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Sand extraction from agricultural fields around Bangalore: Ecological disaster or economic boon?

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Sand supply from the riverbeds to Bangalore is not able to meet the demand of the booming construction sector. Enterprising farmers have taken up extraction of sand by washing surface soils of agricultural fields. Nearly 25% of the sand supplied is from this source. A field investigation and laboratory analysis was undertaken to understand the ecological and economic consequences of sand extraction. The study revealed that significant employment and economic gains are realized at an ecological cost. Loss of surface soils, nutrient losses, crop yield losses, siltation of tanks, excessive groundwater exploitation and soil erosion are taking place due to sand extraction. There are no quality differences between riverbed sand and soil extracted sand. A comprehensive policy is needed to make the enterprise ecologically tolerable and safe.

Keywords: Agricultural fields, eco-degradation, groundwater exploitation, sand extraction.

LAND is a limited resource having competing demands. The need to augment food production also from marginal lands has a serious impact on land use, resulting in accelerated land degradation. Progress in science and technology has eased out pressure on natural resources to some extent, but urban-centric development has resulted in imbalanced growth and exploitation of natural resources. Urban-centric economic growth has increased employment opportunities in these areas, whereas mechanization, stagnant prices and production, increased input costs in agriculture have made it unattractive leading to increased rural unemployment and migration. All these factors have put extraordinary pressure on urban infrastructure.

Riverbeds are major sources of sand and its accumulation as layers of deposits is a dynamic phenomenon. Major user of sand is the construction sector which is growing exponentially. Due to its increasing demand, sand is being over-extracted from different riverbeds. This is resulting in negative externalities on riparian habitats, like the riverbeds losing their ability to hold water. As sand is extracted rapidly, groundwater evaporates fast, reducing groundwater recharge, increasing initial and premature failure of irrigation wells and associated predicament in farming[1].

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Sand mining affects agriculture, rural livelihoods and also leads to environmental problems like rise in atmospheric temperature[2,3]. These activities have affected local economies drastically, leading to conflicts among rural people and sand players as in case of Karnataka[4–6]. Nevertheless, there is increased awareness among the rural people about the negative effects of this activity, as evidenced by a series of protests. Another major source of land degradation is the brick industry. Estimates suggest that the clay brick industry is degrading the fertile topsoil to the extent of 20,000 ha every year in India, thereby causing severe land degradation[7].

Exponential demand for sand has created several environmentally unsafe situations as riverbed sand supply is not able meet the demand. During the last 3–4 years surface soils from tank beds, agricultural fields and village common lands have been excavated and washed to produce a kind of artificial sand all around Bangalore in order to meet the enormous demand. For Bangalore, nearly 4000 lorry loads of sand per day is supplied for construction projects. It is reported that nearly 25% of sand is extracted from surface soils of agricultural fields/village tank beds[8,9]. The remaining (75%) is mined from riverbeds. It is called AT sand. Under these circumstances the entire gamut of trade of sand extracted from topsoils was analysed in terms of environmental, economic, technological, institutional, policy and equity dimensions.

Not only the increased demand for sand in Bangalore, but also the less remunerative crop production enterprises and prevailing drought-like conditions during the last few years have driven farmers to this enterprise. Sand extraction is providing reasonably gainful employment for many farmers and landless labourers in the region.

However, agriculturally essential surface soils have certain unique characters, which make them indispensable for crop production. Such fertile surface soils are the combined result of efforts of farmers and natural forces over a long period of time. When surface soils are removed from agricultural lands for sand extraction, the first negative effect is on soil organic matter (SOM). SOM helps in the functioning of the soil and crop production system by affecting infiltration, water-holding capacity, erosion resistance, run-off, soil crusting, porosity and ease for tillage. SOM accounts for 50–90% of cation exchange capacity of surface soils.

