

Water Degradation and Impact on Agricultural Productivity: A Case Study of Maharajganj District in Uttar Pradesh

**ABSTRACT
DISSERTATION**

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1.1 Introduction

Water is a critical input for agriculture having a determining effect on the eventual yield (WHO 2019: 1). Good seeds and fertilizers fail to achieve their full potential if plants are not optimally watered (Dhawan 2017: 1). India accounts for about 17% of the world's population but only 4% of the world's fresh water resources (World Bank 2017: 12). Distribution of these water resources across the vast expanse of the country is also uneven. The estimated figures from World Health Organization (2018: 1) show that about 785 million people lack even a basic drinking-water service, including 144 million people who are dependent on surface water. Globally, at least 2 billion people use a drinking water source contaminated with faeces. Contaminated water can transmit disease such as diarrhoea, cholera, dysentery, typhoid, and polio. Further, estimated figures also revealed that by end of 2025, half of the world's population will be living in water-stressed area. As far as India is concerned, increasing demand on water resources by India's burgeoning population and diminishing quality of existing water resources additional requirements of serving India's pulp and paper industry, thermal power plants, textile industry, and the iron and steel industry and agriculture growth have led to a situation where the consumption of water is rapidly increasing while the supply of fresh water remains more or less constant (Anappara 2005: 2-5). Industries in India are increasingly criticized for not taking adequate steps to comply with existing environmental standards and vast stretches of major rivers are severely polluted (Anappara 2005: 2). Anappara (2005: 3) argued that the current boom in the real estate sector has raised the demand for construction sand, leading to a dramatic and unsustainable increase in the mining of riverine areas. This has had a negative impact on the ecosystem as well as on the people dependent on it.

The bottled water industry is one of the fastest growing industrial sectors in India, and the country ranks as the 10th largest consumer of bottled water in the world (Bhushan 2006: 2-3). Unchecked expansion of this industry has adverse repercussions for water security in many areas where groundwater is the only freshwater source. With liberalisation and increased awareness of water quality, hundreds of bottled water brands have entered the market. This \$250 million bottled water market is growing at rate of 75-80% (EAW 2012: 12-20).

Almost 70% of surface water and an increasing percentage of groundwater are being contaminated by biological as well as chemical, organic, inorganic and toxic pollutants (MoEF 2009: 3-9). The sources of such pollution include point sources (including industrial effluents and domestic waste) and non-point sources (such as agriculture). The health implications of poor water quality are enormous, and water and sanitation related diseases are responsible for 60% of the environmental health burden in India (Planning Commission 2008: 15-19).

River water is an indispensable natural resource supporting economic and social development. River and streams have largely been exploited for supplying water for human consumption, livestock drinking, aquaculture, irrigation, industries, transportation, recreation, and other purposes (Barakat et al 2016: 284-292). Despite these benefits, in developing countries, rivers and streams are subjected to various anthropogenic and natural sources of pollution. These include expansion of urban, industrial growth, agrochemicals run-off, municipal and domestic wastes (Oketola et al 2013: 466-479). As a result, organic, nutrients, trace metals, and potentially hazardous substances are introduced river system, causing deterioration of river water quality.

Wastewater irrigation is a widespread and growing phenomenon that carries varying degrees of risk. Whether spontaneously practised in urban and peri-urban agriculture or planned as part of water reuse programmes, food and fodder production using untreated sewage or treated effluent can have serious human health implications for farmers and consumers, and can irreversibly degrade the environment.

The cross-country and cross-sector spill-over of environmental pollution through of waterborne effluents continues to be an important topic of research in environmental economics (Costantini et al 2013: 110-114). Environmental pollution, as it is unambiguously accepted in the subject in general is a public ‘bad’ requiring intervention to ameliorate the negative externality associated with it. The loss of agricultural production and lower land fertility owing to pollution transmission are therefore central to various adjustments that an economy may have to endure. Effect of transboundary pollution generated by an upstream country on the welfare of a downstream country through trade linkage offers the mainstay of the present study.

