EXTERNALITIES DUE TO SANDMINING ON GROUNDWATER EXTRACTION IN INDIA

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Abstract

Urbanization, causes surge in sand demand leading to unsustainable sand extraction from dried river paths. Layers of sand deposits are exploited up to the bedrock. This has increased initial and premature failure of irrigation wells in riparian areas. This study attempts to estimate the negative externalities due to sand mining along Uttara Pinakini river, India using field data from Sand mining area (SMA) and Non-sand mining area (NSMA). In SMA (NSMA) proportion of well failure is 0.46 (0.3), groundwater extracted per well 20.67 (32.12) acre inches, negative externality per well Rs. 4189 (Rs. 1328), net return per rupee of groundwater Rs.4.32 (Rs.11.88). In SMA (NSMA), as location of well from sand mining area increased from 30 to 1500 feet, negative externality per well reduced from Rs.7080 to Rs.1585 (Rs.1394 to 1462). In Bangalore city, price of sand was Rs. 4200 per truckload of 350 cubic feet; with inelastic demand (η = -0.88) and transporters earn net return of Rs. 835 per load. It is suggested to impose a Pigouvian tax of Rs. 540 per sand truck load to compensate farmers for loss due to sand mining @ Rs. 4813 per irrigation well.

Key words: Sand mining, negative externality, groundwater irrigation,

INTRODUCTION

Sand is indispensable for modern construction works. In addition, sand has industrial use as raw material in glass making. The major user of sand is by 'construction sector', which has demonstrably not been affected due to drought. Thus, due to its increasing effective demand, sand is being over extracted at different depths varying from three to forty feet, from different river streams and basins. This is imposing negative externalities on riparian habitats as: first, the riverbed loses its ability to hold water as sand takes several years for deposition and affects groundwater recharge especially in a chronically drought stricken area (2). As sand is extracted rapidly, groundwater evaporates fast, reducing groundwater recharge, increasing initial and premature failure of irrigation wells and the associated predicament in farming (Figs 1 through 6).

METHODOLOGY

In order to value the externalities due to sand mining activity, forty farmers located in the sand mining villages, thirty farmers located in immediate neighboring villages where sand excavation or mining is not undertaken are chosen. In addition, 30 sand (truck) sellers are interviewed in Bangalore city. Measures of central tendency were employed to analyze data pertaining to size of holding, gross irrigated area, returns from crops and well investments. The life and age of wells are estimated using 'life tables' approach as in statistical theory. 'Age' of irrigation well refers to wells that are functioning' at the time of collection of field data (2003). 'Life' of irrigation wells refers to number of years a well has already functioned and is no longer functioning. This included initial failure of wells, premature failure of wells and wells which failed after serving a reasonable number of years.

The number of acre-inches of groundwater extracted for each crop in each season and for perennials is estimated as equal to the (Frequency of irrigation per month)*(number of months of crop)*(number of hours to irrigate the crop area)*(average yield of well in GPH) / 22611. The annual cost of irrigation is equal to amortized cost of irrigation well + amortized cost of conveyance + amortized cost of pump set and electrical installation + annual cost of repairs and maintenance.

The negative externality is estimated as equal to amortized cost per functioning wells minus amortized cost per well. The amortized cost per well is equal to the total amortized cost of all wells divided by the total number of wells

Amortized cost per functioning well is equal to total amortized cost of all wells divided by the Total number of functioning wells. The proportion of well failure is equal to the number of failed wells divided by Total number of wells. The net return per acre-inch of groundwater used is estimated as total net returns divided by the total groundwater used. The net return per rupee of irrigation cost is estimated as net return per acre-inch of groundwater used divided by irrigation cost per acre-inch of groundwater used.