Sub-surface soils show reduced biological activity. Organic amendments and fertilization of sub-surface soils are necessary to ensure rapid build-up of microbial populations and initiate nutrient cycling. Once soils are desurfaced for such activities, bulk density of the remaining soil increases and hydraulic conductivity decreases. Plant establishment and growth get affected adversely leading to crop yield losses[10].

There are no scientific studies on the ecological and socio-economic implications of sand extraction from surface soils. Hence the present study was undertaken at 15 sand extraction units in five villages (Linganahalli, Karahalli, Ancharhalli, Dasagondanahalli and Rajaghatta) in Bangalore rural district during 2006–07. Farmers and sand extractors were interviewed to get details of economics and input-use pattern. Soil (surface and sub-surface), silt and sand samples were collected. Nutrient content (N, P, K, Cu, Fe, Mn and Zn), and pH, sand silt and clay content were analysed[11]. Net return per load of sand at farm gate was estimated by taking into account all expenses incurred.

Rectangular pits of dimension 20 × 8 × 2 ft were dug with a slight slant towards the end where washed wastes are let out. Pits are covered from all sides with stone slabs. It costs around Rs 5000 to set up an extraction unit. These are normally set up near bore-wells. Due to erratic supply of electricity, water was pumped during nights to temporary ponds and later to extraction units during daytime using 5 HP diesel pumps. Pumps were normally hired @ Rs 60 per lorry-load of sand (excluding cost of diesel). Nearly 1 ft (30 cm) depth of surface soil was excavated and transported from agricultural fields. It was spread on the extraction pit for further processing. Two to three rounds of washings were done with a water jet to wash the soil and extract sand. Normally a part of silt, sand and clay flows out. However, a part of these components remains in the sand being sold in Bangalore (Table 1). In a day three lorry loads of sand is extracted from one extraction unit.

Only resourceful farmers or contractors undertake these enterprises, as they have to invest on labour (68% of total cost; Table 2), soil, water, diesel, etc. It is evident from the study that the poor farmers are not able to reap many economic benefits, except for employment opportunities as labourers. Economic estimates based on the available data and analysis (Table 2) reveal that sand-extraction enterprises generate a turnover of Rs 146 crores/annum in the region, and also employment of 33 lakh man-days, out of which nearly 75% is on the farm itself. Income generated for labourers by this source is to the tune of Rs 71 crores/annum.

The enterprise shows a favourable effect on rural economy as the region has been witnessing drought-like situation during the last 6–7 years. Incidence of farmers' suicides in this region is also rare, compared to other drought-prone areas in the state. Although farmers are undergoing enormous economic stress due to drought-like situation and falling prices of agricultural produce, the employment and income opportunities have helped them manage critical situations.

For producing one lorry load of sand, 5 HP diesel pump has to run for nearly 3 h and it consumes 3 l of diesel. Hence nearly 3000 l of diesel is consumed every day around Bangalore for sand extraction. That amounted to Rs 4.5 crores worth of diesel in a year.

Sand extractors earn net profit of Rs 2100 per lorry load of sand. This is based on the fact that average quality of sand from these units is sold at Rs 4000 per lorry load

Table 1. Physical and chemical properties of sand used in Bangalore

Sand source	Sand (%)	Silt (%)	Clay (%)	Organic carbon (%)	pH	N (kg/ha)	P_2O_5 (kg/ha)	K_2O (kg/ha)
Soil-sand	95	2.4	2.7	0.17	8.5	80	35.8	36.4
Riverbed sand	91	8.5	0.4	0.41	8.6	96	10.1	27.8

Table 2. Economics of sand extraction from agricultural top soils around Bangalore