At the outset, we need to recognize that an important section of the literature correctly views transboundary pollution as a ‘stock’ problem. Mason et al (2018: 223-248), identify phenomena like water pollution as problem of stock pollution. These types of accumulated externalities can be modelled only in dynamic structures where the net change in pollution follows a time path and is endogenous to strategic decisions adopted by firms and governments. For example, Mason (2017: 12) shows that when trans-boundary stock pollution is improperly priced, downstream countries suffering due to pollution generated in an upstream country may impose tariffs on products traded with such neighbours that should ideally incentivize the polluter to introduce internal pollution control techniques. Moreover, Mason (2017: 15-20) also argued that if flow of water pollution is cross-country in nature, jurisdiction and adoption of

policies become complicated, especially when multilateral negotiations do not deliver immediate results. The spill over of pollution across and within countries, such as those in Africa, Asia and Europe leads to lengthy stand-off on matters of pollution abatement. For instance, Cai and Chen (2016: 84-104) show that for a select set of countries in China downstream river pollution is 20% more than other countries that are identical but not located in the industrial downstream. The collection of fees meant to address the polluting activities in China remains quite in most downstream countries. The native private countries, and not MNCs or public companies, in China seem to be mainly responsible for the river water pollution in downstream countries.

1.2 Farmers' Perception on River Water Pollution

The existing literature claimed that farmers in majority have perceived that river water is contaminated by both domestic waste and industrial waste, and farmers have restricted to use it in agriculture for irrigation production (Woldetsadik et al 2017: 52-64; Withanachchi et al 2018: 2-26; Kabri and Farukh 2012: 41-52). Farmers are also reported that contaminated water is key responsible factor for decline in agriculture production (Kabri and Farukh 2012: 41-52). Health risk is perceived more strongly in areas with more heavily contaminated water compared to less polluted area. A study conducted by Kabri and Farukh (2012: 41-52) in Kushtia district of Bangladesh has identified that farmers are tremendously suffering due to water related problems for their domestic as well as agricultural activities. The scarcity of water in the study area has led significant number of farmers to migrate to different areas for work and to change their occupations. Likewise, a study conducted by Poddar and Byahatti (2019) in Bhima River catchment area of Uttar Pradesh. They have found that economic impact of the water pollution on agriculture and rural livelihood was affected in terms of losses in form income, losses in employment, losses of livestock and health. In

totality, farmers' perception and economic cost of water pollution are confirmed that polluted river water is adversely affecting health and livelihood of the farmers.

1.3 Review of Literature

Prabhu (2009: 818-827) conducted a grass-root study to examine the status of water pollution in Akaki river catchment area in Ethiopia. The results from this study revealed that untreated sewage and industrial effluents are the main source of pollution to Akaki water body and irrigation with contaminated river water containing variable amounts of heavy metals leads to increase in concentration of metals in soil and vegetables, which is grown using the polluted water. The sample data showed that due to irrigation with contaminated water production of cabbage is declined substantially. The study suggests that to avoid entrance of metals into the food chain, municipal or industrial waste should not be drained into rivers and farmlands without prior treatment. Apart from treating the discharge that enters into the farms, it is also imperative to utilize alternative measures of cleaning up the already contaminated substrates. Continuous monitoring of soil, plant and water quality together with prevention of metals entering vegetables is a prerequisite in order to prevent potential health hazards to human beings.

Aselina (2014: 1-109) assessed the level of industrial pollutants and their effects on water resource and livelihood in the Mosimbazi sub catchment. The findings from the study showed that 92 & 80% of respondents have reported that industrial pollutants affected adversely to the livelihood and agriculture. During survey, it is observed that industries are still discharging pollutants into the sub catchment and causing health issues in sample households.

Khai and Mitsuyasu (2013: 248-256) surveyed rice farmers in two areas with the assumptions of the same natural condition and social characteristics. One is considered as the polluted area near and directly receiving wastewater from industrial parks, while the other is assumed to be a non-polluted area far from and having no effect of industrial pollutants. The yield loss of rice production caused by water pollution was estimated by the difference in rice yield between the two regions. The results showed that the yield loss of rice was about 0.57-0.75 tons per hectare per crop. They suggested that government should not use high-yield agricultural land for the construction of new industrial parks unless they install the latest pollution treatment technologies. The impact of environmental pollution should continue to be evaluated.