A log linear function was estimated to measure the effect of distance, sale days and price on volume of sand demanded in parts of Bangalore city. The functional form used was $\text{Log } Y = \text{Log } a + \text{Log } X_1 + \text{Log } X_2 + \text{Log } X_3$

Where, Y = volume of sand in cubic feet per lorry per month

X1 = Distance from source of sand extraction to sale point in kilometers

X2 = Number of days taken for sale of sand at sale point in Bangalore city

X3 = Price of sand at sale point in rupees per cft

RESULTS

As mentioned above, sand layers along riparian areas serves as spongy layer and helps in recharge of groundwater through percolation of water through different layers of sand (6). When sand mining becomes intense, then the vertical and lateral movement of water is checked and affects the recharge of groundwater. This results in initial / premature failure of filter point wells, open wells as well as bore wells. It is found that, in SMA, there is high rate of failure of irrigation wells (46 percent) compared with NSMA (29 percent). This is a *prima facie* indicator of the effect of sand mining on groundwater recharge in irrigation wells. The drastic effect in sand mining areas (SMA) is observed in filter point wells, as about 68 percent were not functioning at the time of field data collection (June 2003). In non-sand mining areas (NSMA), the proportion of non-functioning filter point wells was 23 percent. In SMA main source of irrigation was from bore wells (54 percent), while in NSMA main source of Irrigation was filter point wells (44 percent). This indicated that impact of sand mining is apparent in filter point wells as they are in proximity to SMA and are of shallow depth (30 to 35 ft). These wells are the most susceptible for sand mining done to a depth of 25 to 30 ft. Thus, groundwater in the riparian filter point wells dry up faster compared to bore wells located away from SMA and are drilled to greater depths of 400 to 650 ft (Fig 1).

Net returns per acre from filter point wells were 53 percent higher in NSMA compared to SMA. But after discounting net returns per acre considering the average age and proportion of well success at the rate of two percent, net returns per well were 89 percent higher in NSMA compared to SMA. Net returns per acre under bore wells was seven percent higher in NSMA compared to SMA, after discounting net returns per acre at two percent, considering the average age and proportion of well success, the net return was 19 percent higher in NSMA compared to SMA. This indicates that due to depletion of groundwater due to sand mining activity, farmers in SMA incurring higher irrigation cost which lead to lower net return per acre.

Due to sand mining which led to poor groundwater recharge, farmers in SMA relied on other sources of income for livelihood. Thus, in SMA for every rupee income from sand mining activity, farmer realized 0.53 rupee from agriculture, 0.21 rupee from other allied field -

sericulture and 0.12 rupee from livestock activities. This indicates the wide gap in income earned between sand mining activity and agriculture. This reflects the increasing rate of exploitation of sand resources in the region. (Table 1) (Photo 2)

As number of non-functional wells increases, the amortized cost of irrigation has increased drastically. The analysis of economics of irrigation indicated that gross irrigated area per well was 19 percent lower and groundwater extraction per acre was 44 percent lower due to negative externality effect of sand mining on groundwater recharge. The externality cost involved in drilling of additional wells due to initial and premature failure was 215 percent higher in SMA (Rs. 4189 per well) compared to NSMA (Rs.1328 per well). The net return per rupee of irrigation cost was 43 percent lower in SMA compared to NSMA, as net return per rupee of amortized cost of irrigation is higher in NSMA (Rs. 11.88 per acre inch) compared to SMA (Rs. 4.32 per acre inch) (Table 2).

Considering the location of wells within a distance of 120 feet from sand mining area, the probability of well failure is 0.52 in SMA , while in NSMA the probability of well failure is 0.33. The net return per acre of irrigated area is higher in NMSA irrespective of the distance from the river stream, compared with sand mining area. The amortized cost per functioning well is higher in SMA (Rs.10412) for wells located within 30 feet from the stream than all the wells in NSMA (Rs.4581). Thus negative externality per well is higher for all wells located within 120 feet from stream in sand mining area compared to any well irrespective of distance in non-sand mining area. This amply demonstrates the negative effect of sand mining externality on agriculture. The groundwater extracted per well (24.76 acre inches) in the SMA sand mining area located beyond 120 feet matched with the wells located within 30 feet in non-sand mining area (26.45 acre inches). This apparently demonstrates that distance from stream in sand mining has a large and negative influence on the groundwater extracted for irrigation per well. The groundwater extracted from wells located within 30 feet from stream in NSMA (26.45 acre-inches) is at least 100 percent higher compared with SMA (12.08 acre-inches). (Table 3)

PARTIAL BUDGETING ANALYSIS

Partial budgeting indicated that SMAs are better off compared to NSMA without considering the negative externality. But after considering the externalities, in SMA there was a net loss of Rs.771 per acre, while without considering externalities the net return was Rs.6250. This apparently indicates the effect of sand mining on groundwater extraction and as a result are realizing pseudo illusionary return of Rs.6250 per acre, while they are in fact bearing the negative externality and in turn a loss of Rs. 711 per acre due to sand mining externality (Tables 4 & 5).

