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Impact of River Water Pollution on Rice and Wheat Productivity: A Case Study in Maharajganj District, India

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ABSTRACT

Background: Increased water pollution is a worldwide problem that threatens the well-being of billions of people and their economies, ecosystems and quality of life in both developed and developing nations. Poor wastewater management has exacerbated major water-quality concerns in many regions of the globe, increasing the water crisis. With these, the present study made an attempt to capture the impact of river water pollution on rice and wheat productivity in surveyed villages in Maharajganj district, Uttar Pradesh, India.

Methods: A field survey of 200 farmers was conducted from (1-30/September/2021) using multistage sampling. Further, the productivity change method was used to calculate the impact of river water pollution on crop productivity.

Result: The results from this study show that per acre rice and wheat crop productivity was 8.84 and 7.78 quintals in Rajabari village (a river pollution-affected village) respectively, while the corresponding figures in Taraini village (a non-river pollution-affected village) were 19.86 and 18.14 quintals/acre. Further, net returns for rice and wheat crops in Rajabari village were Rs. 4863 and Rs. 5730, while corresponding figures in Taraini village were Rs. 19319 and Rs. 22070 per acre, respectively. Hence, the present study recommends that the government should take appropriate water contamination measures to limit water pollution through appropriate treatment methods. To prevent contamination of water containing with heavy metals, petroleum hydrocarbons, detergents and any pollutant that causes danger to the environment and in order to achieve normalcy within the limits of standards, attention should be focused on the prevention of water pollution with pollutants and the preservation of the quality and ecosystems of these waters through adequate and uninterrupted monitoring in time and space.

Key words: Developing countries, Productivity change method, Productivity loss, River water pollution, Rice, Wheat.

INTRODUCTION

Increased water pollution is a worldwide problem that threatens the well-being of billions of people and their economies, ecosystems and quality of life in both developed and developing nations (FAO, 2017). Poor wastewater management has exacerbated major water-quality concerns in many regions of the globe, increasing the water crisis (United Nations, 2016; Jatav *et al.*, 2023). Even though emphasis has been placed mostly on water quantity, water usage efficiency and distribution. Global water scarcity is caused not only by the physical shortage of resources but also by the growing degradation of water quality in many nations (FAO, 2017; Singh, 2020a), limiting the amount of water that is safe to use (Singh *et al.*, 2016). An estimated 20 million acres of arable land are irrigated with water that has either not been treated or has been treated insufficiently because it contains residual contributions from home liquids (Fatta-Kassinos *et al.*, 2011; Handral *et al.*, 2017). The presence of heavy metals, which are harmful owing to their toxicity and persistence in the environment, makes this a threat to human health and ecosystems (Mapanda *et al.*, 2005; Jatav and Kalu, 2023). Heavy metals in agricultural soils may have a harmful impact on human health because they can go up the food chain, from the soil to the plants and eventually to the people who eat those plants (Gupta *et al.,* 2010; Khusrizal *et al.*, 2024; Phuong *et al.*, 2024).

Moreover, industrial pollution pollutes the scarce accessible water supplies (Schulte and Morrison, 2014). Industries dump solid trash in open locations and discharge untreated wastewater, which has a detrimental impact on household health and the environment. Pollution is not limited to major businesses; small and rural companies also contaminate rivers, making them unfit for human consumption (Wang *et al.*, 2008; Kumbhare *et al.*, 2012; Nayak, 2014). Additionally, industrial wastewater pollution contaminates rural water with heavy metals, affecting agriculture, aquaculture, animal drinking water and recreational activities (Mekuria *et al.*, 2021). Moreover, the river had to battle with water contamination caused by fertilizer usage (Nayak, 2002; Zhou *et al.*, 2021). Pesticide contamination in water systems exceeded allowable limits,

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endangering public health. Individuals who drink, cook, bathe and wash their clothing in filthy surface water is increasing their risk of diarrheal infections and stunting in children (Nayak, 2005; Kulinkina *et al.*, 2020). Moreover, the livelihood of rural inhabitants was substantially harmed since industrial effluents harmed their water supplies by negatively impacting environmental biotic and abiotic components (Saha *et al.*, 2023).