Yongguan et al (2001: 313-333) have conducted a study in water pollution impact on agriculture productivity in Chongqing, China. They have calculated environmental cost of water pollution by using contingent valuation method under willingness to pay approach. Results show that damaging to agriculture constitutes the largest share of costs, 56%, while damage to health and damage to industry make up 20 & 18%, respectively. The cost estimate of 1.2%, which employs the human capital approach, is sensitive to the valuation of statistical lives. A calculating using willingness-to-pay for avoiding premature death sets the total cost at 4.3% of Chongqing gross product.

Reddy and Behera (2005: 1-19) assessed the economic costs of water pollution (industrial) in the rural communities in terms of losses to agricultural production, human health, and livestock. The cost estimates are based on the detailed primary (household level) data collected from an intensive study of two villages—one a pollution-affected village and another control (not affected by pollution)—located in one of the industrial belts in Andhra Pradesh, South India. The cost estimates revealed

that the impact of industrial pollution on rural communities is quite substantial in monetary terms. The paper argues that the compensation principle might work if the estimates of damage are realistic. Further, mere passing of laws and creating institutional structures are necessary but not sufficient to address the environmental problems. Policies should be implemented in their right perspective. Institutions should be strong enough, with more autonomy and powers, to deal with the problems at hand.

Kimambo et al (2021: 1-17) study aimed to capture occurrence, experience, and perception of Harmful Algal Blooms (HAB) in aquaculture systems from stakeholders in the Ngerengere catchment, Morogoro, Tanzania. A cross-sectional survey focus group discussion (FDG), key informant interviews, and anecdotal observation were adopted. A convenient and purposive sample population was drawn from pond owners, registered water users, and government officials in the catchment. For data analysis, descriptive statistics and constant comparison were performed. Most respondents (95%) were able to recognize the image of blooms displayed. Approximately 70% of the respondents agreed that water quality has deteriorated over time, and blooms occur during the dry season. Further, 60% of the respondents agreed that water pollution is a serious problem attributed to sources other than industrial discharge. There was no consensus regarding the health impacts associated with HABs. Raising awareness on HABs is of paramount importance as it will provide the basis for the development of HABs management framework and health risk assessment.

1.4 Research Gap

After a detailed review on river water pollution and its impact on agriculture production and farmers' perception on sources of water pollution, it is observed that:

(i) polluted river water is adversely impacting to the farm production and revenue, and

(ii) farmers are highly perceived that due to inadequate availability of freshwater, they are imposed to use polluted water for domestic and irrigation, which resulting health risk and higher health expenditure. Further, Rohini River originates from Nepal and passes through Maharajganj district. Industries in Nepal are disposing their industrial waste into river and this leads to river water pollution. As Maharajganj district is located in the downstream area, while Nepal is located in the upstream area, polluted water which comes from Nepal is polluting to river water in Maharajganj too. Further, the economy of Maharajganj is farm-based and majority of farming communities rely on Rohini River for irrigation water. Hence, farmers who are living in the catchment area of Rohini River are enforced without choice to use polluted water as it is cheap and easy to obtain. The polluted water is contaminated with Metals, arsenic and other pollutants. When farmers use this water for irrigation, it decreases the fertility of soil in one hand and on the other hand, when farmers consume polluted farm produce, it increases the health risk.

As far as research gap is concerned, it is observed none of the previous study captured farmers' perception on river water pollution in Majarajganj and also none of previous study has calculated farm production and income loss due to use of Rohin River pollution. Hence, the present study bridges this gap by selecting two villages in Maharajganj district.

1.5 Objectives of the Study

- To understand the demographic, geographical, social and economic status of Maharajganj district in Uttar Pradesh.
- To compare the socio-economic and demographic status of a river water polluted with non-polluted village in Maharajganj district in Uttar Pradesh.

- To compare the impact of contaminated water on agricultural production and productivity of farmers in polluted village with those of non-polluted village in Maharajganj district in Uttar Pradesh.
- To assess the perception of farmers on water pollution in the two villages of Maharajganj district in Uttar Pradesh.

1.6 Hypothesis

- The contaminated quality of water has adversely effected the agriculture and livelihood of dependent community.
- Unmanaged and degraded water resources have negative impact on socioeconomic factors.

