Economic Valuation of Ecosystem Changes Due to Salinity Ingress and Ground Water Depletion: A Study of Coastal Gujarat, India

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Abstract: *The paper is part of an on going study on "the impact of salinity and ground water pollution on rural households living in the coastal area of Gujarat State in India". The paper focuses on the economic and ecological implications of human induced increase in salinity and groundwater depletion in coastal Gujarat and argues for the urgent need to adopt integrated water resources management. The water samples collected from bore and dug wells at different distances of the coastal area has been used to study the water quality parameters. Data collected from farmers located in the coastal area of the state have been used to study the implications of increased salinity and ground water depletion. It is found that the present salinity propagation is 0.5 to 1 km distance every year from the coastline since the ground water tables are going down by 4 to 5 meters every year. In the coastal areas, the total dissolved solid (TDS) far exceeds the permissible levels for irrigation and therefore the water is completely unusable for agriculture activity. The increase in salinity leads to soil degradation and adversely affects agricultural productivity and induces changes in land use. The paper also discusses observations about the inequality in access to water resources in the coastal area of Gujarat State due to increasing salinity and groundwater depletion a failure of state. It is found from the analysis of the data collected from farmers located in the coastal area of the state that the most affected categories are small and marginal farmers. The study found that the poor farmers lose access to resources as water levels declines or wells dry up. The rich farmers extract water by using electricity which is available at highly subsidized rate. Purchase of water at a prohibitive price is also common in rural areas. The paper argues for adopting measures to conserve water resources considering the social, economic and ecological implications of increased salinity and groundwater depletion in coastal Gujarat.*

Introduction

It is well understood that the salinity and water logging plays a crucial role in the decline of agriculture productivity, income and employment in irrigated agriculture (Joshi and Agnihothri, 1984;Joshi, 1987; Chopra, 1989; Joshi and Jha, 1992; Nayak, 2002). Salinity is the presence of soluble salts in or on soils, or in waters. High levels of soluble salts may results in reduced plant productivity or the elimination of vegetation (QDPI, 1987). Most of these studies noted that water logging and salinity has affected the fertility of the soil which in turn leads to decline of agriculture productivity. As a result, the investments made on the development of canal irrigation in the salinity affected area become uneconomic to the society. The main source of this sort of salinity is due to the rise in the subsoil water table resulting from the perennial canal systems (GOI, 1972). However, the salinity ingress in the coastal area due to the depletion of ground water got less attention in the litrature. It is a serious problem in many parts of the coastal Gujarat State (GOG 1978). The estimates shows that the groundwater in the state of Gujarat, which has an area of 1,06,000 square kilometer with 1659 kilometers of coast line, has been adversely affected by the salinity ingress. It was reported that every year on an average 0.5 to 1.0 km distance from the coast lines affected by salinity ingress. Thus about 5 to 7.5 km wide strip of the inland area had been rendered saline till 1996. The groundwater quality has been deteriorated to more than 2000 ppm of TDS in many places of coastal Gujarat (Barot 1996). In many areas of Gujarat, the groundwater draft is more than groundwater recharge, which has resulted in lowering groundwater levels (Gujarat Ecological Commission 2001). The over exploitation of groundwater is driven mostly for irrigation needs. More than 90 per cent of the total cultivated area in north Gujarat is being irrigated by

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groundwater sources. It was also found that the net area suitable for groundwater recharge is on decline over the State. The figures on the decline of net recharge area are found correlated with the large areas affected by salinity (Gujarat Ecological Commission 2001). In short, the ingress of salinity is not only a major environmental degradation or ecological problem facing the coastal belt of Gujarat but also the resultant externalities impose severe economic strains on individual farmers. Remember that the capital intensity of groundwater extraction makes it easier to exclude rival users especially in fragile resource regions where the high cost of groundwater extraction couples with low and inequitable asset ownership makes the resource privy to a few well-to-do household. This give rise to 'free riding externalities which differ in nature and intensity depending on biophysical and climatic conditions (Reddy, 2003). Since the overexploitation of groundwater and the resultant degradation in terms of salinity ingress is largely the result of a lack of proper integrated water resource management practice, there is a real need to understand the magnitude of economic losses due to salinity ingress so that appropriate measures can be adopted for desalinization and groundwater replenishment. This short paper, which is part of an ongoing major study on 'the impact of salinity and groundwater pollution on rural household living in the coastal area of Gujarat state in India' presents preliminary results of the pilot survey on the impact of salinity ingress on the individual farmers living in the coastal area of Gujarat State.

