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Assessing Effect of Fluoride Contaminated Groundwater on Paddy : A Micro-Level Study from Tamil Nadu

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ABSTRACT

This study estimated the agricultural yield damage function on paddy crop in the fluoride affected locales and to suggest policy measure in western zone of Tamil Nadu. The primary data were collected by using multistage random sampling method of about 248 farmers of low fluoride affected, moderately fluoride affected, highly fluoride affected and non-fluoride affected locales in the proportion of sample size. Analysis employed for the study is cobb-Douglas production function and the results revealed that difference in yield of paddy is higher in highly fluoride affected locale (855 kg/ha) when compared to other fluoride affected locale. The agriculture yield damage function in fluoride affected locales results revealed that coefficients of averting expenditure for irrigation was negative significant in less and moderately fluoride affected locale whereas positive significant in high fluoride affected locale this indicates that fluoride contamination intensity is high in these locale. The study suggested that government should educate the awareness of fluoride contamination to farmers and fluoride resistant crops should be identified and recommend to the study area.

Keywords Fluoride contamination, Paddy, Yield, Fluoride resistant crop, Groundwater.

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INTRODUCTION

Water is the primary medium through which climate change influences earth's ecosystem and thus the livelihood and well-being of societies. Groundwater is prime source for agriculture activities. It is one of the most extracted natural resource in the world. Continuous depletion of groundwater increases global threats, including a sudden decline in agriculture (Aeschbach–Hertig and Gleeson 2012, Turner 2019, https://socialissuesindia 2017). This leads to contamination in groundwater such as fluoride discharge in water and it is becoming worldwide problem. India annually extracts around 251 cubic kilometer which is 52% of the total global annual extraction of groundwater compared with China and United states of America together extract just 112 cu.km. India is largest user of groundwater and 90% of groundwater is used for irrigation that covers 60% of the total irrigated area (World press 2017). Over abstraction of groundwater and over use of phosphatic fertilizer are some of the causes of fluoride contamination in groundwater. The occurrence of the high fluoride concentrations in groundwater is a problem faced by many countries, notably India, Srilanka and China, the rift valley countries in East Africa, Turkey and parts of South Africa (Ali et al. 2016). In India many states are endemic fluorosis viz., Andhra Pradesh, Tamil Nadu, Karnataka, Gujarat, Rajasthan, Punjab, Haryana, Bihar and Kerala are the endemic fluorosis states (CGWB 2016). In Tamil Nadu, 23 out of 33 district were affected by fluoride contamination in water. Salem, Erode, Dharmapuri, Coimbatore, Thiruchirapalli, Dindugal, Theni, Perambalur, Vellore, Madurai, Virudhunagar and Krishnagiri are having fluoride contamination and people risk with dental and skeletal fluorosis (CGWB 2016). Paddy crop is majorly cultivated in Tamil Nadu. Total water requirement of paddy crop requires 1250 mm. Groundwater availability in the study area is over exploited. Farmers were continue to extract the groundwater for irrigation and this leads to contamination of fluoride in groundwater. Though there are several empirical studies on agricultural related to soil degradation, wind and water erosion, there are only few studies have dealt with problems in the agricultural sector caused by fluoride contamination in groundwater. With this background the paper aims to (i) To estimate the agricultural yield damage function in the fluoride affected locales (ii) To suggest appropriate policy measure in the study area.

MATERIALS AND METHODS

Multistage random sampling method was used for the selection of study area. At first stage, District wise fluoride affected locales of Tamil Nadu with the permissible limit of above 1.5 mg/L collected from central groundwater board 2016-17. In second stage, district has been segregated into different agro climatic zones based on fluoride content and finally, western zone was selected. At third stage, it was classified into affected locale (highly, moderately and less fluoride affected locale) and non-affected locale. From this two blocks from each of the locales, then three villages of each block were selected based on secondary data. Finally, 248 samples were selected based on sample size methodology given by Slovin formula (1960) :

$$\text{Slovin formula } (n) = N/(N*(d)^2+1)$$

Where, n = Sample size, N = Total number of farmers population (6021618), d = Error limit of 5% (0.05).

Application of the sampling formula with the values specified which in fact maximizes the sample size; yielded a total required sample of 399, out of 399 samples considering time constraint along with convenience about 62% i.e. 248 samples from less fluoride affected locale, moderate fluoride affected locale, high fluoride affected locale and non-affected locale and interviewed through pre tested schedule.