1.7 Methods and Materials

1.7.1 Study Area

The present study is carried out in the catchment area of Rohini River, which lies in the middle of Nautanwa and Nichloul 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: 1-20). 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: 10-15). Water is smelly, black colored and full of toxicity and subsequently dumped into Rohini Riverine India (both are tributary of the Rohini River). These areas were highly productive and fertile for agriculture with sufficient water availability for irrigation and domestic use. The main livelihood source in the district is agriculture. Hence, majority of the population is working in agriculture as cultivators and agricultural laborers. Crop pattern usually adopted by farmers are double, viz., Rabi and Kharif seasons. Crops such as Rice, Wheat, Sugarcane, Green Peas, and Mustard are grown in the catchment area of Rohini and Gandak rivers (Singh 2008: 12-20).

1.7.2 Data types and Sources

The present study uses both field surveyed and secondary data to elicit farmers' perception on river water pollution and its impact on agriculture production and productivity. Secondary data on socioeconomic characteristics of population belonging to Uttar Pradesh and Maharajganj was collected mainly from Census 2011 and NSSO's 77th situation assessment round in published 2019. While field survey data was collected using systematically sampling technique.

1.7.3 Sample Design and Size

In this study, multistage sampling method is adopted. In first step, Maharajganj district is purposively selected. In second step, one Tehsils (i.e., Nautanwa) out of four Tehsils is selected because of water contamination and its adverse impact on agricultural productivity. In third step, two villages (Rajabari and Taraini) are selected. In order to capture water contamination effect, Rajabari village is selected, which is near to the Rohini river catchment area. While second village viz., Taraini is selected, which is located 10 Kilometres from the Rohini catchment area. In the fourth

step, using systematic sampling technique, 50 households from each village are selected with total sample size 100 respondents. Every 10th household is selected from the village. There were many keys indicators such as quality of water, agricultural production and productivity, livelihood, income. On the basis of these keys indicators, information is gathered from the surveyed farmers through a systematic designed schedule.

1.7.4 Approach of Estimation

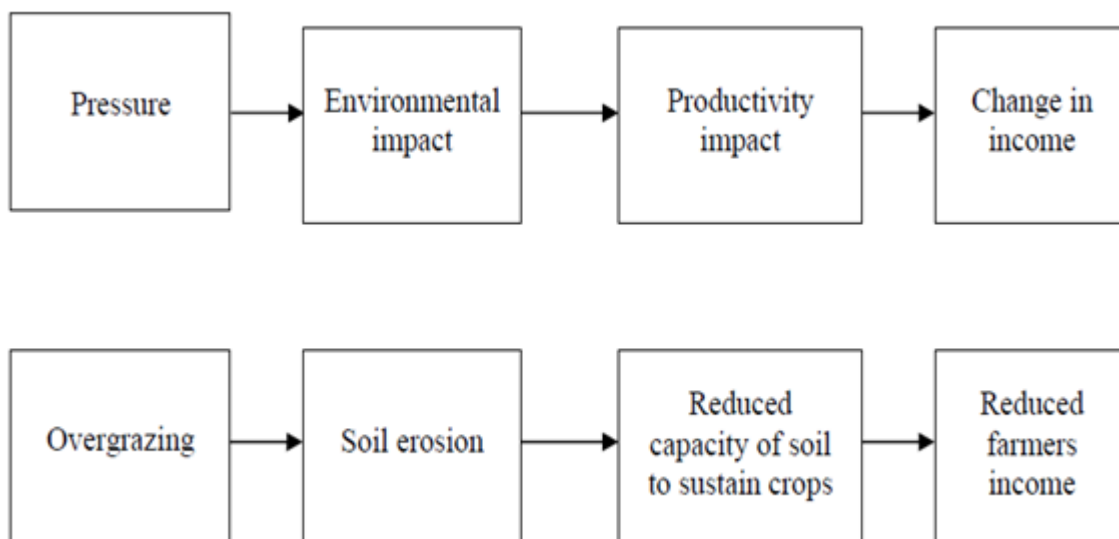
In this study the productivity change method is used to estimate impact of polluted water on farm productivity. The productivity change method is applicable whenever the environmental quality serves as an input for the production of market commodities (Gunatilake 2003: 99). The productivity change method 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 monetary values thus derived are then incorporated into the economic analysis of the project. The boundaries of the analysis are broadened to include all benefits and the cost of an action regardless of whether they occur within the project's ordinary boundaries or beyond them. The productivity change method in other words production-function approach (PFA) has been widely used, particularly to evaluate the impacts of environmental quality changes (e.g. river water pollution) upon agriculture (Adams et al 1986: 1-19). According to Barbier (1998: 12-60), because of the direct dependence of many production systems in developing countries on natural resources and ecological functions PFA is considered widely applicable to many important economic and investment decisions in these countries. Broadly, the PFA consists of two-step procedure. The first one is aimed at

identifying the physical impacts of environmental change on production activity. The second step consists of valuing these changes in terms of the corresponding change in the activity's output.