Details	For one lorry load of sand (90 m^3)	1000 lorry loads (one day's supply)	One year	Remarks
Labour for topsoil excavation (man-days)	3	3000	11 lakhs	
Cost of labour for soil excavation (Rs)	650 (34)	6.5 lakhs	24 crores	
Labour for soil wash (man-days)	3	3000	11 lakhs	
Cost of labour for soil wash (Rs)	650 (34)	6.5 lakhs	24 crores	
Total cost of labour on farm	1300 (68)			
Cost of soil (Rs)	200 (10.5)	2 lakhs	7.5 crores	When purchased from other farmers
Diesel required (l)	3	3000	11 lakhs	
Diesel pump rent (Rs)	60 (3)			
Diesel cost (Rs)	120 (6)	1.25 lakhs	4.5 crores	
Quantity of water used (l)	132,000	1320 lakhs (60 lakh gallons)	481,800 lakhs (21,900 lakh gallons)	
Water cost (Rs)	100 (5.5)	1 lakh	3.6 crores	When purchased from bore-well owners
Total cost (Rs)	1720	17 lakhs	63 crores	
Price at farm gate (Rs)	4000	40 lakhs	146 crores	
Net profit for sand extraction unit owner (Rs)	2280	23 lakhs	83 crores	
Sand loading and transport labours (man-days)	3	2500	912500	
Total employment generated (man-days)	9	9000	33 lakhs	
Income generated for labourers (Rs)	1950	20 lakhs	71 crores	

Values in brackets are per cent of total.

at the farm gate. Normally 30 cm depth of top soil is used for sand extraction. One hectare of land to a depth of 30 cm yields 33 lorry loads (one lorry load = 90 m^3) of sand. Hence, if a farmer himself undertakes sand extraction from his land, he can earn a net profit of Rs 72,000 per ha. Instead, if he sells surface soil for sand extraction, he earns an income of only Rs 6600 per ha.

Nearly 132,000 l of water is needed for washing four tractor loads of soil to produce one lorry load of sand. A conservative estimate suggests that nearly 21,900 lakh gallons of water is used for sand extraction per year around Bangalore. This water is pumped from deep bore-wells. In most regions groundwater level has reached a precarious status[12]. In the study region, it has already gone down to 300 m due to overdrawing. Due to this all open wells in the region have dried up.

Efforts of rainwater harvesting for groundwater re-charging are few. Hence, additional burden on groundwater for sand extraction is an impending ecological disaster and needs immediate interventions. There are some ex-tractors who are reusing wash-water by making it stand in series of lagoons and allowing silt to settle down. This water is reused for one more round of soil washing. The practice is more due to the scarcity of water rather than concern for the ecosystem. Even with this practice, which is quite rare, only 25–50% of water is recovered. The re-maining is lost in conveyance, evaporation, infiltration, etc.

Wash-water contains a large amount of silt-clay (Table 3). While producing one lorry load of sand, nearly 30 m^3 of silt-clay is produced. Hence nearly 11 million m^3 silt-clay is produced due to sand extraction in a year. During the washing process itself or during the rainy season all the accumulated silt-clay invariably reaches the nearest tank. These particles block pores in the tank bed or agricultural fields where they are allowed to enter. The net result is reduced infiltration rate and groundwater recharging. This causes enhanced water run-off from fields during heavy rains. Hence, wash-water coming out of sand-extraction units is not safe enough for direct use on agriculture fields or village tanks. The small quantum of settled silt-clay is being used by brick-makers to make beds for raw bricks. However, silt-clay mixture can be used for mixing with highly sandy soils with caution. This process is called soil hybridization[13,14]. It is evident from Table 4 that sandy soils of banana plots showed improvement in their physical and nutrient content after application of tank silt @ 900 m^3/ha over two seasons.