DEMAND FUNCTION FOR SAND

Sand is purchased by those in house construction and other civil works throughout the year. The key factors determining the demand for sand are the distance from the sand mining area, number of days taken for sale of sand at the place of destination and the price of sand. The estimated demand function for sand is

$$Y = (6.572)\ (\text{Distance})^{0.323}\ (\text{No. of sale days})^{0.0036}\ (\text{Sand Price})^{-0.876}$$

The demand function of sand estimated in Bangalore city using data from 30 sand suppliers indicated that, on an average a sand truck or lorry supplies 25 loads per month realizing a gross return of Rs.4500 per load and net return of Rs. 1285 per load. The demand function for sand indicates that for a one percent increase in the price of sand, the quantity demanded decreases by 0.88 percent. Thus, the quantity demanded is inelastic with respect to price. (Table 6)

IMPLICATIONS

Groundwater is a crucial source of irrigation for the farmers in Gauribidanur taluk to eke out the living since there is no other perennial source of irrigation. Currently the irrigation wells in the riparian areas of uttara Pinakini River are seriously threatened due to excessive sand extraction, which in turn affects the groundwater recharge. This has manifested in increase in proportion of well failure. It is imperative that sand mining is seriously (negative externality) affecting the interests of the economy of riparian farmers in this river basin. This calls for a serious, effective and efficient implementation of regulation of sand mining for the benefit of both agriculture and civil works.

Currently sand extraction is permitted up to three feet by remitting a royalty of Rs.45 per truckload of sand to the Department of Mines and Geology. On the other hand, however, sand miners are excavating even up to 40 feet in Uttara pinakini stream. Thus, department of mines and geology has to seriously monitor the sand mining activity for the overall benefit of society.

The estimated negative externality per irrigation well in the Gauribidanur SMA was Rs. 4186 per year. There are about 8000 irrigation wells located in the riparian areas of the Gauribidanur river stream, where sand mining is actively being undertaken. Thus, the total estimated negative externality is Rs.3,34,88,000. The total estimated sand accumulated in uttara pinakini river stream is 1,74,00,000 cubic meter in fifteen years, of which 61 percent was extracted, constituting 1,06,14,000 cubic meter or 37,14,90,000 cft in fifteen years(6). Therefore annual sand extracted is 2,47,66,000 cft imposing externality of Rs 1.35 per cft or Rs .540 per load. In order to conserve the sand resources, along the riparian areas, this environmental cost Rs 540 per load should be imposed to internalise the pressure on this natural resource in the market price of sand. Imposition of the pigouvian tax of Rs. 540 per truck load of sand transported will create a corpus fund with the Government's Department of Mines and Geology with which (i) the farmers possessing irrigation wells which have failed due to sand mining would be compensated on the basis of loss in net returns which would result from mining a truck load of sand.

Table 1 Sources of income in sand mining and NSMAs along Uttara Pinakini river basin in Gauribidanur taluk, Karnataka 2003.

(Rs. Per farm per year)

Source	Net income per farm in sand mining (Rs.)	Share of different farm activities per rupee of income from sand mining (Rs.)	Net income per farm in non-sand mining (Rs.)	Share of different farm activities per rupee of income from Agriculture (Rs.)
Agriculture	26298 (31)	0.53	47404 (60)	1
Livestock	7532 (9)	0.15	9054 (11)	0.19
Sand mining	49250 (59)	1	0 (0)	0
Sericulture	3500 (4)	0.07	16937 (21)	0.35
Others*	10575 (12)	0.21	5600 (7)	0.12
Total	82437 (100)		78995 (100)	

Note: Figures in parentheses represent percentage to the respective total

*Other activities are petty shop business, Milk vendor, electrical worker, contractor, tractor driver and Government employee.

Table 2 Access to Groundwater resources for irrigation in NSMAs and SMAs from all wells along Uttara Pinakini river basin in Gauribidanur taluk, Karnataka 2003.