Objectives

The specific objectives of the study are as follows:

1. To examine the water quality in the coastal areas of Gujarat State;
2. To estimate the forgone agricultural benefits due to salinity ingress (an external cost of salinity).
3. To suggest an appropriate policy for desalinisation and groundwater replenishment.

Study Area , Data and Methodology

The pilot survey has been carried out in a village named Pinjarat located in the coastal area of Gujarat State. The village has a total area of 3382 sq km and a total population of 5183 (976 households) persons[2]. Majority of the households depend on open wells for drinking water. As per the village records, the total land under cultivation is 1029 out of which 1000 acres of land are irrigated by government canal. The remaining 1572.5 are unirrigated land. Total non cultivable area of the village is 5462.5 acres.

The important crops grown in the village are rice (750 acres), jowar (125 acres), wheat (250 acres), Bajra (150 acres), and vegetables (100). These crops are grown in three different seasons called Kharif (June to December), Rabi (December to march) and summer (March to June). The farmers who have access to sweet water from the government canal cultivates all the three seasons. It is reported that those who depend on ground water, cultivates both the seasons such as kharif and Rabi. We also found that small farmers cultivates only one season that is Kharif. The present short paper is based on a sample of 6 households located in different hamlets of the village, which are located approximately 7 kilometres inside from the seashore. Data has been collected in the year 2004 through a detailed structured interview schedule comprising questions on socio economic aspects of the household and question related to agricultural production and water salinity. Moreover, we have collected data on water quality of the village by doing a physical and chemical analysis of water collected from the wells located in and around the villages. The important parameters like colour, turbidity, conductivity, Alkalinity, hardness, total dissolved solids, salinity, calcium, magnesium, chloride, pH, nitrite, fluoride *etc*., have been analysed to understand the quality of both drinking and irrigation water. In addition to these tests we have conducted microbiological tests for one sample of water from the most frequently used well in the village. The methodologies adopted for the physical, chemical and micro biological analysis of water have been given in table 1.

In order to estimate the forgone agricultural benefits due to salinity ingress, we have selected 6 plots from a

[2] Village data have been collected from village records.

distance of approximately 7 kilometres inside from the seashore. These households are selected purposively, and classified into two strata, such as, farmers who cultivates in all the three seasons (without salinity) and farmers cultivates only two season (groundwater is saline during summer). Total number of farmers in each stratum is 3.

To assess the external cost of salinity ingress in terms of the forgone agriculture benefits, we need to compute the net benefits from agriculture. Two alternative viability measures have been used viz., net present value (NPV), and benefit cost ratios. The selected farmers grow three important crops that are rice, wheat and vegetables. The cultivation cost of these crops includes cost of preparing the plot, cost of seeds and sowing and cost of harvesting. In addition to this, there are fixed costs by way of agricultural implements and irrigation investments. The recurring costs include material cost such as costs for applying fertilisers, manure and pesticides, repair, maintenance and supervision *etc*. The benefits include total production of crop and crop residuals. The benefits and costs are expressed in 2004 prices, and assumed agriculture cultivation over a period of 25 years. The NPV has been computed at three alternative discount rates: 8, 10, and 12 percentages. The differences in the NPV for the two different scenarios; viz a scenario without and with salinity have been interpreted as the external cost of salinity.