For generating a lorry load of sand, nearly 120 m^3 of topsoil is used (Table 3). In a year nearly 43.8 million m^3

Table 3. Soil degradation due to sand extraction in peri-urban and rural Bangalore

Details	Per lorry load of sand	In one day (1000 lorry loads)	In one year	Remarks
Soil used (m^3)	120	120,000	438 lakhs	
Area of land used for soil excavation (ha)	0.04	40	18,600	0.3 m depth (normally)
Quantity of water used (l)	132,000	1320 lakhs (60 lakh gallons)	48,180 million (2190 million gallons)	
Quantity of silt-clay generated (m^3)	30	30,000	11 million	

Table 4. Physical and chemical properties of surface soil and silt-clay due to sand extraction (Available N, P, K in kg/ha and others in ppm)

Sample	Sand (%)	Silt (%)	Clay (%)	Texture	Average N	Average P_2O_5	Average K_2O	Cu	Fe	Mn	Zn	pH
1	79.7	13.4	6.9	Loamy sand	173	168	249	0.64	19.6	10.6	1.0	7.2
2	87.0	6.8	6.1	Loamy sand	187	217	170	0.44	10.2	8.8	3.1	8.1
3	59.4	8.1	32.5	Sandy clay loam	231	298	419	0.90	16.2	18	1.1	7.4
4	81.4	6.7	11.9	Sandy loam	158	184	280	0.88	33.2	9.8	0.5	5.7
5	78.8	10.7	10.5	Sandy loam	144	132.2	321	0.82	16.8	19.8	0.8	6.7
6	68.8	21.1	10.1	Sandy loam	144	22.4	175	0.40	15.6	24.6	0.5	6.6
7	69.0	22.2	8.8	Sandy loam	187	132	175	1.38	15.6	17.2	0.4	7.9
8	87	6.8	6.1	Loamy sand	187	217	170	0.44	10.2	8.8	3.1	8.1
9	61.4	13.9	24.7	Sandy clay loam	187	284	628	2.02	14.2	27.6	5.6	7.1

1, Topsoil used for sand extraction (site 1: upland situation); 2, Topsoil use for sand extraction (site 2: valley land situation); 3, Subsurface soil after removal of surface soil for sand extraction (site 1); 4, Exposed sub soil after removal of surface soil for sand extraction (site 2); 5, Soils from plot grown with ginger on subsurface soil for one season (after removal of topsoil for sand extraction); 6, Silt left at the sand extraction site after sand extraction from topsoil (site 1); 7, Silt left at the sand extraction site after sand extraction from topsoil (site 2); 8, Soil properties of banana plot before application of tank silt; 9, Soils of banana plot applied with tank silt.

of soil is now extracted for sand extraction. Due to this, surface soil from 18,600 ha of land is being lost. These lands will not go out of cultivation permanently. Crops are being raised on sub-surface soils which are poorer in physical and biological parameters and plant nutrient status. Hence, in the next season there is a crop yield loss to an extent of 10–20% depending upon crop and management[10] (also the farmers own experiences recorded during the study). It takes 5–8 years to regain its original status. Yield reduction was observed in desurfaced soils even though soil fertility differences were removed by fertilizer additions[15]. Topsoil removal not only lowered the yield but also reduced the ability of crops to respond to favourable conditions, whether better landscape position or increased precipitation during the growing season.

Farmers normally use class III or class IV land for sand extraction. Fertile pockets (classes I and II) are always used for growing cash crops like mulberry, grapes, vegetables, etc. Class III and class IV lands are generally used for growing hardy crops like ragi in the region. It was found that productivity, area and production of ragi are going down in recent years[16]. Sand extraction is one of the main reasons for this.

Silt-clay carries considerable amounts of phosphorus and potassium (Table 4). Due to concentration effect, silt-clay showed increased amounts of these nutrients when compared to topsoil. Similar is the case with other micronutrients. It was reported that soils of the eastern dry zone in Karnataka (Bangalore region) are generally poor in potassium[17]. However, in the present study subsurface soil contained higher quantities of available potassium compared to surface soil (Tables 4 and 5). In general, excavation of surface soils from agricultural fields and tank beds for sand extraction results in fertility depletion (Tables 5 and 6). Estimates suggest that in a year nearly Rs 25 million worth of N and Rs 17.68 million worth of P_2O_5 are lost due to sand extraction. Increased bulk density of the sub-surface soils indicated unfavourable soil conditions for the next crops. Grewal and Kuhad[10] also reported similar unfavourable soil conditions on desurfaced soils in Haryana. Deep excavations done in village common lands have become a source point for gully erosion in many cases.

