESEARCH INSTITUTE
KARNAL-132 001, HARYANA, INDIA

2007

Science in nation building

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SAND, MINING OR NO MINING IN AGRICULTURAL FIELDS IN HARYANA

Consultancy Project

Investigating team

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Dr. K.K.Mehta Head & Principal Scientist	Principal Investigator	(Soil Science) Crop yield, supervision and report compilation
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EXECUTIVE SUMMARY

The Director of Mines and Geology, Haryana in reference to a case in the High Court of Punjab and Haryana, Chandigarh requested the Director, CSSRI Karnal, to study different mining sites in Karnal, Panipat and Sonipat districts so as to know the impact of sand mining on soil properties and crop growth in comparison to the un-mined fields. The scientists of CSSRI under a consultancy project conducted the investigations. The Yamuna basin located between river Yamuna and national highway number 1 from Karnal to Sonipat is deposited with several meters deep good quality sand. This sand is overlaid with 1 to 4 meters topsoil. The sand is mined under the Minor Mineral Act of the Government of India under which the contractor pays royalty to the Government of Haryana and a mutually agreed sum to the landowner. During sand extraction, topsoil layer is peeled and stacked aside and exposed sand is excavated to a depth of 10-12 m. Afterwards, stacked topsoil is spread and mixed with sand bed. As mining proceeds further, the mined fields are handed over to the owner for cultivation. The team investigated the mined and adjacent un-mined fields at several places in the above three districts for soil profile studies, physical, chemical and microbial characteristics, infiltration rate, fertility, crop yield and ground water quality to know the effect on soils, water, crops and landform.

Sand mining apparently is a land degradation process, which disturbs soil profile, spoils surface configuration and considerably alters topography of the land. Rehabilitation of sand mines starts with spreading, mixing and leveling of topsoil with sand bed. The resulting loose mass contains about 50 to 60 percent lesser clay and silt in comparison to topsoil but most importantly they inherit some useful genetic characteristics that plays a catalytic role in soil development. Commencement of agricultural operations for crop production caused soil cohesion, which further triggered the processes of soil formation and profile development. As crop cultivation continued the physical, chemical, biological and nutritional properties of soil improved as evident by darkened soil colours, build up of horizonation and improvements in soil structure, which adds to the stability and productivity of the soil. Soil organic carbon content increased from 0.2 percent in 1st year to 0.42 percent in the 5th year and had reached to 0.69 percent in the 12th year surpassing that of original soil by 16 percent. All the major and micro plant nutrients also made notable recovery and reached to the level found in un-mined soils by 5th year. Microbial population and dehydrogenase activities that favour decomposition of crop residues and nutrient transformations also improved with time. Excessively rapid infiltration rates in the freshly leveled fields had significantly come down to moderate level in the 5th year of reclamation thus significantly reducing the need of frequent irrigation in these soils.

The reclaimed soils produced significantly lesser yields in the initial one or two years. The extent of decrease in crop yields depends upon the management level. The decrease was about 30 percent in case of rice and 20 percent in case of wheat crop in the first year and this decrease was reduced to about 10 percent after 5 years. By 12th years, the yields were surpassed by nearly 11 percent. Yields of sugarcane, sorghum, gram, tuber crops and vegetables initially yielded lesser but reached at par with the yields obtained from un-mined soils after 5 to 7 years of reclamation. Thus, governed by the methods and process of soil-rehabilitation, the breakeven point in crop production and soil improvement was reached between 5th and 12th years of reclamation.

Several fruit and timber trees performed exceedingly well when planted on reclaimed soils. Natural vegetation in the form of “ber” (*Zizyphus jujube*), ”aak” (*Calotropis spp.*), grasses and bushes reappeared and performed well on side slopes eliminating any doubt about possible damage to bio-diversity due to sand mining.

Sand mines have definite impact on surface configuration and topography of the land. Small sized mines are prone to flooding and erosion and a permanent threat to the adjoining lands. While large sized sand mines by virtue of their size are less threatened by floods, rather these could play vital role of a large ground water recharging or water harvesting body in the event of unusually large floods feared in future due to global warming. Highly sloping edges and buffer zones were found the most fragile components in sand mining. High degree of priority must be accorded to preserve them by computing appropriate width of buffer zone and suitable degree and shape of slopes with long term stabilization under vegetation adopting site-specific soil and water conservation measures.

The findings indicate that sand mining causes loss in the yield of major crops in the initial 2 to 3 years but a break-even point in yields and soil improvement is achieved after 5th year of reclamation. Therefore, sand mining from agricultural fields should be permitted provided the mine lands must be returned to agricultural land use after concurrent reclamation under guidance and monitoring of agricultural experts.

INTRODUCTION AND NEED FOR SAND MINING

Sand is an integral part of soil. When present in right proportions it imparts favourable properties and improves soil productivity. Similarly, sand is an important aggregate used in bulk in construction industry. Beginning 21st century, India is witnessing a spurt in infrastructure sector. Construction of high rise group housing and commercial complexes, growth of new private townships, adding more lanes to highways, expressways, flyovers, bridges, modernization of airports, metros, game villages, stadiums and construction of abodes by ordinary people has given ample impetus for mining large quantities of sand (Plate-1). Rivers are the major sources and suppliers of sand as they replenish themselves every year during four months of monsoon. In southern states, River Godavari is sand mined over 28 km stretch at Lanjamadagu Sivaram Wildlife Santury in Andhra Pradesh, River Tungbhadra is sand mined in Honalli and Harpanthali tehsils, Similarly, rivers like Palar, Thamiraparani and Sankaraparani in Tamil Nadu, Cauvery in Karnataka and Bharathapuzha in Kerala are sand mined legally and illegally for over decades. In northern states too, sand extraction is common in River Ganga in Uttrakhand and Uttar Pradesh; River Chambal at Pipari Sand Mines and across Chambal Bridge on National Highway no. 3, River Ravi and Beas at Madhopur and Mirthal in Punjab and River Yamuna in Haryana and Delhi. Several protection groups and environmentalists are raising concern about sand mining of riverbeds. According to them, unregulated and illegal sand extraction might deepen the riverbed, erode riverbanks and prove dangerous to river ecology. In order to save River Yamuna and avoid any catastrophic affect on Delhi, the authorities have rightly acted to regulate sand extraction from Yamuna riverbed. But construction boom in Delhi and surrounding National Capital Region in the bordering states of Haryana and Uttar Pradesh has generated tremendous demand for additional and alternative sources of sand. Quarry dust to some extent is available in the region but its particle size is not suitable for concrete making. Therefore, additional sources of sand have to be found to save the construction industry from difficulties and to check rise in construction costs.

Plate 1 : *Booming construction and infrastructure sectors have generated tremendous demand for sand in India.*

SAND MINING IN AGRICULTURAL FIELDS IN HARYANA

Nature has given us sand as a natural resource. The man has to use it wisely for the larger benefit of the society and sustainable development. The extraction of minerals not only provides the building materials but also generate employment to the locals engaged directly in extraction of sand as well as indirectly in transportation and sale of mineral. It also earns huge sum of revenue in the form of mineral royalty for the State Exchequer. In early days, sand mining was confined mainly to riverbeds. As the demand for sand increased, sand mining started in agricultural fields too (Plate 2). In Haryana, sand mining in agricultural fields started in Karnal district where sand mineral existed 2 meters below the ground deposited by the River Yamuna, which used to flow from these sites. The Government of Haryana under the Minor Mineral Act of the Government of India is granting contracts for the last three decades for extraction of buried sand from agricultural fields in district Karnal. Such contracts subsequently were extended to Panipat and Sonipat districts. Till the year 2006 only 1070 ha area was sand mined but recently sand extraction in these districts has increased significantly to meet the demand of booming construction activities.

Plate 2 : *Sand mining is increasingly practised in agricultural lands, Nagla Mirgain Sandmine in Karnal*

SOURCE OF SAND IN YAMUNA BASIN

Yamuna basin is bordered by river Yamuna from Yamunanagar to Delhi and National Highway No. 1 from Nilokheri to Delhi. Between Nilokheri and Delhi the National Highway No. 1 is aligned on the levee of River Yamuna and acts as water divide between the ancient River Saraswati and Yamuna. The Riverine action deposited several meter thick sand layers in the riverbed. Slow shifting of river Yamuna towards east left behind several meter deep sand deposits, which was subsequently covered by alluvium consisting sand, silt and clay to form topsoil. The Yamuna basin (Figure 1) measuring around 1700 sq km is estimated to have 300 billion cu m sand deposits lying below agricultural land.