Particulars	SMAs (SMA)	NSMAs (NSA)	Difference between SMA & NSA	% Difference over NSA
Total number of wells	76	57	NR	NR
No. Of functional wells	40	40	NR	NR
No. Of failed wells	35	17	NR	NR
Proportion of well failure	0.46	0.3	0.16	53
Gross irrigated Area (acre)	127	152	NR	NR
Gross irrigated area per well (acres)	3.1	3.8	-0.7	-18.42
GW extracted per well (acre inches)	20.67	32.12	-11.44	-35.6
GW extracted per acre (acre inches)	5.73	8.05	-2.3	-28
Total GW extracted	827	1325	497	37
Amortized cost of irrigation per acre inch of GW (Rs.)	309	133	176	133
Net return per well (Rs.)	27638	46913	-19274	-41
Net return per acre (Rs.)	8705	12143	-3438	-28
Total net return (Rs.)	1105535	1875590	NR	NR
Total amortized cost of irrigation (Rs.)	306772	211855	NR	NR
Amortized cost per well (Rs.)	4622	4189	433	10
Amortized cost of irrigation per functioning well (Rs.)	8811	5517	3294	60
Negative externality per well(Rs.)	4189	1328	2861	215
Net return per acre inch of GW used (Rs.)	1336	1602	-265	-16
Net return per rupee of amortized cost of irrigation (Rs.)	4.32	11.88	-7.56	-63

Note: wells include open wells, Filter point wells and bore wells

NR =Not relevant

1. Negative externality= Amortized cost per functioning wells minus amortized cost per well.
2. Amortized cost per well =Total amortized cost of all wells/Total number of wells
3. Amortized cost per functioning well = Total amortized cost of all wells/Total number of functioning wells
4. Proportion of well failure = Number of failed wells divided by Total number of wells
5. Net return per acre-inch of groundwater used= Total net returns/Total groundwater used
6. Net returns per rupee of irrigation cost
   = Net return per acre inch of groundwater used/Irrigation cost per acre inch of groundwater used (Rs.)

Table 3: Economics of irrigation according to distance from river stream in sand mining and non-sand mining areas along Uttara Pinakini river basin in Gauribidanur taluk, Karnataka 2003.

Particulars	Sand mining (n = 40)			Non sand mining (n = 30)		
	Distance from streams (ft)			Distance from streams (ft)		
	0-30	30-120	120-1500	0-30	30-120	120-1500
Total number of wells	25	25	26	24	12	21
Failed wells	17	13	5	8	4	5
Functioning wells	8	11	21	16	8	16
Proportion of well failure	0.68	0.52	0.19	0.33	0.33	0.23
Net return per acre of GIA (Rs.)	6824	7509	10064	9732	10962	12895
GIA (acres)	26.5	44	56.5	50.5	34.5	67.5
Expected net return per acre of GIA (Rs.)	2183	3604	8151	6520	7344	9929
Amortized cost per well (Rs.)	3332	4785	6656	3187	3353	4679
Amortized cost per functioning well (Rs.)	10412	13292	8241	4581	5030	6141
Irrigation cost per acre of GIA (Rs.)	861	569	332	173	295	127
Total groundwater extracted (acre inches) for the sample farmers	96.69	209.95	520	423.22	136.31	769
Groundwater extracted per functioning well (acre inches)	12.08	19.08	24.76	26.45	17.04	48
Negative externality per well (Rs.)	7080	8507	1585	1394	1677	1462

Note: GIA =gross irrigated area

1. Excepted net return per acre of GIA = (Net return per acre of GIA * Proportion of well failure)
2. Negative externality= Amortized cost per functioning wells minus amortized cost per well.
3. Amortized cost per well =Total amortized cost of all wells/Total number of wells
4. Amortized cost per functioning well = Total amortized cost of all wells/Total number of functioning wells

   Proportion of well failure = Number of failed wells divided by Total number of wells

Table 4. Partial budgeting analysis of Sand mining by farmers without considering externalities due to sand mining in Gauribidanur taluk, Karnataka, 2003