With the above, the present study aims to capture impact of contaminated river water on the farm productivity (Rice and What) in surveyed villages of Maharajganj district of Uttar Pradesh, India.

METHODS AND MATERIALS

Study site

The present study is carried out in the catchment area of Rohini River, which lies in the middle of Nautanwa and Nichlaul Tehsils in Maharajganj district. Thuthibari is a town and it is located northeast of Maharajganj and also touches to border of Nepal. The Thuthibari lies under the Nautanwa Tehsils. This Tehsil is widely polluted due to flow of the Jharain and the Chandan River originated from Nepal and they are passed through Nawal Parasi and Sunwal cities of Nepal. Nawal Parasi city is highly industrialized area, there are various types of heavy industries and factories established and these industries emit toxic and solid wastes in these rivers (Singh, 2008). The toxic and solid waste reaches to India through these rivers and it has adverse impact on people who live around these rivers. The Jharain river (other name is Piyas) is more polluted compare to the Chandan river, the water quality of this river is very poor (Singh, 2008).

Data collection

The present study was conducted in the two villages of Maharajganj district of Eastern Uttar Pradesh, India. The study was carried out in the catchment area of Rohini River lies in the middle of Nautanwa and Nichlaul Tehsils (administrative unit) of Maharajganj district from (1-30/ September/2021). The present study uses systematically collected field survey data to capture impact of contaminated water and crops productivity, while secondary data collected from Census, 2011 was used to examine the socioeconomic status of Maharajganj district with respect to Uttar Pradesh. A multistage sampling technique was adopted. In the first step, Maharajganj district was purposively selected because the Rohini River is passing from it and affecting the livelihoods of farming communities. In the second step, one *Tehsil* namely Nautanwa (administrative unit) was selected out of four *Tehsils*. In the third step, one developmental block was selected out of 12 was purposively selected. In the fourth step, two villages (micro administrative unit) were selected. The selection criteria for villages were as follows. The first village namely Rajabari was selected as it is near the bank of Rohini River (exposed to river water contamination), while the second village namely Taraini was selected as it is far from the bank of Rohini River (more than 10 kilometers). In the fifth step, 50-50 samples sample farmers were selected using a systematic sampling technique. In totality, 1 state, 1 district, 1 *Tehsil*, 1 Development Block, 2 villages and 100 samples were selected to capture farmers' responses on river water pollution and its impact on agriculture and human health. Lastly, descriptive statistics such as percentage and mean were used to analyze the field-level data.

Productivity change calculation

In this study, the productivity change (Production function) method is used to estimate impact of polluted water on productivity of rice and wheat crops. The productivity change method is applicable whenever the environmental quality serves as an input for the production of market commodities (Gunatilake 2003). The productivity change method first quantifies physical changes in production due to environmental quality changes. Then market prices are used to value the productivity changes attributed to environmental quality changes. When there are distortions, appropriately adjusted market prices should be used to value productivity changes. The resulting monetary values are incorporated into the project's economic analysis. The potential advantages and costs of an action, whether they occur within or outside the normal scope of the project, are considered. The production-function approach (PFA), also known as the productivity-change method, has seen extensive application for assessing the results of environmental quality changes (such as river water pollution) on agricultural output (Adams *et al.*, 1986).

In PFA, natural capital is treated as a factor in the manufacturing process. When an input deteriorates, the services it provides to production decrease and the producer's bottom line takes a hit as a result. An illustration of this connection is shown in Fig 1. Soil erosion has occurred due to overgrazing. The earth's ability to support grass for the animals to feed on decreases when the grass gets uneven and the soil is washed away. The farmer's income consequently suffers as a result. To put a price on environmental degradation, the productivity approach looks at its ultimate impact: Lower farming income.