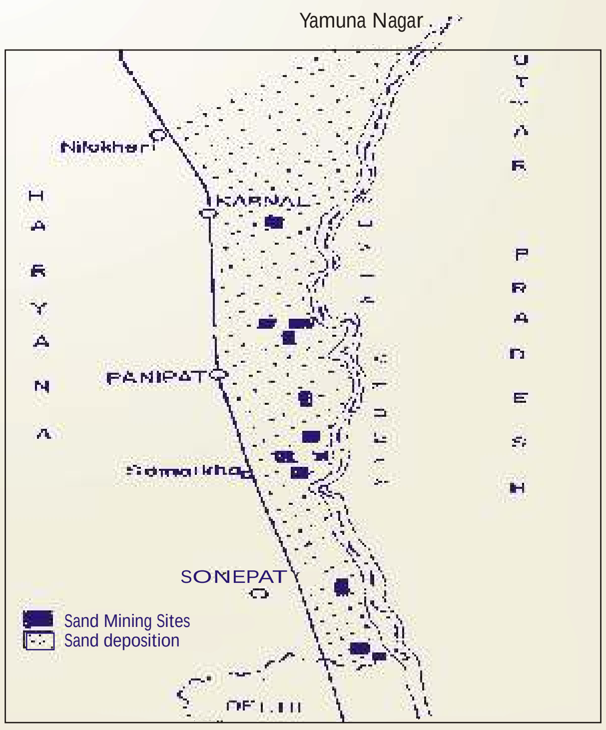

Fig. 1 : *Sand deposits in Yamuna basin*

SAND MINING VIS-À-VIS AGRICULTURE

Mining and agriculture are the only two industries from which the mankind receives directly. In the fast growing economics of vibrant India both of them play important role, one in developing infrastructure and the other in maintaining food securities. Agriculture is a low-return, sustenance activity practiced year after year on the same piece of land and do not cause much hazards to environment and topography, while mining is a high-return industry, restricted to lands where large deposits of concentrated minerals occur. Mining changes the topography and demography of the area and triggers environmental hazards. In a situation like Haryana, where large deposits of sand exist beneath agricultural land in the immediate neighbourhood of mega construction zone, question arises, should it be mined or left to agriculture? Answer to this is not simple. The market driven forces govern the land use of such lands (Plate 3). Much constrained agriculture is often non-remunerative and small farmers therefore, lease out their land for sand mining for 2 to 3 years, which fetches an income of Rs. 6-8 lakhs per hectare. Sand mining also becomes a source of livelihood for the people in the vicinity. The workers in sand mines get as much as Rs. 1,000 a day. Thus, the locals have a positive mindset towards sand mining. Therefore, imposing a total ban on sand mining and protect the land for agriculture may not succeed. Guided by the easy money and vested interests the powerful sand mining lobby might resort to illegal and indiscriminate sand mining causing devastation and degradation of land resources. Keeping in mind interest of both the agriculture and construction industry, the best option would be to regulate sand mining under the provision of the law and prescribe concurrent reclamation of the mined land for return to the agricultural use. Thus, sand mining from agricultural fields could be considered provided ecologically sensitive areas and diverse habitats are protected and mined areas are immediately reclaimed to preserve the nature of property as an agricultural enterprise.

Plate 3 : *Market driven forces are governing the land use of agricultural lands. Machharauli sand mine in Panipat*

VILLAGERS RESPONSE TO SAND MINING

Small farmers in need of money lease out their land to the contractor, while some big farmers purchase land from small farmers and give it for sand mining or they themselves do it as they or their associates are contractors. Some farmers with money in their hands purchase earth-moving machinery for sand extraction. Soon their economic and social status improves, which attracts other farmers also to follow suit. While some farmers apprehend sand mining as a degradation process and doesn't want any mining activities in their neighbourhood. One such farmer Mr. Ajit Singh of village Harisinghpura in Karnal district fearing damage to his land from nearby sand mine approached the courts. As per directives of the courts, the Mining Department of the Government of Haryana approached the Central Soil Salinity Research Institute, Karnal (CSSRI) to study the impact of sand mining on soil properties and crop yields so as to provide guidelines for framing sand mining policy in the state. A team of scientists from the CSSRI under a consultancy project studied the mined and adjacent un-mined sites (Plate 4) at several places in Karnal, Panipat and Sonepat districts to ascertain the impact of sand mining on soil properties and crop growth, which so far has not been studied in India.

Plate 4 : *Investigating team interacting with the farmers at Hari Singh Pura sand mine*

METHODS OF INVESTIGATIONS

After a rapid field survey of small and large sand mining sites occurring in three districts of Karnal, Panipat and Sonipat, five representative mine sites undergoing mining and land-rehabilitation for different periods were selected for investigation (Plate 5). The locations of selected sites were marked with Geographical Positioning System (GPS) and studied for soil-site characteristics. Soil profiles were dug to 1.5 m depth to study soil morphology and degree of soil development. Depth wise soil samples were collected for physico-chemical analysis to access salinity, alkalinity and carrying capacity of soils. Soil samples for nutritional and microbiological properties were collected separately. Soil infiltration rates were measured by installing infiltrometer rings in the fields. Few ground water samples from nearby sources were collected for quality appraisal. Standard laboratory procedures were adopted in all analysis. Crop growth mainly of wheat, sugarcane and vegetables was recorded both in the mined and un-mined areas for comparison. Measurements of plant growth parameters such as number of tillers per unit area of wheat, height of wheat plants and length of wheat ears were recorded. As the wheat crop was in the advanced stage of maturity, estimated grain yields were made based upon visual observations and discussions with the farmers. Photographic record was made for mining operations, sandpits, slopes, soil profiles, growth of crops, trees, vegetation etc.

(a)

(b)

Plate 5 : *Group of scientists studying (a) 10m high sand column and (b) freshly leveled sand pit at Nagla Mirgain sand mine*

LOCATION OF STUDY AREA

The sand mining areas are located between the Yamuna River and National Highway no.1 in the districts of Karnal, Panipat and Sonepat. The present studies were mainly confined to sand mines of village Nagla Mirgain and Harisinghpura (Karnal), Khotpura and Machhrauli, Garhi Chhaju, Beoli, Jorasi (Panipat) and Palra, Basodi, Nandnour (Sonipat). Site characteristics of sand mine sites are presented in Table 1. The thickness of topsoil cover varies from a thin cover of 0.7m at Basodi mines in Sonepat district followed by medium thickness of 1.5 m at Nagla Mirgain in Karnal district and a thick soil cover of 4.0 m at Machhrauli-Baholi mines in Panipat district. Similarly, the range of soil textural classes in different sand mines differs from loamy sand to sandy loam at Sonepat, sandy loam to sandy clay loam at Karnal and sandy loam to clay loam at Panipat. In most of the mines sand has been removed upto 10-12m from the ground surface and land-rehabilitation activities by the farmers are in operation for the last 1 to 12 years.

Table 1. Location and site-characteristics of studied sand mines in Haryana

Sr. No.	Village/location	District	Mining Area (ha)	Top soil cover (m)	Soil texture Class	Mining depth (m)	Years of land rehabilitation
1	Nagla Migrain 29^0 37' 42" N and 77^0 3' 22.2" E	Karnal	300	1.5	Sandy loam to sandy clay loam	10 -12	1-12
2	Harisinghpura and Khotpura 29^0 27' 29"N and 77^0 0' 57"E	Karnal & Panipat	40	3.6	Sandy loam to sandy clay loam +	10 -12	3
3	Machhrauli, Garhi Chhajoo and Baholi 29^0 16'7" N and 77^0 2' 35"E	Panipat	80	4.0	Sandy loam to clay loam	12 -14	2 - 7
4	Jaurasi and Poanti 29^0 13'51" N and $77^0$2'29" E	Panipat	30	1.2	Loamy sand to sandy loam	9 -12	5
5	Basodi & Nandnour 29^0 0' 41.5"N and 77^0 8' 20" E	Sonepat	500	0.7	Loamy sand to sandy loam	10 -14	2 - 7

PROCESS OF SAND MINING

The sand mine contractor after obtaining mining rights pays the auctioned royalty to Haryana Government and a mutually agreed sum ranging between Rs. 6-8 lakhs per hectares to the farmer to take on lease his land for sand extraction.