Cost (A)	Cost (B)
Increase in cost Nil	**Decrease in cost** Nil
Decrease in returns 1. Opportunity return from cultivated land forgone for providing road linkage to transport the sand per acre = Rs.2659 2. Net return per acre from agriculture in NSMA minus net return per acre from agriculture in SMA excluding groundwater irrigation cost per acre = (Rs. 13680- Rs. 10227) = Rs. 3453 A=Total =Rs. 2659 + Rs. 3453 =Rs. 6112	**Increase in returns** 1. Annual Net returns per acre from sand mining activity for the farmer =Rs.12362 (= total income from sand extraction for all farmers divided by gross irrigated area B= Total =Rs.12362
Net returns in SMA = B-A= Rs. 12362 - Rs. 6112 =Rs. 6250	

Note:

<u>Explanation for item 1 &3:</u>

1. Oppournity cost of cultivated land foregone for road linkage is estimated as below:
a. Net return from agriculture per acre in SMA excluding the irrigation cost= Rs.9499
b. Number of sample farmers who provided road space = 8
c. Total cultivated area of eight sample farmers who provided road linkage in SMA = 27.5 acres
d. Estimated cultivated area lost due to provision of road space for transporting sand by sample farm=7.75 acres
e. Road linkage space /total cultivated land area =7.75/27.5=0.28 acres
f. Oppournity cost of cultivated land for providing road link space = (a X e)
= 9499 X 0.28 =Rs.2659

2. Annual net returns incurred by sand mining by sample farmers = Rs.1909929.
Annual Net returns per acre from sand mining activity for the farmer = 1909929/154.5 = 12362

Table 5. Partial budgeting Analysis of sand mining in the farm internalizing externalities along Uttara pinakini river in Gauribidanur Taluk of Karnataka, 2003

Cost (A)	Cost (B)
Increase in cost due to sand mining activity in the farm through groundwater irrigation Externality cost 1.Amortized cost of ground water irrigation per acre in SMA minus amortized cost of groundwater irrigation in NSMA = (Rs.3008-Rs.1384) = Rs.1624	**Decrease in cost due to sand mining activity on agriculture** Since 7.75 acres out of 27.75 acres are lost for providing road linkage, on an average 0.28 acre is lost. Thus the decrease in cost of cultivation is (0.28XRs.3500 per acre) – Rs.980, is the savings in cost of cultivation due to the land foregone for transporting sand
Decrease in returns due to sand mining activity in the farm **Externality cost in terms of returns foregone due to provision of road space for transporting sand, linking the sand source and the main road** 2. Amortized opportunity return for cultivated land forgone for providing road linkage to transport sand per acre = Rs.924 3.Net return per acre from agriculture in NSMA minus net return per acre from agriculture in SMA in the farm excluding groundwater irrigation cost = (Rs. 13680-Rs.10227) = Rs.3453 A=Total =Rs.1624 +Rs.924 +Rs.3453=Rs.6001	**Increase in net returns due to sand mining activity on the farm** 4. Amortized net returns per acre from sand mining = Rs.4310 B= Total = Rs.980+Rs.4310=5290
Net returns in SMAs = B-A= Rs.5290 – Rs.6001 = -Rs.711	

Note: Assumptions of partial budgeting analysis

1. Riparian farmers undertake sand mining, as they are closer to river stream carrying sand and due to squatters right.
2. Though 17 farmers out of the sample of 40 farmers in SMA are involved in sand mining activities gross cropped area of all sample farmers is considered in estimating externality due to sand mining.
3. Returns from road linkage, oppournity cost of labour and net return per acre from sand mining are amortized for three years at an interest rate of 2%, since sand is assumed to accumulate once in three years due to pattern of rainfall.
4. Amortized cost of irrigation per acre = Amortized cost of investment on all wells, conveyance, pump set and pump house.

<u>Explanation for item 2 & 4:</u>

Opportunity cost of cultivated land foregone for road linkage is estimated as below:

a. Net return from agriculture per acre in SMA excluding the irrigation cost= Rs.9499
b. Number of sample farmers who provided road space = 8
c. Total cultivated area of eight sample farmers who provided road linkage in SMA = 27.5 acres
d. Estimated cultivated area lost due to provision of road space for transporting sand by sample farm=7.75 acres
e. Road linkage space /total cultivated land area =7.75/27.5=0.28 acres
f. Opportunity cost of cultivated land for providing road link space = (a X e) = 9499 X 0.28 =Rs.2659
g. Externality cost for providing road links is amortized for 3 years @ 2% = Rs.924
h. The oppournity cost for road link space of Rs.2021 is realized approximately once in three years as sand mining activity is assumed to take place once in three year due to pattern of rainfall.