Any effect on production can be examined using Fig 1. Over-grazing is the initial pressure that causes environmental damage (soil erosion). As a result, this has an effect on productivity (reduced capacity of soil to sustain crops).

There are three components to the economic loss associated with rice and wheat cultivation. First, if water contamination reduces rice and wheat yield, then crop quantity will fall. Second, the price-based measure of crop loss posits that lower prices for rice and wheat in a given region are indicative of worse rice and wheat quality as a result of water pollution. Finally, a rise in input prices is predicated on the idea that farms will respond to potential productivity declines by increasing their investment in costly but effective countermeasures. The expectation of the profit loss is summarized by the following formula (Wang *et al.*, 2008):

$$\pi_p = (\bar{P}-\Delta P)\ (\bar{Q}-\Delta Q)-(\bar{C}-\Delta C)$$
$$=\bar{P}\bar{Q}-\bar{P}*\Delta Q-\ \Delta P*\ \bar{Q}+\Delta P*\Delta Q-\bar{C}-\Delta C$$
$$=(\bar{P}\bar{Q}-\bar{C})-(\bar{P}*\Delta Q+\Delta P*\bar{Q}+\Delta\bar{C})+\Delta P*\Delta Q$$
$$=\pi_n-\text{ Profit loss}$$
$$=\text{Profit loss}=\ P*\Delta Q+\Delta P*Q+\Delta C$$

Where:

$\bar{P}*\Delta Q$ = Quantity loss.

$\Delta P*\bar{Q}$ = Quality loss, cost increase.

π_n and π_p = Rice and wheat profits in the non-polluted and polluted areas.

RESULTS AND DISCUSSION

Socioeconomic profile of maharajganj and uttar pradesh

Table 1 depicts that the population of Maharajganj district is 2684703, which is ranked 34th among districts in Uttar Pradesh (Census, 2011). Male and female population gap is very less as per Census, 2011. A higher gender gap leads to lower farm productivity as it is directly linked to the decision-making process on which crop will be grown to deal with water contamination. The literacy rate of Maharajganj is 62.76 per cent, male literacy rate is 75.85 per cent, while the corresponding figure for female is 48.92 per cent. The share of urban and rural population in the district is 15 per cent and 85 per cent respectively, which is substantially lower than the urban population of Uttar Pradesh, *i.e.*, 22.3 per cent (Census, 2011). Mahrajganj district has population density of 909 persons per square kilometre (sq. km), while the corresponding figure is 829 per sq.km in Uttar Pradesh (Table 1). Rural population along with low literacy rate and low labour force participation rate are few important factors responsible for higher population density in the Maharajganj compared with Uttar Pradesh.

Maharajganj district had population from different social and religious groups. The Scheduled caste population is 18.36 per cent, which is lower compared to Uttar Pradesh, *i.e.*, 20.70 per cent. Further, the population belonging to the Scheduled Tribe is 0.61 per cent, while the corresponding figure is relatively lower for Uttar Pradesh, *i.e.*, 0.57 per cent. The dependency rate is calculated by dividing the number of dependents by the total population for a given age range. Specifically, it evaluates those aged 0-14 and those aged 65 and over. This can help illustrate how high unemployment rates place a strain on the economy by distinguishing between individuals who are able and those who are unable to work. Simply put, a high dependency ratio percentage means that the working population must shoulder a heavier share of the cost of caring for the dependent population. The population growth during 2001 and 2011 is also relatively higher for Maharajganj than that of Uttar Pradesh (Table 1). Maharajanj district has reported 23.50 per cent growth in population during 2001 to 2011, while corresponding data is relatively lower in Uttar Pradesh (*i.e.*, 20.23 per cent). Crude Birth and Death rates are also relatively higher in Maharajgaj compared with Uttar Pradesh. As per the Census 2011, crude birth rate was 27.90 per cent in Maharajganj, while it was only 24.80 per cent in Uttar Pradesh. Likewise, the crude death rate was 9.60 per cent in Maharajganj, while it was only 8.30 per cent in Uttar Pradesh.