It is important to understand as how sand mining is done so that one can understand the reasons for the changes in soil properties etc (Plate 6&7). First of all, the soil mass is scraped from upper 2 to 3 meters, which contains mostly clay, silt and sand and is purposely saved and stacked aside in heaps, for use later on as soil spread on sand debris. The exposed column of sand is removed by the contractor and sold in the market. About 15 years ago, manual extraction and higher water tables restricted the sand removal to 5 and 6 m but in recent times use of Earth Moving Machines (EMM) and receding water tables have facilitated sand extraction to a depth of 10-12 m. After sand is removed, the heaped soil mass is evenly spread over the sand bed for the farmer to begin land restoration by leveling, bunding and tending his land to start cultivation.

Plate 6 : *Process of sand mining : thick column of sand (light grey) is removed. Overlying top soil cover (dark grey)is pushed down the slope to evenly spread over the sand pit*

Plate 7 : *After spreading and mixing top soil with sand, the field is compacted, leveled and bunded to commence cultivation*

IMPACT OF SAND MINING ON AGRICULTURE

To know long-term impact of sand mining on agriculture data obtained from Nagla Mirgain sand mine have been discussed as this sand mine was operating for the last two decades and also land-rehabilitation activities were in place for last 12 years. Wherever needed, relevant data and experiences gained from other sand mine sites is also included.

Effect of sand mining on soil profile development

Soil morphology and physico-chemical characteristics of studied soil profiles are presented in Appendix-I. The morphology of soil profile like colour, texture, structure, compaction, porosity and roots etc indicates soil development. The soils of village Nagla Mirgain sand mines under three stages of land rehabilitation viz; immediately after soil mixing and leveling (0-Year), crop cultivation for 5 years and 12 years in comparison to original and un-mined soil showed changes in soil morphology. These changes are easily discernable from the pictures of soil profiles and morphology presented in Plate 8-11 and Table 2. The original un-mined sandy clay loam soil in the field of Sh. Sher Singh is a young moderately developed soil with grayish brown colour, strong blocky structure and well-differentiated soil horizons. In comparison the first stage of land-restoration (0-year) in the nearby field of Sh. Sher Singh can be termed as virgin soils with loose soil mass, pale brown colour, and weakly developed granular peds, which indicate inheritance of useful characteristics of original Nagla Mirgain soil. Mixing of topsoil with sand bed has resulted into loamy soil texture, which is likely to appropriate air-water balance to enhance soil productivity. Nevertheless, such lighter soil textures might pose difficulties in seedbed preparation during the initial years of cultivation. But soil compaction by heavy machinery, irrigation and root activities etc are likely to cause soil cohesion, which should favour soil development in the subsequent years. Common occurrence of clay-clods of 5 and 40 cm in the soil profile during rehabilitation stages indicate improper mixing of topsoil. Careful mixing after breaking such clods is desirable for affecting improvements in soil texture and structure. The soils represented by rehabilitation for 5 and 12 years in the fields of Sh. Balwant Sangwan and Sh. Balkar Singh Bhindar, respectively, showed marked signs of soil development by way of darkening of colours from pale brown to dark brown, structure from very weakly blocky to granular and blocky. Presence of abundant roots and firm compaction indicate marked degree of soil formation and horizon development. Biotic factors (roots, microbes and human activities) appear to have played a key role in soil forming activities. Extensive root

Plate 8 : *Profile of an original soil at Village Nagla Mirgain. See moderate degree of soil development and sharp boundary of sand layer at 1.50m depth*

Plates 9-11 show progression of soil development during reclamation of sand mine

Plate 9 : *0-1 year ; loose soil mass and no horizon formation indicate no soil development*

Plate 10 : *5 years ; slight differentiation of horizons and granular structure indicate very slight soil development*

Plate 11 : *12 years ; darkening of soil colours and granular blocky structure indicate slight soil development*

Table 2. : Progressive improvements in soil morphology under different periods of land rehabilitation of sand mine in village Nagla Mirgain (Karnal)							
Soils class Un-mined/ rehabilitated	Horizons	Colour	Textural class (Clay %)	Structure	Compaction	Roots	Pores
Un-mined soil	Well formed	Grayish Brown	Sandy clay loam (24.0)	Strong blocky	Very firm	Abundant	Less porous
0-Year rehabilitation	Loose mass	Pale Brown	Loamy sand (8.1)	Very weakly granular	Very slight	Nil	Highly porous
5-Years rehabilitation	Very slight	Brown	Loamy sand (8.5)	Weak granular	Slightly firm	Abundant	Very porous
12-Years rehabilitation	Slight	Dark brown	Light sandy loam(9.2)	Granular/ blocky.	Moderately firm	Abundant	Slightly porous

proliferation and subsequent decay has resulted in binding loose sand grains into granular structure to improve water-holding capacity, which in turn has favoured soil-weathering processes. These changes in the initial years of rehabilitation were restricted to surface layers but in due course of time extended to subsurface layers too. Rehabilitated soils from other sand mine sites at villages Harisinghpura, Khotpura, Machhrauli, Garhi Chhajoo and Basodi etc also showed similar improvements in soil morphology and profile development.

Temporal changes in soil development

Sequential changes in rehabilitated soils over a period of 1 to 12 years have been shown in Fig. 2. Five classes of soils viz; sand, loose soil mass and soil under rehabilitation for 1,5 and 12 years have been correlated and compared with the original un-mined soil for colour, structure and organic carbon content. Yields of wheat obtained from respective soil were also plotted. The colour had gradually darkened from pale brown in 1st year to dark brown in 12th years, which were 2 values darker than the grayish brown colour of un-mined soil. The soil structure a very useful property of soil and a good indicator of soil development had gradually graded from weak granular in 1st year to granular blocky in the 12th years. Granular blocky structures denote aggregation of granules in the shape of small blocks leading to a stable soil profile. Similarly, organic carbon had increased by more than 400 percent in 12th year and had even surpassed the un-mined soil by 16 percent. Clay content from 24 percent in the original soil decreased to 8.1 percent in the 1st year and very slowly increased to

Fig. 2 : *Graphical representation of soil development and crop production during successive years of reclamation of sand mines*

8.5 and 9.2 percent in 5th and 12th years thus, changing soil textural class from loamy sand to very light sandy loam. In line with soil improvement and development, the wheat yield had also increased from 2.5 t/ha to 4.2 t/ha to reach at par with the yields obtained from un-mined soils. The graph show that a break-even point of soil development and crop production is achieved somewhere between 5th and 12th years of land rehabilitation.

Effect on soil physico-chemical characteristics

Physico-chemical characteristics like soil reaction, calcium carbonate, organic carbon, cation exchange capacity (Table 3) etc. govern the fertility and productivity of a soil. The soil pH influences the availability of essential plant nutrients. Soil pH was found slightly alkaline in both the un-mined soil and in the soil of 0-year of land-rehabilitation indicating mixing effect of topsoil. The other two rehabilitated soil classes showed neutral pH, which is optimum for availability of most nutrients. The $CaCO_3$ content decreased from 4.2 percent in un-mined soil to less than 1.6 percent in rehabilitated soils. Occurrence of soil organic matter is important for good health of soil as it stores and makes available nutrients and water to plants. The organic carbon contents in soils depend upon the amount of manures and other organic material added. During land-rehabilitation, the farmers usually apply heavy doses of organic materials, which has build up organic carbon content to 0.42 and 0.69 percent, respectively in the soils after 5 and 12 years of rehabilitation. Similar improvements in physico-chemical characteristics of other sand mines were observed. Soil Cation Exchange Capacity (CEC) is the most vital soil property. In all three rehabilitated soil classes, CEC values of 6.2, 5.6 and 4.7 were found slightly lower, requiring higher doses of nutrient application and better tillage management.