Annual net returns incurred by sand mining by sample farmers = Rs.1909929.

a. Annual Net returns per acre from sand mining activity for the farmer
= 1909929/154.5 = 12362
b. The annual net returns per acre from sand mining is realized approximately once in three years as sand mining activity is assumed to take place once in three year due to pattern of rainfall.
c. The amortized net return per acre at the rate of two percent = Rs.4310

Table 6. Estimation of demand function for sand (Volume in cubic feet) in Bangalore city, year 2003 (Log linear function)

Dependent variable: Ln of volume of sand demanded per month per lorry (Geometric mean of sand demanded per month = 9897 cft)				
	Coefficient	t-value	R^2	Geometric mean
Ln of Intercept	6.572	22.712	0.873	715 cft
Independent variables				
Ln of distance travelled per lorry each time (Kms)	0.323*	6.473		106.06 kms
Ln of sale days (days) to sell each load	0.003622	0.237		1.785 days
Ln of price per cft (Rs.)	-0.876*	-11.629		10.45 (Rs/cft)

- Significant at 1 percent

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Fig 1. Sand mining to a depth of 30 feet in Uttara pinakini river stream in Kalludi in Gauribidanur Taluk, Karnataka, 2003

Fig 2: Sand being washed using compressor pump to remove red sting as white color sand fetches high price, Gauribidanur taluk, Karnataka, 2003

Fig 3: Sand being mined in agricultural field near the Uttara Pinakini river stream in Heribidanur village, Gauribidanur taluk, Karnataka, 2003

Fig 4: Check dam at Chigatagere separating the non-sand mining villages on left side from sand mining villages on right side, Gaurubidanur taluk, 2003

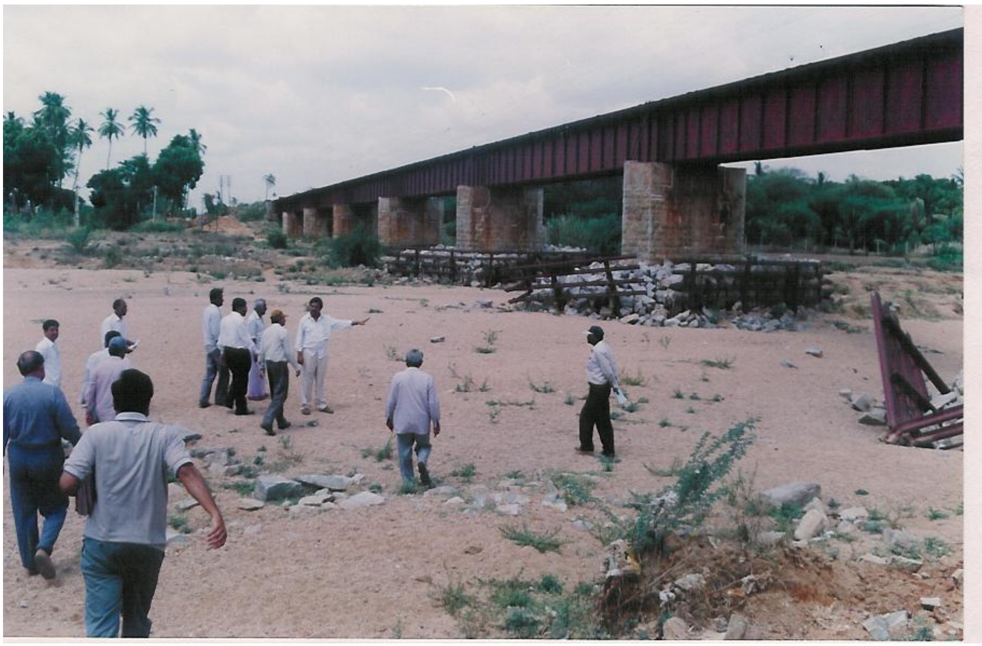

Fig 5: Railway bridge foundation frequently being repaired due to sand mining across Uttara Pinakini river in Gauribidanur taluk, Karnataka, 2002.

Fig 6: Public protesting against sand mining activity in Gauridanur town, 2002