Table 1: Methodologies adopted for the physical, chemical and micro biological analysis of water

1	Parameter (Units)	Methodology Adopted
2	Colour (colour units)	Visual Comparison Method
3	Turbidity (NTU)*	Nephelometric Method
4	Conductivity ms/m	Conductivity Metre
5	Alkalinity mg Ca CO_3 L at pH 4.5	Titration Method
6	Total Hardness mg/I	EDTA Titrimetric
7	Total dissolved solids mg/L	Dried at 180^0 C
8	Salinity 0/00	Argentometric Method
9	Calcium mg/I	EDTA Titrimetric
10	Magnesium mg/I	Calculation method
11	Chloride mg/I	Argentometric Method
12	pH	pH metre
13	Nitrate mg/L	Colorimetric Method
14	Nitrate mg/L	Cadmium Reduction
15	Fluoride mg/L	SPADNS method
16	Total coli form MPN Index/100ML	Multiple tube fermentation technique.

Notes: * NTU (Nephelometric turbidity units; ** 0/00 parts per thousand

Results and Discussion

In Pinjarat village, people generally depend on open wells, canals and village tank to meet their water requirements. We found that open wells are still an important source of water in the village even with salinity ingress. In an earlier study, we found that 55 per cent of the villagers use open well, 29 per cent use public taps and 9.3 per cent depends up on both open wells and public taps for their water requirement (Joshi and Jyothis 2004). A small percentage of the total population, that is 5.5 per cent, fetch water from the village tanks for drinking purposes. However, the tank water is primarily used for bathing, washing and livestock needs. This tank is found in bad condition with high silt and euotrophication. This tank gets water from the government irrigation canal.

In order to understand the water quality of the region, we have collected water samples from 10 open wells situated in an around the village. The characteristics of the sample wells are provided in table 2.

It is clear from the table 2 that villagers fetch water from 3 wells for drinking purpose. These wells are located approximately 6 kilometres inside from the sea shore. Another important character of these wells (2 wells) is that it is proximate to irrigation canals. It is getting recharged due to its proximity to canal water. The well which is away from the canal water is situated 7 kilometres inside the sea shore. It is opined that one well is not usable (abandoned) since it got highly saline water which is located 1 kilometre inside from the sea shore. The water from all other 7 wells is used for bathing, washing cloths, livestock and agriculture. The water from these wells is not used for irrigation purposes during summer since the salinity is more during the summer season. As a result, the farmers from the non-irrigated area of the village have to forgo some amount of agricultural output. The forgone agricultural benefit of these farmers as compared to the benefits of similar agricultural plots from the irrigated area has been interpreted as the external cost of salinity ingress. We will be discussing this aspect in the later part of the paper.

Table 2 Characteristics of the wells examined in and around Pinjarat Village

Well No	Depth of the well	Distance from sea	Quality as per villagers opinion	Availability of irrigation water nearer to the well
1	30	6	Drinking	Irrigation water available
2	40	6	Uses other than Drinking	Irrigation water not available
3	22	1	Not usable	Irrigation water not available
4	20	2	Uses other than Drinking	Irrigation water not available
5	30	6	Uses other than Drinking	Irrigation water not available
6	25	7	Not Drinking	Irrigation water not available
7	25	3	Uses other than Drinking	Irrigation water not available
8	40	7	Drinking	Irrigation water not available
9	15	4	Drinking	Irrigation water available
10	35	4	Uses other than Drinking	Irrigation water not available

Note: Micro biological test also have been conducted for water sample from well number 1.

Source: Primary data

The table.3 provides the physical and aggregate properties of water collected from these sample wells. It is clear from the table. 3 that certain properties of drinking water exceed the permissible limit as per the Indian and WHO standards of drinking water. We found high TDS in all the wells which are used for drinking water purpose although other parameters are in the upper limit of Indian standard. The dissolved solids for the 3 drinking water wells are in the range of 560-1800 Mg/L which are in excess of permissible limit. It is reported that TDS is inferior to palatability and may induce an unfavourable physiological reaction in the transient consumer (Srinivas *et al* 2000).