Table 3. Changes in physico-chemical characteristics of original un-mined and rehabilitated soils for different years at sand mine in village Nagla Mirgain (Karnal)

Soil class	pHs	$CaCO_3$ (%)	Organic Carbon (%)	CEC cmol(p^+) kg^{-1}
Original Un-mined soil	8.4	4.2	0.58	11.2
0-Years	8.4	1.5	0.07	3.2
5-Years	8.2	1.6	0.42	3.3
12-Years	7.9	1.4	0.69	4.0

Effect on soil salinity and alkalinity

The subsurface layers showed negligible salt content, therefore salt content in the surface of Nagla Mirgain soils is given in Table 4. Salt concentration in excess of ECe 4.0 causes soil salinity. The total salt concentration and ionic composition in the studied soils of Nagla Mirgain village were found safe to cause any problem of soil salinity. The ECe and ionic composition in rehabilitated soils were significantly low in comparison to original un-mined soils. Similarly, these soils did not suffer from any residual alkalinity as concentration of Ca and Mg ions exceeded than the HCO_3 ions. Thus, sand mining did not pose any salinity/alkalinity threat to these soils.

Table 4 : Total salt content and ionic composition in studied soils

Soil class	ECe (dS/m)	Na	Ca+ Mg	K	HCO_3	Cl
		me/l				
Original Un-mined soil	1.10	5.4	5.1	0.11	3.8	6.6
0-Years	0.83	4.3	2.5	0.14	1.7	5.7
5-Years	0.46	1.9	2.7	0.15	2.2	2.6
12- Years	0.34	1.3	1.9	0.17	1.7	2.1

Effect on soil infiltration rate

Soil infiltration rate indicate the movement of air and water in soil. Steady Infiltration Rate (IR) was measured in original un-mined and rehabilitated soils by double ring method (Plate 12). To overcome spatial variability in the field average of three rings were obtained. Steady IR of original soil was generally low and ranged from 1.7-4.0 cm/day (Table 5). This type of IR can be considered good for growing rice, a crop grown in standing water conditions. However, for other arable crops low IR can lead to water logging resulting in soil aeration problems. Steady IR in freshly rehabilitated soil (0 years) was very high i.e. 97.5 cm/day. This was due to marked change in soil texture resulting in mixing topsoil with sand bed. Steady IR of rehabilitated soil for 3-5 years ranged from 6.5 - 8.2 cm/day. Though these values are higher than the original un-mined soils still these are in the optimum range for most of the agricultural crops. This fact is evidenced by the variety of crops like sugarcane, pulses, oilseeds, vegetables etc. being grown by the farmers in the rehabilitated soil. Thus, improvements in IR and soil aeration have opened new options of crop diversification in rehabilitated soils.

Plate 12 : *Measurement of soil infiltration rate by double ring method*

Effect on soil microbiological properties

Soil health of agricultural fields is reflected by its biological activity in term of microbial population and dehydrogenase activity. There is so far no study of biological activity of sand mine soils in Haryana. Therefore, microbilogical properties of

Table 5. Effect of sand mining on infiltration rate

Mining Site	Soil classes & rehabilitation	Name of the farmer	Steady Infiltration Rate (cm/day)	Soil Bulk Density (Mg/m^3)
Village, Nagla Mirgain Distt Karnal	Un-mined soil	Mr. Sher Singh	1.7	1.59
	0-1 year	Mr. Sher Singh	97.5	1.58
	5 Years	Mr. Balwant Singh	7.6	1.55
Villages, Khot Pura-Hari Singh Pura Distt. Panipat-Karnal	Un-mined soil	Mr. Krishan Lal	2.1	1.60
	3 Years	Mr. Devi Singh	6.5	1.54
Village, Machhrauli Distt. Panipat	Un-mined soil	Mr. Balbir Singh	4.0	1.56
	5 Years	Mr. Ram Kumar	8.2	1.49
Village, Jourasi Distt. Sonepat	Un-mined soil	Mr. Suresh Kumar	3.3	1.60
	5 Years	Mr. Gulab Singh	7.1	1.57
Average	Un-mined soil		2.8	1.59
	Rehabilitated (3-5 Years)		7.3	1.54

sand mines soils under different years of rehabilitation and original un-mined soils were studied in Karnal, Panipat and Sonepat districts. The soil samples were collected from Nagla Mirgain, Hari Singh Pura, Machhrauli and Jaurasi. Bacterial and fungal populations of soil samples were estimated by standard Pour Plate Method using Nutrient Agar medium for bacteria and Martin Rose Bengal medium for fungi. Dehyrogenase activity was also estimated by standard method.

Results presented in Table 6 and 7 show that sand samples taken from 10-14 m sand column did not show any biological activity in terms of micro-organisms and dehyrogenase activity. However, microbial activity in terms of micro-organisms and dehydrogenase activity was found to be much more when top soil was spread and mixed with sand and it increased further in rehabilitated soils

Table 6 Microbial population in original un-mined soil, sand and rehabilitated soils for different periods at various sand mines in Haryana

Mining site and soil rehabilitation		Bacteria (No./g dry soil) x 10^7	Fungi (No./g dry soil) x 10^4
Nagla Mirgain Distt. Karnal	Sand	0.00	0.00
	2-3 years	1.00	0.20
	5-10 years	1.20	0.30
	Original un-mined	6.50	0.70
HarisinghPura Distt. Karnal	Sand	0.00	0.00
	2-3 years	0.04	0.20
	Original un-mined	3.90	0.50
Macchrauli Distt. Panipat	Sand	0.00	0.00
	2-3 years	3.16	1.12
	Original un-mined	4.50	2.76
Basodi Distt. Sonepat	Sand	0.00	0.00
	2-3 years	1.00	0.08
	8-10 years	1.10	0.34
	Original un-mined	1.30	1.00

due to cultivation of crops, decomposition of root stubbles and crop residues. The original un-mined fields showed maximum biological activity in terms of bacteria and dehydrogenase activity at all the mining sites where cultivation of crops was practiced for decades. It can thus be inferred that biological activity is absent in pure sand in mined areas but it improved with mixing and spreading of original topsoil and increased further with subsequent rehabilitation of soils through cultivation of crops. Sufficient increment in microbial population was observed within 2-3 years of rehabilitation to favour decomposition of crop residues and nutrient transformations.

Table 7 Dehydrogenase activity of original un-mined soils, sands and rehabilitated soils at Nagla Migrain, Karnal

Site of sampling	DHA (ug TPF/g dry soil)
Sand	0
2-3 yrs. rehabilitation	56
5-10 yrs. rehabilitation	73
Original un-mined	105

Effect of sand mining on soil fertility

Soil fertility is governed by the contents of organic carbon (OC) and available plant nutrients present in soil. To determine soil fertility, soil samples were collected from sand mines under different years of rehabilitation at Nagla Mirgain, Harisinghpura, Machhrauli and Basodi. Soil samples from adjoining original soils were also collected for comparison. Soil samples using standard methods were analysed for OC and available nutrients like, Nitrogen, Phosphorus, Potassium, Iron, Zinc, Manganese and Copper.

The data on OC, Nitrogen, Phosphorus and Potassium is presented in Table 8. Data on OC reveal that the original un-mined soils at the four sand mine sites contained OC in the range of 0.55 to 0.62 percent with a mean value of 0.58 percent, which drastically decreased to 0.07 percent in the beginning or 0-year of rehabilitation, it gradually increased to 0.42 percent in 5th year and 0.69 percent in 12th years of rehabilitation, attaining a higher content than the original soils.

The available N content in the original soils varied from 105 kg/ha at Machhrauli to 118.5 kg/ha at Basodi with an average content of 112kg/ha. Its content significantly decreased to 32 kg/ha in the beginning of rehabilitation. In spite of regular cultivation and fertilization, the N content in soil

Table 8. Contents of organic carbon, available N, P and K in surface soils of original un-mined and rehabilitated sand mine soils in Karnal, Panipat and Sonipat districts of Haryana.