Tools of analysis

Agricultural damage function

The agricultural value damage function relates value of agricultural damages for paddy crop to averting expenditure of land and irrigation water and quality indices of land, irrigation water and management index. Cobb-Douglas production function was used for assessing agricultural damage in categories of fluoride affected locales.

$$Y = a\, X_1^{b1}\, X_2^{b2}\, X_3^{\ b3}\, X_4^{b4}\, X_5^{b5}\, e^U$$

$$ln\,(Y) = a + b_1\, ln\,(X_1) + b_2\, ln\,(X_2) + b_3\, ln\,(X_3) + b_4\, ln\,(X_4) + b_5\, ln\,(X_5) + e$$

Where, Y = Yield damage for paddy crop (Rs/ha), X_1 = Averting expenditure incured for land (Rs/ha), X_2 = Averting expenditure incured for irrigation water (Rs/ha), X_3 = Land quality index (poor-1, average-2, good-3), X_4 = Water quality index (poor-1, average-2, good-3), X_5 = Management index, e = Random error term.

The agricultural yield damage was computed by calculating the differences in the value of each fluoride affected locales over the value of the non-affected locale.

RESULTS AND DISCUSSION

Yield of paddy crop in fluoride affected locales and non-fluoride affected locale

Yield of paddy was higher for non-affected locale (4842 kg/ha) when compared to less fluoride affected locale (4600 kg/ha) followed by moderately affected

Table 1. Yield of paddy crop (kg/ha). Source : Field survey (2017-18).

Sl. No.	Particulars	Less affected	Moderately affected	Highly affected	Non-affected
1	Yield of paddy	4600	4283	3987	4842

(4283 kg/ha) and highly affected (3987 kg/ha). Difference in yield of paddy is higher in highly fluoride affected locale (855 kg/ha) when compared to other fluoride affected locale.

Averting or defensive expenditure for irrigation water

The details of averting or defensive expenditure on irrigation and drinking water of fluoride affected locale are furnished in Table 1.

The averting expenditure on irrigation water was found higher in highly fluoride affected locale (Rs 3185/ha) which showed that direct association of this expenditure in fluoride pollution intensity followed by moderatelym fluorde affected locale (Rs 2629/ha) and less fluoride affected locale (Rs 1725/ha). The averting expenditure on land was found higher in highly fluoride affected locale compared to other fluoride affected locales. Expenditure increased with increase in fluoride pollution intensity (Table 2).

Agricultural damage function for less fluoride affected locale

The estimates of agricultural damage function for less fluoride affected locale are given in Table 3 and it could be observed from the table that the adjusted coefficient of multiple determination (R^2) was 0.89 indicating that 89% of the variation in yield damage

Table 2. Estimation of averting expenditure for irrigation water and land. Source : Field survey (2017-18).

Sl. No.	Particulars	Less affected	Moderately affected	Highly affected
I	Averting expenditure on irrigation water (Rs/ha)	1725	2629	3185
II	Averting expenditure on land (Rs/ha)	10937	14085	16312

Table 3. Estimates of agricultural damage functions for less fluoride affected locale. *** - Significant at 1% level, **-Significant at 5% level, * -Significant at 10% level, NS - Non significant.

Sl. No.	Particulars	Coefficient	Std error	t stat
1.	Constant	16.679***	1.570	10.626
2.	Land averting expenditure in rupees per hectare	-0.202***	0.067	-3.032
3.	Averting expenditure for irrigation water per hectare	-0.477**	0.230	-2.072
4.	Land quality index	0.151^{NS}	0.108	1.389
5.	Water quality index	-2.891***	0.166	-17.444
6.	Management index	0.363***	0.124	2.939
	Adjusted R^2 value	0.89		
	Observation	62		

per hectare was explained by the explanatory variable included in the model. Agricultural damage in these locale were influenced by land averting expenditure, water quality index and management index were signification at 1% level and averting expenditure for irrigation water was signification at 5% level.

It can be seen from the table that land based averting expenditure had negative influence on agriculture damage in these locale. One percent increase in land based averting expenditure from the geometric mean level, keeping other factors constant, there would be an decrease in agricultural damage by 0.202% which is due to prevailing low fluoride contamination intensity in these locale. Likewise 1% increase in water quality index from the geometric mean level, keeping other factors constant, there would be an reduction in agricultural damage by 2.891% which is due to prevailing low fluoride contamination intensity in these locale and may be therefore water quality made the farms to interchange over to irrigate the closest available good quality water, supplied it was low in cost. Therefore, there was a scope to reduce yield damage. The coefficient of management index was found positive significant, which indicated that for every 1% increase in management index from the geometric mean level, keeping other factors constant. The agricultural damage in less fluoride affected farms could be reduced by improving the management index by 0.363%. The estimated coefficient of averting expenditure for irrigation water was found to be statistically significant at 5% level. The elasticity of averting expenditure for irrigation

Table 4. Estimates of agricultural damage functions for moderately fluoride affected locale. *** - Significant at 1% level, **-Significant at 5% level, * - Significant at 10% level, NS - Non significant.