The total hardness is also an important parameter of quality of water. Depending on the interaction of other factors such as pH and alkalinity, water with hardness above 200 may cause scale deposition in the distribution system and results in excessive soap consumption and subsequent scum formation (Srinivas *et al* 2000). Hardness of drinking water wells in the study area ranges from 280 to 3000 mg Ca CO3/L. The reason for high solid and hardness is that these wells are unprotected wells. In these drinking water sources, calcium and magnesium are found within the permissible limit that is 75 and 50 Mg/L respectively. Chlorides, Nitrates and fluorides are also found with in the permissible limit (Table 4). It is important to mention that all these parameters are controlled within the permissible limit just because of its proximity to the sweet water canal. However, the micro biological test conducted for a water sample of the most frequently used well for drinking water showed an MPN index 130 which is quite high, suggest that water is not at high-quality for drinking.

The well water used for agriculture and other purposes are found highly contaminated. Low salinity water can be used for irrigation with most crops on most soils with little likelihood of developing salinity problem (Elango et al 1992). Excellent irrigation water is found with TDS less than 200 mg/L. The permissible limit of TDS in the irrigation water ranges 500 to 500 mg/L (Elango *et al* 1992).

The water samples from all wells except one well (Well No 5) show the value of TDS that exceeds 1500 Mg/L. This indicates water is highly saline and not suitable for irrigation under ordinary conditions. It makes farmers to forgo their agricultural benefits due to high salinity. It was reported that water is more saline during rabi and summer season. Many farmers are not able to cultivate during this period especially the small farmers who cultivates in unirrigated area.

Table 3 Physical and aggregate properties of water samples collected from the Pinjarat village

Well No	Conductivity Ms/m	Color Units	Turbidity NTU	Alkalinity mg Ca CO3/L at pH 4	Hardness mg Ca CO3/L	TDS Mg/L	Salinity
1	1.788	10.00	2	105	370	1400	0.41
2	1.748	15.00	2.5	108	182	1800	0.33
3	16.216	75.00	2.5	165	2470	11600	8.77
4	6.170	40.00	22	170	568	3900	2.59
5	1.320	10.00	10	146	330	1220	0.16
6	5.320	5.00	2	140	850	3200	2.34
7	9.790	<5	<1	76	3100	7600	4.72
8	1.110	10.00	<1	98	3000	600	0.14
9	0.930	10.00	2	76	280	560	0.11
10	2.350	25.00	3	118	1000	1860	0.75
INDIAN STD	6			150	200	500	
WHO STD	6			150	150	500	

Note STD (standard)

Source:Primary data

Table 4: Inorganic non-metallic constituents of water samples collected from the Pinjarat Village

Well No	pH	Calcium Mg/I	Magnesium Mg/L	Chloride Mg/I	Nitrate Mg/L	Phosphate Mg/I	Florride Mg/L
1	7.9	53.7	57.35	211.90	0.670	0.050	0.15
2	8.5	36.07	22.35	167.90	0.300	0.070	0.15
3	8.4	561.12	260	4838.40	0.700	0.175	ND
4	8	120.24	65.12	1419.50	0.250	0.240	.20
5	7.8	84.17	29.16	71.97	0.200	0.095	.15
6	8.2	64.13	167.67	1279.60	1.100	0.130	ND
7	7.7	480.96	461.7	2599.10	0.950	0.040	ND
8	8	68.14	31.59	59.98	0.900	0.040	ND
9	8.2	40.08	43.74	43.98	0.950	0.070	.16
10	7.8	112.22	174.96	399.80	1.000	0.090	.13
INDIAN STD	7.50-8.50	75	50	250	50		1.5
WHO STD	7.50	75	50	250	50		1.5

Note STD (standard), ND (not detectable)

Source: Primary data

An estimation of the forgone benefits of agriculture for an acre of land in two scenarios is provided in table 5. The scenario one represents farmers who cultivates all the three seasons since they have access to irrigation water. The scenario two represents farmers who do not have access to irrigation water so that they cultivates only one or two seasons. The scenario two represent rain fed agriculture supplemented with well water irrigation during rabi season. During summer they hardly cultivate their land due to high salinity ingress.