Location of sand mines	Original un-mined soil	Sand mines under rehabilitation for 0-Year	5-Years	12-Years	Sand layer at 10m depth
		Organic Carbon (%)			
Nagla Mirgain	0.58	0.07	0.42	0.69	0.02
Harisingh Pura	0.57	0.09	0.45	0.73	0.01
Machhrauli	0.55	0.06	0.40	0.66	0.04
Basodi	0.62	0.08	0.39	0.68	0.02
Mean	*0.58*	*0.07*	*0.42*	*0.69*	*0.02*
		Available N (kg/ha)			
Nagla Mirgain	112.0	42.5	84.5	93.3	14.0
Harisingh Pura	112.5	17.5	56.0	-	14.2
Machhrauli	105.0	49.0	105.4	114.8	12.5
Basodi	118.5	21.0	51.5	91.8	7.0
Mean	*112.0*	*32.5*	*75.1*	*100.0*	*11.9*
		Available P (kg/ha)			
Nagla Mirgain	24.3	11.6	15.6	16.8	9.2
Harisingh Pura	13.7	7.8	11.7	-	7.6
Machhrauli	18.4	12.5	13.0	12.8	9.2
Basodi	19.9	8.1	10.1	11.2	6.5
Mean	*19.1*	*10.0*	*12.6*	*13.6*	*8.1*
		Available K (kg/ha)			
Nagla Mirgain	119.2	60.3	68.5	98.1	44.8
Harisingh Pura	124.2	52.6	84.2	-	37.8
Machhrauli	121.8	87.6	76.0	91.8	60.3
Basodi	118.2	60.3	76.0	99.8	44.8
Mean	*120.9*	*65.2*	*76.2*	*96.6*	*46.9*

could only build up to 75 and 100 kg /ha in 5th and 12th years of rehabilitation, respectively. The available P content of original soils ranged between 13.7 kg/ha at Harisinghpura to 24.3 kg/ha at Nagla Mirgain with a mean value of 19 kg/ha. Rehabilitation process increased available P content from 10 kg /ha at 0-year to 12.6 and 13.6 kg/ha in 5th and 12th years, respectively. Average available K content in original soils varied from 118.2 kg/ha at Basodi to 124.2 kg/ha at Machhrauli with mean value of 121 kg/ha. In the post rehabilitation, the average available K contents for 0-year, 5th years and 12th years were found to the extent of 65, 76 and 97 kg/ha, respectively.

Data in Table 9 show that concentration of micronutrient namely; Iron, Zinc, Manganese and Copper in soils also followed the similar trends as were noticed for major nutrients like Nitrogen, Phosphorus and Potassium. Maximum concentration of these nutrients was observed in

Table 9. Contents of available micronutrients in surface soils of original un-mined and rehabilitated sand mine soils in Karnal, Panipat and Sonepat districts of Haryana.

Location of sand mines	Original un-mined soil	Sand mines under rehabilitation for			Sand layer at 10m depth
		0-Year	5-Years	12-Years	
		Available Zn (mg/kg)			
Nagla Mirgain	0.99	0.29	0.60	0.61	0.24
Harisingh Pura	0.78	0.32	0.57	-	0.20
Machhrauli	0.88	0.40	0.76	0.82	0.26
Basodi	0.63	0.21	0.30	0.38	0.19
Mean	*0.82*	*0.31*	*0.56*	*0.60*	*0.22*
		Available Fe (mg/ kg)			
Nagla Mirgain	8.39	5.55	6.90	6.87	3.56
Harisingh Pura	8.92	6.11	6.77	-	3.72
Machhrauli	4.10	3.80	4.86	5.16	3.95
Basoudi	8.59	6.07	6.24	6.67	2.07
Mean	*7.50*	*5.53*	*6.19*	*6.23*	*3.33*
		Available Mn (mg/ kg)			
Nagla Mirgain	7.85	4.01	5.94	6.86	1.49
Harisingh Pura	7.31	2.55	5.56	-	1.37
Machhrauli	6.87	5.92	6.04	6.44	1.22
Basodi	7.41	4.86	5.16	6.85	2.61
Mean	*7.36*	*4.34*	*5.68*	*6.72*	*1.67*
		Available Cu (mg/kg)			
Nagla Mirgain	1.86	0.23	0.52	0.86	0.08
Harisingh Pura	1.56	0.23	0.67	-	0.12
Machhrauli	1.25	0.42	0.86	0.96	0.03
Basodi	3.10	0.40	0.45	0.93	0.16
Mean	*1.69*	*0.32*	*0.63*	*0.92*	*0.10*

original un-mined soils and minimum in soils of 0-year of rehabilitation. Their concentration increased with time during the process of rehabilitation.

Before we draw some meaningful inferences from the above results, it should be understood that in soils, the sand fraction constitutes the major storehouse of all the plant nutrients except Nitrogen and Carbon. Because sand is a slow releaser of nutrients therefore, intensive agriculture always resorts to supplemental application of fertilizers and organic manures. The improved economic status of the farmers during the post-mining era enable them to use higher doses of manures and fertilizers, which gradually build up soil fertility. This is exactly what has happened during concurrent reclamation of sand mines. The contents of OC and N drastically decreased initially as pure sand contained negligible contents of both OC (0.02%) and available N (12kg/ha). Mixing topsoil with sand increased their values to meagre 0.14% and 32.5 kg/ha, respectively. Quick build up of OC content in rehabilitated soils had been due to increased application of FYM. Application of nitrogenous fertilizers to crops and increased microbial activities improved the N contents in soils with time. Weathering of Mica in sand always release large quantities of K, thus even pure sand contained 47 kg /ha available K and therefore, deficiency of K to plant was never an issue in any of these soils. In case of P, pure sand contained 8 kg/ha available P, which increased to 10 kg/ha after mixing with topsoil. Subsequent slow build up of P in soil over a period of time is ascribed to its complex absorption, adsorption and fixing phenomenon occurring in soil.

It thus emerges that in their initial stages of rehabilitation sand mines show significant decrease in soil fertility. This is due to very low contents of OC and major and minor available plant nutrients present in the soil and sand mixture. However, vigorous cultivation practices utilising higher doses of FYM and fertilizers soon triggers the process of weathering resulting in release of nutrients like K, P, Fe, Zn, Mn and Cu etc to build up their contents in soil profile. For increasing OC and N concentrations in soils, it is necessary to apply manures and fertilizers as is the case in other cultivated soils.

EFFECT ON GROWTH AND YIELDS OF CROPS

After stacked topsoil is spread and mixed with sand bed, the land is handed over to the farmer who commences rehabilitation. Each field is brought to a desirable level and bunded. It was noted that farmers take up land rehabilitation programme very enthusiastically. Because of small holdings they manage to procure and apply adequate doses of FYM (Plate-13). Some farmers were found to apply @ 20 to 30 t/ha of FYM or any other kind of manures including urban garbage and pressmud. Normally, they start with rice as first crop followed by wheat or sugarcane. Assessment of crop growth and their

Plate 13. : *Farmers usually apply heavy doses of organic manures during reclamation of sand mines*

yields were estimated on the basis of visual observations and inquiries from the farmers. Some crop growth parameters such as number of tillers per unit area, height of plants and length of seed bearing ears were also recorded to correlate yield estimates. The yield data of different crops grown in sand mine areas under rehabilitation for 1, 5 and 12 years was collected (Plate 14). Yield data of corresponding crops from adjacent

Plate 14. : *Sequential reclamation of sand mines, see reclamation in 1st year (foreground) and for 5-years (background)*

original un-mined soil, was also collected for comparison. The data given in Table 10 revealed that first year of rehabilitation recorded significantly lower yields in most of the crops. Wheat, rice, sugarcane and gram reported 29, 22, 65, and 33 percent decrease in comparison to the original un-mined soils. However, the yields gradually increased to cut down losses to 11, 11 and 20 percent for wheat, rice and sugarcane by 5th year of rehabilitation. Afterwards in the 12th year, the yields reached at par or even surpassed by 11, 11 and 25 percent. The gram yields reached at par in 5th year of rehabilitation. Unlike other crops, the decrease in berseem (*Trifolium alexandrinum*) recorded 53, 40 and 20 percent decrease in yield in the 1st, 5th and 12th year, respectively. Lesser berseem yields are due to higher infiltration rates in these soils.

Alterations of soil texture to lighter grades have helped the tuber crops and vegetables to grow well in rehabilitated soils (Plate 15).