Analysis of physical and chemical properties revealed no drastic differences between sand samples extracted from surface soil of agricultural fields or normal riverbed sand (AT sand) (Table 1). Hence the allegation that soil-extracted sand is not good for durability of construction may not hold well.

When soils are removed from tank beds for sand extraction, it increases the water-storage capacity of tanks. Hence there is scope for higher water storage and recharging. Similarly, ponds are created due to soil excavation to greater depths. Regeneration of soil structure by

Table 5. Nutrient content and fertility depletion from surface soil of agricultural fields due to sand extraction

Nutrient	Surface soil	Sub surface soil	Silt	Fertility depletion/ha	Fertility depletion/yr*	Value of nutrient at present rate (Rs)
N	319.6	191.8	90.0	127.8	2.38 million	25 million
P_2O_5 (kg/ha)	83.7	25.2	11.7	58.5	1.09 million	17.68 million
K_2O (kg/ha)	74.8	158.7	62.1	83.9*	Gained*	–
Cu (ppm)	0.66	0.3	0.1	0.56	–	–
Fe (ppm)	0.38	0.76	0.53	0.15	–	–
Mn (ppm)	21.6	14.1	2.96	18.84	–	–
Zn (ppm)	18.4	13.13	0.18	18.22	–	–
Bulk density (g/cm^3)	1.4	1.7	–	–	–	–

*18,600 ha of land being excavated to a depth of 30 cm in one year.

Table 6. Nutrient content in surface soil of tank bed used for sand extraction

Nutrient	Surface soil	Sub surface soil	Silt	Nutrient loss/ha
N (kg/ha)	245.5	227.4	100.1	145
P_2O_5 (kg/ha)	15.5	12.5	9.6	5.9
K_2O (kg/ha)	188	59.4	49.9	138
Cu (ppm)	0.8	0.1	0.32	0.48
Fe (ppm)	11.4	7.16	11.2	0.2
Mn (ppm)	7.68	1.1	3.42	4.26
Zn (ppm)	0.24	0.14	0.14	0.10
Bulk density (g/cm^3)	1.2	1.4	–	–

organic amendments and tillage system or their combination is considered appropriate for the management of desurfaced soils. As available nutrient status is invariably poor in desurfaced soils, use of higher doses (25–50%) of fertilizers and water input than for normal soils may prove beneficial for crop growth[10]. By undertaking required modifications, alternative uses of desurfaced lands for social forestry, waste disposal, water-harvesting structures, farm ponds or even fish or Azolla rearing ponds can be achieved. However, such efforts are rare.

As of now, the State Government is trying to stop this activity citing reasons of ecological degradation. However, the enterprises are still thriving due to huge demand for sand. A complete ban may lead to unaffordable price rise of sand. This may severely hurt construction and infrastructure projects. Hence, there is a need to evolve comprehensive policy to make this activity ecologically tolerable. Area and type of soil suitable for sand extraction, reuse of wash-water, safe disposal or use of silt-clay residues, etc. are the issues to be sorted out scientifically.

The future line of work must include the following:

(i) Research efforts need to be initiated to improve the present techniques of extracting sand from the soil to make it more efficient in terms of the amount of sand recovered and quantity of water used.

(ii) The present technique of reuse of water for sand extraction needs to be made easier and more efficient.

(iii) The possibility of using waste water more efficiently to recharge the groundwater needs to be attempted, since the location of sand extraction is normally in the vicinity of a bore-well.

(iv) Feasibility studies to understand the effect of applying the waste materials containing mostly silt and clay to the sandy soils or to the excavated area to change the texture of the soil and thereby making the soil more productive, need to be undertaken.

(v) Application of organic materials like FYM/compost/green manure/other organic wastes in improving the productivity of the excavated soil is required.