Sl. No.	Particulars	Coefficient	Std error	t stat
1.	Constant	5.675***	0.631	8.990
2.	Land averting expenditure in rupees per hectare	-0.064 NS	0.186	-0.344
3.	Averting expenditure for irrigation water per hectare	-0.151**	0.066	-2.291
4.	Land quality index	0.044NS	0.254	0.172
5.	Water quality index	0.647***	0.255	2.536
6.	Management index	-2.153***	0.171	-12.572
	Adjusted R^2 value	0.78		
	Observation	62		

Table 5. Estimates of agricultural damage functions for highly fluoride affected locale. *** -Significant at 1% level, ** - Significant at 5% level, * - Significant at 10% level, NS - Non significant.

Sl. No.	Particulars	Coefficient	Std error	t stat
1.	Constant	-15.44NS	9.69	1.593
2.	Land averting expenditure in rupees per hectare	1.665***	0.336	4.955
3.	Averting expenditure for irrigation water per hectare	5.453***	1.887	2.890
4.	Land quality index	1.026***	0.334	3.073
5.	Water quality index	-0.045NS	0.541	-0.084
6.	Management index	1.022***	0.202	5.052
	Adjusted R^2 value	0.77		
	Observation	62		

water were 0.477, which indicated that 1% increase in averting expenditure for irrigation water would decrease the agricultural damage by 0.477% when all other variables were kept at their respective geometric mean levels.

Agricultural damage function for moderately fluoride affected locale

The estimates of agricultural damage function for moderately fluoride affected locale are given in Table 4 and it could be observed from the table that the adjusted coefficient of multiple determination (R^2) was 0.78 indicating that 78% of the variation in yield damage per hectare was explained by the explanatory variable included in the model.

The estimated coefficient of the water quality index was found significant at 1% level. The coefficient of water quality index was found positive significant, which indicated that for every 1% increase in water quality index from the geometric mean level, keeping other factors constant. The agricultural damage in less fluoride affected locale could be reduced by improving the water quality index by 0.647%. The coefficient of averting expenditure for irrigation water was found to be negative significant at 5% level. One percent increase in irrigation water based averting expenditure from the geometric mean level, keeping other factors constant, there would be an decrease in agricultural damage by 0.151% which is due to prevailing moderately fluoride contamination intensity in these locale. The coefficient of averting expenditure for management index was found to be negative significant at 1% level. One percent increase in management index from the geometric mean level, keeping other factors constant, there would be an decrease in agricultural damage by 0.151% which is due to prevailing moderately fluoride contamination intensity in these locale.

Agricultural damage function for highly fluoride affected locale

The estimates of agricultural damage function for highly fluoride affected locale are given in Table 5 and it could be observed from the table that the adjusted coefficient of multiple determination (R^2) was 0.77 indicating that 77% of the variation in yield damage per hectare was explained by the explanatory variable included in the model.

The coefficients of land averting expenditure, irrigation averting expenditure, land quality index and management index were significant at 1% level. The agricultural damage was positively influenced by land averting expenditure, irrigation averting expenditure, land quality index and management index was 1.665, 5.453, 1.026 and 1.022, respectively. This phenomenon is due the prevailing high fluoride contamination intensity in these locale. Hence the present level of averting expenditure incurred at farmers level was insufficient to counter the agricultural damage. Therefore highly fluoride affected locale, the agricultural damage could be reduced by undertaking more of averting expenditure for both land and irrigation and also by improving land quality index.

CONCLUSION

The averting expenditure on land and irrigation water was found higher in highly fluoride affected locale compared to other fluoride affected locales. Expenditure increased with increase in fluoride pollution intensity. Difference in yield of paddy is higher in highly fluoride affected locale (855 kg/ha) when compared to other fluoride affected locale. The agriculture yield damage function in fluoride affected locales results revealed that coefficients of averting expenditure for irrigation was negative significant in less and moderately fluoride affected locale whereas positive significant in high fluoride affected locale this indicates that fluoride contamination intensity is high in these locale. The coefficients of land averting expenditure was negative significant in less fluoride affected locale and positive significant in highly fluoride affected locale this indicates that fluoride contamination in groundwater is high. Therefore, agricultural damage could be reduced by undertaking more of averting expenditure for both land and irrigation. The study suggests that government should give awareness about fluoride contamination to farmers and fluoride resistant crops should be identified and recommend to the study area.

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