Table 10. Comparison of crop yields obtained from rehabilitated sand mines and original soil at village Nagla Mirgain (Karnal)

Crops/ Farmer	Yield (t/ha) from rehabilitated sand mines for			Yield from original soil(t/ha)
	1-year	5-years	12-years	
WHEAT Sh. Balwant Sangwan	3.2	4.0	5.0	4.5
RICE Sh. Balwant Sangwan	3.5	4.0	5.0	4.5
SUGARCANE Sh. Balkar Singh Bhinder	35.0	80.0	125.0	100.0
GRAM Sh. Balwant Sangwan	1.0	1.5	1.7	1.5
BERSEEM Sh. Balwant Sangwan	14.0	18.0	24.0	30.0

Yield data (Table 11) for onion, garlic and other vegetables were collected from sand mines at villages Jaurasi (Panipat) and Kunjpura (Karnal). Onion and garlic reported a yield loss of 32 and 40 percent in the first year of rehabilitation. Nevertheless, the loss narrowed down to 14 and 13 percent in the 3rd year and surpassed by 14 and 13 percent than the original soil in the 7th year. Several other vegetables like brinjal, radish and

Plate 15. : *Garlic and other tuber crops grow well in reclaimed soils*

carrot etc when introduced showed good growth. Sh. Balkar Singh Bhinder of village Nagla Mirgain obtained a bumper crop of extra-size potatoes, each potato on an average weighed around 350 gram.

Table 11. Yields of onion and garlic obtained from rehabilitated sand mines at Jaurasi (Panipat) and Kunjpura (Karnal)

Crops/ Farmer	Yield (t/ha) from rehabilitated sand mines for			Yield (t/ha) from original soil
	1-year	3-years	7-years	
ONION Sh Gulab Singh (Jaurasi)	9.5	12.0	16.0	14.0
GARLIC Sh. Joginder Singh (Kunjpura)	9.0	13.0	17.0	15.0

As mentioned earlier, crop growth parameters were recorded to correlate yield estimates. Data on growth parameters of wheat crop grown in mined soil under 3rd year of rehabilitation was recorded in the fields of two farmers namely, Sh. Omi Lal and Sh. Kirpal Singh at villages Kunjpura and from the nearby un-mined fields of Sh. Arjun Dev and Sh. Joginder Singh. Number of tillers, plant height and ear length in one square foot area was measured. The average value obtained from five locations is presented in Table 12. The wheat crop grown in 3rd year of rehabilitated soil showed slightly lesser values of growth parameters in comparison to the un-mined soil (Plate 16 & 17). This minor difference in crop growth parameters is very well reflected in minor yield reduction from respective soils.

Table12 Average values of growth parameters of wheat recorded in mined and original un-mined soils in villages of Karnal district.

Wheat crop growth parameters (30 cm^2 area)	Mined soil under 3rd year of rehabilitation	Un-mined soil
Number of tillers	59.8	62.5
Plant height (cm)	86.7	91.0
Ear length (cm)	9.0	9.3
Wheat grain yield (t/ha)	4.2	4.6

Garlic has emerged as a major cash crop in villages around Kunjpura. Some farmers have also taken up garlic cultivation in the sand mine rehabilitated areas. Sh Joginder Singh purchased sand mine area and started cultivation of garlic. Average of plant height and bulb diameter of 15 garlic plants grown in un-mined and mined but rehabilitated soil for 3 years did not show much differences indicating good adoption of garlic crop in sand mine areas. The average height and bulb diameter of garlic was 56 cm and 4.6 cm, respectively in original un-mined soil compared to 56.8cm and 4.3 cm in soils rehabilitated three years back.

Plate 16

Plate 17

Plate 16 & 17. : *Comparable crop growth in 3rd year of reclamation & original un-mind soil*

CROPS AND VEGETATION GROWN IN SAND MINES

The rehabilitated soils, grow several crops like rice, wheat, sugarcane, sorghum fodder, vegetables, gram, mustard, berseem, methi, potato and tomato etc. These were also satisfactorily growing a variety of trees like poplar, eucalyptus, neem, guava, pome- granate and papaya etc. Even the natural vegetation grew very well on the slopes of the 5-7 years old mines. The dominant species, which colonize these soils, included grasses, aak, prosopis, bacain, neem, sheesham and castor etc. Anjan grass *(cenchrus ciliaris)* and sheesham tree *(dilbergia sisso)* were found best for vegetating and stabilizing side slopes of mines (Plate 18). A farmer, Sh. Gulab Singh of village Jaurasi (Panipat) has converted 4 ha sand mine into a well-developed farm. He has constructed pucca water channels for conveyance of canal and run-off water, pucca field channels and pluggable nakas for each field and has made small sized fields for uniform application of irrigation. Such practices has enabled him to cut down on water losses through infiltration and also minimized soil erosion. Obviously, he obtains much more crop yields than his counterparts (Plate 19). Here nearly 10-meter high side slopes also appeared better vegetated and stabilized. The roots of Sheesham trees planted on the top edge of the slope have run down the entire height of the slope and sprouted several new sheesham sapling, which have grown as healthy as the mother plant, a good example of self propagation by tree.

Plate 18 : *Dilbergia sisso and Anjan grass thrive well in sandy soils*

Plate 19 : *A well reclaimed sand mine at Jaurasi in Panipat*

QUALITY OF GROUND WATERS IN SAND MINE AREAS OF HARYANA

Ten ground water samples (Table 13) from different sources like tubewell, hand pumps, and run off water located on the un-mined and mined soils were collected and analysed using standard laboratory methods to investigate the quality of water for irrigation. Fluoride was analysed using Specific Ion Meter. The EC value less than 1.5 and RSC less than 1.1 make these waters good for irrigation without any detrimental effect on soils and crops. However, higher fluoride contents of 3.09, 2.59 and 1.01 ppm in three water samples collected from tube wells in villages, Garhi Chhajoo, Macchrouli and Jaurasi in Panipat district might pose health hazards to humans and animals. Fluoride rich waters were drawn from 22 and 26 meters depth

Table13 Water quality in sand mine areas in Haryana

Sample No.	Source, Location, District	Depth (m)	Sample No.	Source, Location, District	Depth (m)
SM-1	Rain water collected in a mine pit, village Nagla Mirgain, (Karnal)	--	SM-6	Tubewell, vill Machhrauli, (Panipat)	26
SM-2	Tubewell, Sh. Deva Singh, Nagla Mirgain, (Karnal)	15	SM-7	Tubewell, Sh. Ajit Singh, Harisinghpura, (Karnal)	82
SM-3	Hand pump, Nagla Mirgain, (Karnal)	20	SM-8	Tubewell, Sh. Sant Kumar, Nandnour, (Sonepat)	14
SM-4	Tubewell, Sh. Ram Singh, Garhi Chhajoo, (Panipat)	22	SM-9	Tubewell, Sh. Suresh, Jaurasi, (Panipat)	26
SM-5	Field stagnation, vill. Baholi, (Panipat)	--	SM-10	Tubewell, Sh. Gulab Singh, Jaurasi, (Panipat)	40

Sample No	pH	EC (dS/m)	Na	Ca+Mg	K	HCO_3	Cl	RSC	Fluoride (ppm)
			me/l						
SM-1	7.8	1.50	5.6	9.0	0.42	7.0	6.8	Nil	0.00
SM-2	7.5	0.85	1.6	6.5	0.20	2.7	4.5	Nil	0.00
SM-3	7.4	0.75	2.1	6.0	0.17	4.7	4.0	Nil	0.00
SM-4	8.0	0.50	2.0	2.6	0.17	0.9	3.8	Nil	3.09
SM-5	8.2	0.50	1.8	2.7	0.07	2.2	2.5	Nil	0.59
SM-6	8.0	0.70	3.0	3.9	0.18	5.0	2.3	1.1	2.59
SM-7	7.9	0.66	2.6	3.9	0.06	3.9	2.8	Nil	0.47
SM-8	8.1	0.60	2.3	3.7	0.17	3.6	2.5	Nil	0.00
SM-9	8.1	0.48	2.0	2.5	0.06	1.8	2.5	Nil	1.01
SM-10	8.0	0.45	1.6	2.5	0.18	1.7	2.8	Nil	0.24

EFFECT ON GENERAL LANDSCAPE

Sand mining affects the general landscape in two ways:

i. Ground level of the otherwise flat terrain is deepened to about 10 m. This disfigures the countryside and interrupts the surface topography of general landform.

ii. The highly sloping edges of sand pits might pose threat to the life of man and animals and may induce soil erosion if left unattended.