As far as economic condition is concerned, the per capita income at current prices (2011-12) was nearly half from the Uttar Pradesh of Maharajganj. The per capita income of Maharajganj was only Rs. 35,175 in 2012, while per capita income of Uttar Pradesh was Rs. 62, 652. This shows the economic backwardness of the district. The

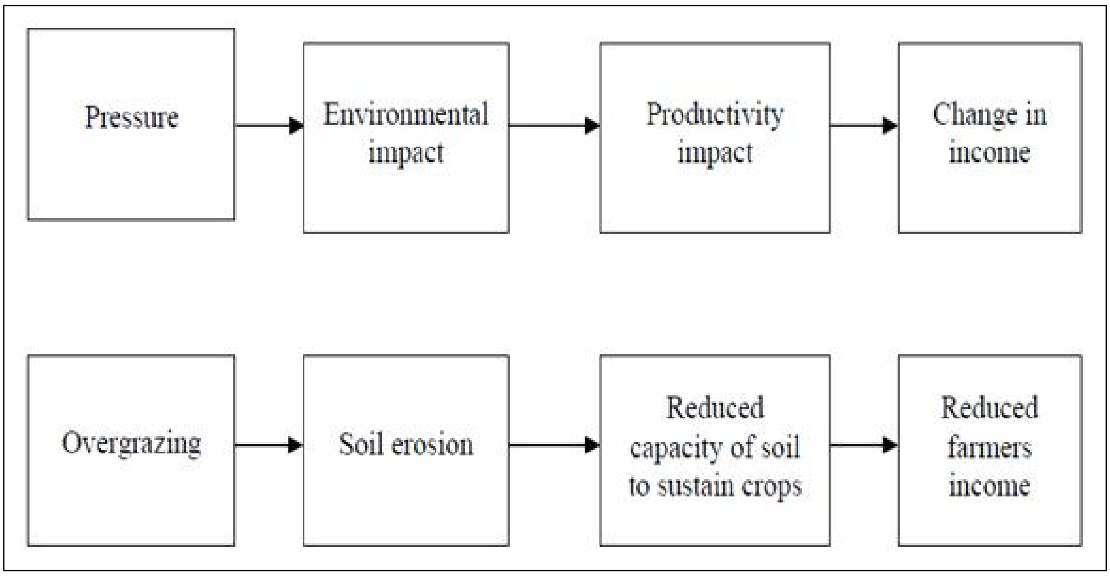

Fig 1: Linking environmental degradation to changes in agriculture production (Gunatilake 2003).

results reported from Table 2.1 also confirmed that the poverty rate was relatively much higher in Maharajganj than that of Uttar Pradesh. As per National Sample Survey Organization (NSSO, 2012), nearly 50 per cent of the population belonging to the Maharajganj district was living below poverty line, while the corresponding figure for Uttar Pradesh was only 39.80 per cent.

Moreover, Table 1 shows that about 81.83 per cent of population belonging to the Hindu religion, while Muslim population was only 17.08 per cent and 1.09 per cent of population belonging to the other religions in Maharajganj district. In other words, the majority of the population in Maharajganj and Uttar Pradesh belonged to the Hindu religion. Further, the population belonging to the Scheduled Caste and Scheduled Tribe Caste are considered, about 18.36 per cent in Maharajganj, while corresponding figures are higher for Uttar Pradesh (*i.e.*, 20.70 per cent). The Scheduled Tribe population is relatively higher in Maharajganj (*i.e.*, 0.61 per cent) compared to the Uttar Pradesh (*i.e.* 0.57 per cent). On the contrary, the average household size is relatively lower in Maharajganj (5.3 per household) compared to Uttar Pradesh (5.5 per household). Lastly, the majority of farmers fall under marginal landholding (less than one hectare) in both Maharajganj and Uttar Pradesh. As it reported from Table 1 that more than 85 per cent of landholders are marginal farmers, whereas, corresponding figures is lower for Uttar Pradesh (*i.e.*, 75.42 per cent).