Sand extraction from topsoils of agricultural fields is a significant economic activity. It has significant ecological dimensions in terms of groundwater exploitation, tank siltation, rain-water infiltration, nutrient loss, etc. Loss of crop productivity is temporary but significant and can be restored gradually with consistent efforts. Government policy initiatives and technological and research interventions can be of help in sustaining the enterprise with minimum damage to the ecosystem and agricultural production.

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Post-impact carbonate deposition in the Chicxulub impact crater region, Yucatan Platform, Mexico

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The Chicxulub crater has attracted considerable attention as one of the largest terrestrial impact structures and its association with the Cretaceous/Palaeogene boundary. Analyses of stable isotopes and magnetostratigraphic results for the Paleocene carbonate sequence in the Santa Elena borehole are used to investigate the post-impact sequence and estimate the age of basal sediments in the southern crater sector. Studies of impact ejecta and cover sediments and modelling of post-impact processes suggest erosion effects due to sea-water back surge, block slumping and partial rim collapse of post-impact crater modification. Correlation of stable isotope patterns with the global pattern for marine carbonate sediments provides a stratigraphic framework for the basal Paleocene carbonates. Magnetic polarity constrains correlation of stable isotope variations with the reference Cenozoic isotopic data suggest that the first 17 m above the breccia–carbonate contact represents about 2.5 Ma. The stable isotope data suggest a gap of less than 0.1 Ma, whereas the magnetic polarity data (absence of reverse-polarity samples above impact breccia contact) suggest a gap up to 0.25 Ma.

Keywords: Chicxulub impact crater, Cretaceous/Palaeogene boundary, stable isotope stratigraphy, magnetostratigraphy.

CHICXULUB is the youngest and best-preserved crater of only three large, multi-ring impact structures found on earth[1,2]. The Chicxulub structure was recognized from the concentric circular-pattern of gravity anomalies in the 1940s during oil exploration surveys by Pemex. The buried structure responsible for the anomalies lies in an extensive shallow-water carbonate platform. It was subsequently investigated by further geophysical surveys and drilling. Pemex drilling recovered volcanic-textured rocks towards the centre of the anomaly pattern. The structure was interpreted as an Upper Cretaceous volcanic field till the early 1980s, when an alternative interpretation in terms of an impact crater was proposed[3]. In the early 1990s Chicxulub attracted international attention when the crater was linked to the Cretaceous/Palaeogene (K/Pg) boundary[4], and considered as the long sought after impact crater proposed by Alvarez and coworkers[5]. Analyses of few remaining samples from the Pemex intermittent core recovery programme supported the inference of a K/Pg boundary age for the impact event[4,6]. Alternative interpretations were also reported for the subsurface stratigraphy of Yucatan[7,8]. With the recognition of the origin of the Chicxulub impact, volcanic-textured rocks, geophysical anomalies and age of units were reinterpreted. Ar/Ar dating on melt samples from Chicxulub-1 borehole gave an age of approximately 65 Ma, indicating a K/Pg age for the impact[6]. The reverse magnetic polarity of melt and breccia samples from Yucatan-6 borehole placed the impact within 29r chron that spans the K/Pg boundary[9].

The 200 km-diameter crater lies in the Yucatan platform in southern Gulf of Mexico, completely covered by Cenozoic carbonate sediments. The carbonate cover has protected the structure from erosion processes. Studies of crater morphology, impact melt and ejecta, cratering, post-impact processes and basin characteristics require geophysical surveys and drilling/coring. Chicxulub was identified as a potential drilling target since creation of the International Continental Scientific Drilling Programme (ICDP) in the early 1990s, and it has recently been investigated by drilling with continuous coring[10] as part of the UNAM and ICDP scientific drilling projects (Figure 1).

Analyses of core samples have examined the stratigraphy of the cover carbonate sequence, impact breccia contact and implications for the age of impact, global correlations

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