Creation of sand pits alters the surface topography of the otherwise uniformly flat plain. The smaller mines covering 10 hectares or less spoil the land configuration and are also a threat to the adjoining agricultural lands. On the contrary, larger mines spread over hundred and thousand hectares covers sizeable areas with lowered topography and assume the identity of a small landform unit. Such landforms can be suitably designed and managed by appropriate agricultural technologies for quick reclamation and return to agricultural land use for sustainable crop production. Similarly, highly eroding slopes can be shaped, graded and strengthened through applicable soil and water conservation measures to control soil erosion and merge them well with the surrounding landscape (Plate 20). The small sized mines may prove hazardous during flash floods, while large sized mines could be available and capable for disposing extremely large quantities of flood waters to save large areas of upland countryside from the fury of floods which do occur in the region occasionally.

Plate 20 : *Unattended side slope leads to severe land degradation while well managed side slopes can be strengthened and stabalised*

ISSUES CONCERNING SAND MINING IN AGRICULTURAL LAND

1. Sand mining in agricultural land

Sand is the major bulk material used in the building infrastructure. The Infrastructure sector is the top priority of the Govt. of India; therefore huge quantities of sand are needed. Yamuna basin offers a huge reserve of good quality sand. The study indicated that rehabilitation activities are capable of restoring optimal soil development and crop production from mined areas. Therefore, to check illegal sand mining the State Government may consider allowing of sand mining from agricultural fields. However, to minimize the degradation impact of sand mining on land, agriculture and environment, sand mining operations and especially concurrent reclamation of mined areas for return to agriculture must be operated under the advise of agricultural and soil conservation experts.

2. Identify and prioritize sand mine areas

The whole Yamuna bed is not uniformly homogenous by way of topsoil and underlying sand layers. The topsoil has varied thickness and textures. Therefore, the sand mining areas has to be prioritized on the basis of location specificity and soil site characteristics.

3. Slope stabilization and management

Complete alteration of topography of mined area result in deep steep slopes, which are susceptible to wind and water erosion. It was noted that some of the slopes have been stabilized to some extent, while the others are moderately to severely eroded. Slope shaping, degree of slopes, slope stabilization by vegetation or other means have to be accorded top priority.

SALIENT FINDINGS AND SOME RECOMMENDATIONS

1. Sand is an integral part of soil composition and also an important aggregate used in bulk in construction industry.

2. Small sized sand pits spoil surface configuration of the landform and are difficult to rehabilitate. Therefore, large contiguous areas should be earmarked for sand mining.

3. Depth of sand mining, which used to be about 5-6 m earlier, has now increased to about 10 m. This has direct bearing on soil erosion especially when side slopes of mines bear an angle of 45^0 or more. Restricting mining depth and decreasing degree of side slopes are recommended to prevent erosion of adjoining lands and silting of the bottoms of sand pits. The mining depth and degree of slope shall vary from site to site depending upon soil texture and other site characteristics.

4. Width of buffer zone around the sand mine pit should be sufficiently wide to save any form of loss accruing from sand mine to the land and property of the neighbouring farmer. Side slopes and buffer zones are the most fragile components of rehabilitation, their stabalization is extremely important. Therefore, regular maintenance and monitoring by a team of experts and other stakeholders is recommended.

5. Rehabilitated sand mines have responded well to soil development and improvements in soil physical, chemical, microbiological and nutritional properties. However, the resulting lighter soil textures are likely to induce higher infiltration rates causing loss of water and plant nutrients through enhanced leaching. To prevent such losses and also to keep down cost of crop production, state of the art and location specific soil and water management measures are recommended.

6. Lighter soil textures have opened new options for crop-diversification. A host of commercial crops like tubers, vegetables, flowers, fruits and herbal plants etc hold good promise in these soils.

7. Crop yields remained subdued until 4-5 years of rehabilitation. Afterwards, the yields were comparable or even better than those obtained from the original un-mined soils. This has happened due to nutrient transformation, weathering of sand minerals and adoption of best management practices.

8. Cultivation of sugarcane that produces abundantly dense root system and leaf-trash for recycling into soil was found the most useful crop to improve soil during initial years of rehabilitation.

9. Research studies to fine-tune various aspects of sand mining and rehabilitation of mined areas to agriculture and other profitable land uses are recommended. Scope of mine areas for ground water recharge and rain water harvest needs exploitation.

10. Sufficient scientific literature addressing problems arising due to sand mining and their solution including packages of practices for quick rehabilitation of land be prepared and disseminated to the concerned officials and farmers.

CONCLUSIONS

Sand mining apparently is a land degradation process, which disturbs soil profile, spoils surface configuration and considerably alters topography of the land. Rehabilitation of sand mines starts with spreading, mixing and leveling of topsoil with sand. The resulting loose mass contains about 60 to 70 percent lesser clay and silt in comparison to topsoil but most importantly they inherit some useful genetic characteristics that favour soil profile development. Commencement of agricultural operations for crop production causes soil cohesion, which further lead to improvements in soil properties. The reclaimed soils produce significantly lesser yields in the first few years but picks up gradually to reach almost at par by 5^{th} year of reclamation . The processes of soil formation like profile development; physical, chemical, biological and nutritional properties of soil improve simultaneously. Depending upon the method and process of rehabilitation, the breakeven point in crop production and soil improvement is reached between 5^{th} and 12^{th} years of reclamation. It is, therefore, concluded that sand mining from agricultural fields in Yamuna basin should be permitted but regulated and managed in scientific manner to enable concurrent reclamation of sand mines for immediate return to agriculture.

APPENDIX-I

Morphology and physico-chemical characteristics of soil profiles from sand mines of three districts were largely similar. Therefore, data from four soil profiles representing original un-mined soil and rehabilitated soils under different years at Nagla Mirgain sand mine in Karnal district is presented in Appendix-I. Most of the sand mines differed in site characteristics, thickness of topsoil cover and depth wise range of soil textural classes, which is presented in Table 1.

Soil profile No. SM - 1	Original un-mined soil
Soil prifile No. SM - 2	Rehabilitation has just started
Soil profile No. SM - 3	Under rehabilitation for 5 years
Soil profile No. SM - 11	Under rehabilitation for 12 years

Profile no. SM-1 Soil morphology of original un-mined soil in the field of Sh. Sher Singh, village Nagla Mirgain, (29^0 37' 54.2" N and 77^0 3' 22.2"E)

Soil depth (cm)	Horizons	Colour	Texture	Structure	Compaction	Roots	Pores
0-15	Well formed	Grayish brown	Sandy clay loam	Sub angular blocky	Very firm	Abundant	Less porous
15-150	-do-	Yellowish brown	Sandy loam	Grannular	-do-	Common	Common pores
150-190	No horizon	Light gray	Sand	Single grained	Loose & unfirm	Nil	Highly porous
SAND + +							

Profile no. SM-2 Soil morphology in the beginning (0-1 year) of rehabilitation of a sand mine field belonging to Shri Sher Singh, village Nagla Mirgain, (29^0 37' 42.2" N and 77^0 3' 12.8"E)

Soil depth (cm)	Horizons	Colour	Texture	Structure	Compaction	Roots	Pores
0-55	No horizon	Pale brown	Loamy sand	Very weak granular	Very slight	Absent	Highly porous
55-135	-do-	Light gray	Loamy sand/ sand	Single grained	Loose & unfirm	-do-	Highly porous
SAND + +							

Profile no. SM-3 Soil morphology after 5 year of rehabilitation in the field of Shri Balwant Sangwan, village Nagla Mirgain, (29^0 37' 42.8" N and 77^0 3' 17.8"E).