Water contamination and crop productivity in sample villages

Table 2 represents the productivity of rice and wheat crops in study site (2 villages). The area, production and productivity of both crops show that Taraini village, where no water contamination exists, is in better condition compared to Rajabari village, where contamination exists. The mean area under rice crop is relatively higher in Taraini village (*i.e.*, 1.73 acres) compared with Rajabari village (*i.e.*, 1.44 acres). Furthermore, because of the availability of clean water for irrigation, the mean rice crop production in Taraini village is relatively higher (34.36 quintals) than in Rajabari village (12.73 quintals). Likewise, productivity of the rice crop is also more than two times higher in Taraini village (*i.e.*, 19.86 quintals per acre) than that of Rajabari village (*i.e.*, 8.84 quintals per acre). The mean area under wheat crop in Taraini village (1.73 acres) is relatively higher than that in Rajabari village (*i.e.*, 1.43 acres). Further, the production of the wheat crop in Taraini village is nearly three times higher (31.38 quintals) than that of Rajabari village (*i.e.*, 11.12 quintals). Furthermore, the wheat productivity in Taraini village is also relatively two and a half times higher (18.14 quintals per acre) than that of Rajabari village (*i.e.*, 7.78

Table 1: Socioeconomic status of population in Uttar Pradesh and Maharajganj (Census, 2011and *NSSO, 2012).

Indicator	Uttar Pradesh	Maharajganj
Gender ratio (per cent)	912	943
Literacy rate (per cent)	67.68	62.76
Population density (persons per Sq. Km)	829	909
Geographical area (Sq. Km)	240,928	2952
Population growth (per cent)	20.23	23.50
Crude birth rate (per cent)	24.80	27.90
Crude death rate (per cent)	8.30	9.60
Per capita income (Current Prices)	62, 652	35, 175
Poverty rate (per cent)*	39.80	49.10
Labor force participation rate (per cent)	45.00	48.85
Hindu population (per cent)	79.70	81.83
Muslim population (per cent)	19.30	17.08
Scheduled caste population (per cent)	20.70	18.36
Scheduled tribe population (per cent)	0.57	0.61
Average household size (Person)	5.50	5.30
Marginal farmers (per cent)	75.42	85.89

Note: Per capita income is current prices at 2024.

Table 2: Village wise area, Production and productivity of rice and wheat (Field Survey Data, 2021).

Village	Rice			Wheat		
	Mean Area	Mean of Production	Productivity	Mean Area	Mean of Production	Productivity
Rajabari	1.44	12.73	8.84	1.43	11.12	7.78
Taraini	1.73	34.36	19.86	1.73	31.38	18.14

Note: Area in acre, Production in quintal and production in quintal per acre.

quintals per acre). Though there are several factors that contributed to the higher production and productivity and wheat crops in Taraini village, the main possible reason for higher production and productivity is the availability of clean water. On the other hand, lower crop production and productivity in Rajabari village are due to the use of contaminated water for irrigation purposes. This confirms that water contamination is a serious problem for the farming community. In totality, it has an effect on farmers' income.

Costs, gross value and net returns of cultivation of rice and wheat

Table 3 depicts the cost of cultivation per acre, value and net farm returns. The results from Table 3 revealed that the cost of cultivation for the rice crop in Rajabari village is Rs. 7,752 per acre, while it is relatively lower in Taraini village, *i.e.*, Rs. 6,329. Further, the cost of cultivation for the wheat crop is Rs. 10,576 in Rajabari village, while it is only Rs. 9,614 in Taraini village. Hence, we can draw inferences from Table 3. First, farmers belonging to the Rajabari village are spending relatively more to grow crops compared to farmers belonging to the Taraini village. Second, due to the contamination of the output, they are getting relatively less value from their farm products, which results in lower net returns. Hence, water contamination poses dual challenges for farmers belonging to the Rajabari village. It is not only lowering crop productivity but also lowering farm returns.