Table 5 shows the benefits net of all costs at 12 per cent discount rate for a period of 25 years in scenario one which is less than the benefits net of all costs in scenario 2. The benefit cost ratio of the first scenario is 1.44 which is far less than the benefit cost ratio of the second scenario that is 1.96 at 12 per cent discount rate. The difference in the net present value of the two scenarios at 12 per cent discount arte is Rs 72221.33 per acre, which is to be considered as an external cost of salinity ingress. Therefore, the total external cost due to salinity ingress is approximately Rs 11,35,68,041 in the case of the Pinjarat village. This justifies all initiatives of investments that aim desalinisation of ground water. It is an externality created by farmers themselves with excessive extraction of ground water. Therefore, there are many policy options available with us to control this external cost which ranges from developing new water institutions among farmers, controlling water markets, direct state intervention *etc.*

Table 5 Sensitivity Analysis of net benefits from agriculture under alternative assumptions (for cash flows summed up over 25 years at 2004 prices)

Scenarios	Discount rate in percentages	Discounted benefits in Rupees	Discounted Cost in Rupees	Net Present Value in Rupees	Benefit Cost Ratio	Differences in NPV of two scenarios	Percentage difference in NPV of two scenarios
Scenario I	12	142745.1	98516.83	44228.27	1.44	72221.23	62.01
	10	165202.1	113488.2	51713.9	1.45	83518.6	61.76
	08	194280.9	132856.4	61424.5	1.46	98145.2	61.51
Scenario II	12	237647.1	121197.6	116449.5	1.96		
	10	275034.3	139801.8	135232.5	1.96		
	08	323445.7	163876	159569.7	1.97		

Source: Estimated from Primary data

Apart from these costs, this study has made few field level observations, on how the incidence of these costs shared among various strata of farmers such as small, medium and large farmers. We found small and marginal farmers are usually facing more salinity problem, because of their lack of access water from alternative sources. As a result farmers disproportionately face the consequence of salinity. This type of externality is referred as vertical externality (Reddy 2003). It was also observed that groundwater markets can take care such vertical externalities (equity problems) to a large extent (Shah, 1993). But evolution of water markets is possible only in regions where groundwater is available in sufficient quantities which is not the present case. Markets do not evolve where there is not enough water to share or to sell (Reddy, 2001). Therefore, it warrants an integrated water resources management approach by considering social, economic ecological aspects of it. Therefore, this study aims to work into these policy matters, especially towards policies with respect to groundwater development which include the role of subsidised credits/power/diesel in groundwater development, pricing of groundwater drafting, land rights and groundwater rights.

Conclusion

The paper tries to value the changes in the ecosystem due to human induced increase in salinity and groundwater depletion on the lives of people living in the coastal area of Gujarat State. The water samples collected from bore and dug wells at different distances of the coastal area has been used to study the water quality parameters. We found the total dissolved solid far exceeds the permissible levels for irrigation and therefore the water is completely unusable for agriculture activity. The increase in salinity leads to soil degradation and adversely affects agricultural productivity and induces changes in land use. We found the benefits net of all costs at 12 per cent discount rate for a period of 25 years in a salinity affected area is less than the benefits net of all costs in irrigated agriculture. The benefit cost ratios of these two scenarios are 1.44 and 1.96 respectively. The difference in the net present value of these two scenarios at 12 per cent discount arte is Rs 72221.33 per acre, which is to be considered as an external cost of salinity ingress per acre of land. This justifies all initiatives of investments that aims desalinisation of ground water. We also observed that the incidence of this cost is disproportionately distributed among farmers. It is a vertical externality created by farmers themselves with excessive extraction of ground water. Therefore, there are many policy options available with us to control this external cost which ranges from developing new water institutions among farmers, controlling water markets, direct state intervention *etc*. Therefore, it warrants an integrated water resources management approach by considering social, economic ecological aspects of it.

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