Soil depth (cm)	Horizons	Colour	Texture	Structure	Compaction	Roots	Pores
0-19	Very slight	Brown	Loamy sand	Weak granular	Slightly firm	Abundant	Very porous
19-41	Diffuse	Brown	Loamy sand	Weak blocky	Slightly firm	Common	Very porous
41-143	Diffuse	Brownish yellow	Sand/ Loamy sand	Massive	Very slight	Few	-do-
SAND + +							

Profile no. SM-11 Soil morphology after 12 years of rehabilitation in the field of Shri Balkar Singh Bhinder, village Nagla Mirgain, (29^0 38' 9.9" N and 77^0 2' 56"E).

Soil depth (cm)	Horizons	Colour	Texture	Structure	Compaction	Roots	Pores
0-27	Slight	Dark brown	Sandy loam	Granular/ blocky	Moderately firm	Abundant	Slightly porous
27-90	Slightly moderate	Brown	Loamy sand	Weak brittle blocky	Slightly firm	Common	Very porous
90-120	Very slight	Light gray	Sand/Loamy sand	Massive	Very slight	Few	-do-
120-170	No horizon	Light gray	sand	Single grained	Slight	Very few	Very porous
SAND							

PHYSICO-CHEMICAL CHARACTERISTICS

Profile no. SM-1: Physico-chemical characteristics of original un-mined soil in the field of Sh. Sher Singh, village Nagla Mirgain, (29^0 37' 54.2" N and 77^0 3' 22.2"E)

Soil depth (cm)	pHs	ECe (dS/m)	Na	Ca+ Mg	HCO_3	Sand	Clay	Organic carbon	$CaCO_3$	CEC
			-------------	meq/l	------------	------------------------		%	-----------------	Cmol (p+)kg^{-1}
0-15	8.4	1.10	5.4	5.1	3.8	49.0	24.0	0.58	4.2	11.2
15-150	8.5	0.62	2.9	3.1	1.4	66.0	15.3	0.26	1.7	6.1
150-190	8.7	0.46	2.2	1.5	1.3	92.0	4.0	0.22	1.7	1.8
SAND +										

Profile no. SM-2 Physico-chemical characteristics in the beginning (0-1 year) of rehabilitation of a sand mine field belonging to Shri Sher Singh, village Nagla Mirgain, (29^0 37' 42.2" N and 77^0 3' 12.8"E)

Soil depth (cm)	pHs	ECe (dS/m)	Na	Ca+ Mg	HCO_3	Sand	Clay	Organic carbon	$CaCO_3$	CEC
			------------	meq/l	------------	------------------------		%	------------------	Cmol (p+)kg^{-1}
0-55	8.4	0.83	4.3	2.5	1.7	83.4	8.1	0.07	1.5	3.2
55-135	8.5	0.62	2.9	3.1	1.4	85.0	7.7	0.26	1.7	3.0
SAND ++										

Profile no.SM-3 Physico-chemical characteristics after 5 years of rehabilitation in the field of Shri Balwant Sagwan, village Nagla Mirgain, (29^0 37' 42.8" N and 77^0 3' 17.8"E).

Soil depth (cm)	pHs	ECe (dS/m)	Na	Ca+ Mg	HCO_3	Sand	Clay	Organic carbon	$CaCO_3$	CEC Cmol (p+)kg
			------------ meq/l ------------			------------------------ % ------------------				
0-19	8.2	0.46	1.9	2.7	2.2	81.2	8.5	0.42	1.6	3.3
19-41	8.2	0.33	0.9	2.2	2.2	82.0	8.0	0.32	1.2	3.0
41-143	8.3	0.48	1.5	2.6	1.9	84.0	7.0	0.17	0.5	2.7
SAND ++										

Profile no.SM-11 Physico-chemical characteristics after 12 years of rehabilitation in the field of Shri Balkar Singh Bhinder, village Nagla Mirgain, (29^0 38' 9.9" N and 77^0 2' 56"E).

Soil depth (cm)	pHs	ECe (dS/m)	Na	Ca+ Mg	HCO_3	Sand	Clay	Organic carbon	$CaCO_3$	CEC Cmol (p+)kg
			----------- meq/l ------------			------------------------ % ------------------				
0-27	7.9	0.34	1.3	1.9	1.7	78.7	9.2	0.69	1.4	4.0
27-90	8.2	0.30	1.6	1.0	2.1	75.0	8.6	0.37	0.3	3.3
90-120	8.4	0.20	0.4	1.0	1.2	89.0	6.8	0.07	1.1	3.0
120-170	8.3	0.27	0.6	0.8	1.0	93.0	4.3	0.07	1.0	2.0
SAND ++										

APPENDIX-II

OPINION OF STAKEHOLDERS IN SAND MINING

Views of various stakeholders including the farmers, villagers, labourers, mine contractors etc. were ascertained during investigations. The farmers who had leased their land for sand mining were found satisfied as they felt that the money received from land- leasing had raised their financial and social status in the village and also they had utilized the money for rehabilitating their land to produce better yields than before. On the other hand, the neighbouring farmers whose land is adjacent to the sand mines showed apprehension about some damage to their lands by soil erosion due to steep slopes of sand mines. The other stakeholders were generally satisfied with sand mining activities

Name of the Person	Views about sand mining
Sh. Raghbir Singh, a farmer of Harisinghpura (Karnal)	Has used leased money to buy a earth moving machine, he is of the opinion that erosion of mine slopes can be checked by slope stabilization with joint responsibility of both the farmers viz; one who has leased his land and the nearby neighbouring farmer.
Sh. Surinder Singh/ Sh. Ajit Singh Harisinghpura (Karnal)	They have their fields adjacent to sand mines of village Khotpura, do not intends to lease land for sand mining, have apprehension that steep slopes of mines may erode their fields. Therefore, they demand at least 10m wide buffer zone between the mines and the agricultural fields and proper stabilization of the side slopes. However, they did not find any water leakage from their agricultural fields to the sand mines so far.
Sh. Kidar Singh Biholi (Panipat)	He thinks that leasing his land for sand mining was a good decision as he obtained better crop yields from his reclaimed fields. According to him sugarcane yields obtained @ 400 t/ha after 4^{th} year of reclamation and was better than obtained from any original land.
Sh. Ram Chander, Garhi Chhajoo, (Panipat)	Earlier their land was suitable mainly for rice due to heavy texture and a thick column of soil profile, after sand mining the soil texture has become lighter, which offers him a choice of crops and ease in field operations. He has started obtaining better crop yields than before.
Sh. Jagdish Chander and Sh. Subhash neighbouring farmers of Sh. Ajit Singh	They have their fields about 100 m away from the sand mines and did not find any adverse affect of sand mining in their fields. Mr. Ishwar Singh, a nearby farmer, is not interested in leasing his land for sand mining in near future.
Sh. Devi Singh, a farmer of Khotpura (Panipat)	After sand mining his fields did not experience any water stagnation during rains, tubewell discharge has increased and problem of Mandusi weed has decreased after sand mining.

Sh. Joginder Singh, Kunjpura (Karnal)	He has leased about 3 ha land for sand mining and obtains better crop yields than before. He is interested in giving more land for sand mining provided he gets good lease price. Mr. Omi Lal, says he has no repentance for giving his land for sand mining, getting better yields than before. Mr. Hari Lal, a neighbour of Mr. Omi Lal, do not find any adverse effect of sand mining in his fields. According to Mr. Kirpal Singh, the leased money paid to the farmer is less, if increased he can also lease his land for the purpose.
Sh. Sher Singh, Nangla Mirgain (Karnal)	Sand mining is beneficial for the farmer provided a proper slope is kept and maintained later on. According to Mr. Uttam Singh, wheat crop needs 2-3 more irrigations than in the unmined soil.
Sh. Gulab Singh, Jaurasi, (Panipat)	No regrets has made exemplary reclamation after sand mining, his few ha. farm is probably best example of land rehabilitation of sand mining fields.
Sh. Het Ram, Sh. Hari Singh and Sh. Ram Rattan	Works as a labourer with sand mining contractor at Nandnour mines and earns @ Rs. 1000-1200/- a day.
Sh. Sangwan, Nangla Mirgain, Karnal	A farmer who leased his land and later on started purchasing adjoining land for sand mining. He is continuing sand mining and simultaneously reclaiming the land in more than 50 ha. A yield obtained from reclaimed land is better than the unmined fields.