Land Size-wise costs of cultivation for rice

Table 4 shows the cost of rice crop cultivation per acre. The results from Table 4 show that the cost of cultivation for marginal farmers is relatively higher compared to large farmers. Per acre, the total cost of cultivation by marginal farmers for the rice crop is Rs. 7,927, while it is only Rs. 3,847 for large farmers. The comparative analysis at the component level revealed that, out of total cost, marginal farmers are paying relatively more on pesticide, irrigation and harvesting compared to large farmers. Pesticides cost for marginal farmers about 7.49 per cent of their income, while large farmers spend only 3.72 per cent. Likewise, about 11.06 per cent of total expenditure is going for irrigation of marginal farmers, while only 5.15 per cent of expenditure is going for irrigation of large farmers. Further, more than 13 per cent and 5.15 per cent of the total expenditure on irrigation are spent by marginal and large farmers, respectively.

Land size-wise costs of cultivation for wheat

Table 5 depicts the costs of cultivation for a wheat crop on different land sizes. The results from Table 5 show that the per-acre costs of cultivation are Rs. 11,007 and Rs. 4,743 for marginal farmers and large farmers, respectively. It means marginal farmers are spending more per acre compared to large farmers. Further, component-wise analysis shows that marginal farmers are spending about 15.82 per cent on irrigation, while large farmers are spending only 7.27 per cent on irrigation. During the field survey discussion, marginal farmers argued that they are relying on large farmers for irrigation and paying the charges of machines for irrigation on an hourly basis to rich and medium farmers. Further, their farms are also relatively far away from the river. This resulted in higher irrigation costs. On the contrary, large farmers are well-equipped with machines, so their costs on land preparation and sowing are relatively lower than those of marginal farmers. Large farmers are spending only ` 751 per acre for land preparation, while marginal farmers are spending almost double, *i.e.*, ` 1,346 per acre. Furthermore, the cost of

Table 3: Village wise costs, Gross value and net returns of cultivation (per acre) (Field Survey Data, 2021).

Village	Rice			Wheat		
	Cost of cultivation	Gross Value	Net Returns	Cost of cultivation	Gross Value	Net Returns
Rajabari	7752	12615	4863	10576	16306	5730
Taraini	6329	25648	19319	9614	31684	22070

Table 4: Land size-wise costs of cultivation for rice (Field Survey Data, 2021).

Components	Marginal	Small	Semi-medium	Medium	Large	Total
Land preparation	1619 (20.42)	1239 (20.26)	1238 (19.50)	813 (18.33)	771 (20.04)	1136 (19.81)
Sowing	1525 (19.24)	1545 (25.27)	1801 (28.36)	1300 (29.31)	1212 (31.51)	1477 (25.75)
Seed	515 (6.50)	506 (8.28)	460 (7.24)	333 (7.51)	293 (7.62)	421 (7.35)
Fertilizer	1719 (21.69)	1570 (25.68)	1526 (24.03)	1063 (23.97)	933 (24.25)	1362 (23.75)
Pesticide	594 (7.49)	447 (7.31)	456 (7.18)	216 (4.87)	143 (3.72)	371 (6.47)
Irrigation	877 (11.06)	303 (4.96)	335 (5.28)	305 (6.88)	198 (5.15)	404 (7.04)
Harvesting	1077 (13.60)	503 (8.23)	535 (8.43)	405 (9.13)	298 (7.75)	564 (9.83)
Total	7927 (100.00)	6114 (100.00)	6350 (100.00)	4435 (100.00)	3847 (100.00)	5735 (100.00)

Note: Values are in rupees per acre.

Table 5: Land size wise costs of cultivation for wheat (Field Survey Data, 2021).

Components	Marginal	Small	Semi-medium	Medium	Large	Total
Land preparation	1346 (12.23)	1262 (12.78)	1273 (13.46)	813 (11.85)	751 (15.83)	1089 (12.98)
Sowing	448 (4.07)	348 (3.52)	340 (3.60)	235 (3.43)	187 (3.94)	312 (3.71)
Seed	1466 (13.32)	1509 (15.28)	1504 (15.91)	1150 (16.77)	751 (15.83)	1276 (15.21)
Fertilizer	3343 (30.37)	3042 (32.70)	3092 (32.70)	2239 (32.64)	1472 (31.04)	2638 (31.44)
Pesticide	657 (5.97)	933 (5.02)	475 (5.02)	363 (5.29)	293 (6.18)	544 (6.49)
Irrigation	1741 (15.82)	812 (9.31)	880 (9.31)	526 (7.67)	345 (7.27)	861 (10.26)
Harvesting	2006 (18.22)	1970 (19.99)	1890 (19.99)	1533 (22.35)	945 (19.92)	1669 (19.89)
Total	11007 (100.00)	9877 (100.00)	9455 (100.00)	6859 (100.00)	4743 (100.00)	8388 (100.00)

Note: Values are in rupees per acre.

Table 6: Village wise net returns for livestock (Field Survey Data, 2021).

Village	Rearing Cost	Disease cost	Total cost	Total revenue	Net returns
Rajabari	6000	910	6910	25300	17673
Taraini	5788	836	6623	28167	20167

Note: Values are in rupees per annual.

Table 7: Village wise income from livestock and agriculture (Field Survey Data, 2021).

Village	Livestock income	Agriculture income	Total income
Rajabari	25300	28921	54221
Taraini	28167	57332	85499

Note: Values are in ` annually.

sowing per acre for large farmers is only ` 187, while it is ` 488 for small farmers. In totality, the cost of cultivation for marginal farmers is relatively higher compared to that of large farmers.

Village wise cost, revenue and returns on livestock management

Table 6 depicts cost of livestock management in sample villages. The results from table 6 show that livestock management cost is relatively higher in water contaminated village *i.e.*, Rajabari compared to Taraini village. In Rajabari village rearing cost is Rs. 6000, while it is only Rs. 5788 in Taraini village. Further, disease cost is also relatively higher in Rajabari village (*i.e.* Rs. 910 per livestock) compared to Taraini village (*i.e.* 836 per livestock). Total cost on per livestock in Rajabari village is Rs. 6910, while it is only Rs. 6623 in Taraini village. This is also resulted in terms of per livestock revenue. Farmers in Rajabari village are getting only Rs. 25,300 from livestock and on the other hand, farmers in Taraini village are getting Rs. 28,167 from livestock. Hence, net return figures show that farmers in Rajabari village are getting Rs. 17,673 per livestock, while corresponding figures are only Rs. 20,167.

Comparison of income from agriculture and livestock

Table 7 depicts income from livestock and agriculture. The results from Table 7 revealed that farmers in Rajabari village are getting income from livestock (*i.e.* Rs. 25, 300), while farmers belonging to the Taraini village are getting income from livestock (*i.e.* Rs. 28,167) which is relatively less compared to Rajabari village. Further, farm income of farmers belonging to the Rajabari village is relatively less than that of farmers belonging to Taraini village. The mean annual income of farmers belonging to the Rajabari village is Rs. 54, 221, while mean annual income of farmers belonging to the Taraini village is Rs. 85, 499. In totality, farmers in Taraini village are in better position compared to farmers belonging to the Rajabari village.

CONCLUSION

This paper analyzed the impact of water contamination on crop productivity in surveyed villages. Contaminated water is adversely affecting to total production and productivity of rice and wheat crops in Rajabari and resulted lower farm income across land sizes. Same way per acre cost of marginal farmers is relatively higher compared to large farmers. Disaggregated-level analysis revealed that marginal farmers are spending more on pesticides, irrigation and harvesting compared to large farmers.

Hence, the present study recommends that:

1-The government takes appropriate water contamination measures.

2-Water pollution with heavy metals should be avoided at all costs and the quality and ecosystems of these waters should be preserved by proper and uninterrupted monitoringin both time and space in order to ensure normalcy within the boundaries of requirements.

Conflict of interest

All author declare that they have no conflict of interest.

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