The PFA method focuses on environmental resources as an input to the production of goods or services. When an input is degraded, this leads to a reduction in the services provided to production with a resulting loss in profit for the producer. Figure 1.1 provides an example of this relationship. In this case, overgrazing has led to soil erosion. As the grass becomes patchy and the soil is washed away, it reduces the soils capacity to sustain grass on which the animals graze. In turn this reduces the income of the farmer. It is by focusing on this final impact—of reduced farming income—that the productivity approach can be used to value environmental degradation.

Figure 1.1 can be used to analyze any type of productivity impact. First a pressure (over-grazing) leads to an environmental impact (soil erosion). This in turn leads to a productivity impact (reduced capacity of soil to sustain crops). This alters farmers' income. This framework is commonly used to analyze cause and effect relationships. Another typical example is that of health. For example, increased vehicle use (behaviour), leads to air pollution (environmental impact). This in turn results in an increased number of workers with respiratory infections caused by the air pollution (productivity impact). The loss of workdays leads to a loss in wages for the workers.

Figure 1.1: Linking Environmental Degradation to Changes in Agriculture Production



Source: adopted from Gunatilake 2003.

Further, descriptive statistics are used to capture farmers' perception of river water pollution and for the assessment of socioeconomic characteristics of sample farmers. The details of method of estimation of variables are given in the respective chapter.

1.7.5 Theory behind Productivity Change Method

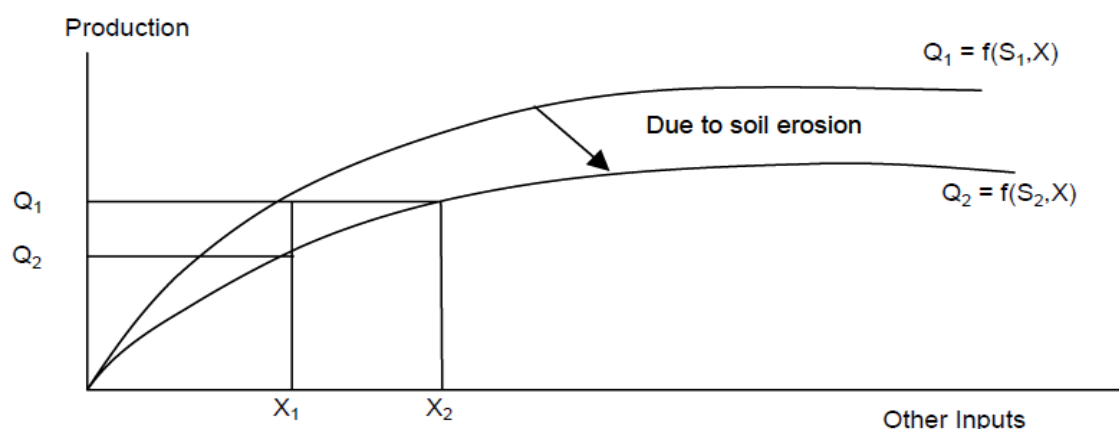
When there is a change in an environmental input, this can lead to a change in the quantity produced. For example, in the case of soil erosion there may be an accompanying decline in the volume of crops harvested. However, it may be possible for the farmer to replace the loss of one input (soil) for a substitute input (in this case perhaps fertilizer). Figure 1.2 shows a production function, where production is a function of soil (S), and other inputs (X). As the quality of the soil declines from S_1 to S_2 due to soil erosion, the production function shifts down to Q_2 . The farmer faces two options. First, he can do nothing and produce at Q_2 instead of Q_1 , using the same level of other inputs. The second option is to keep production at Q_1 , by increasing other inputs, such as fertilizer, from X_1 to X_2 . In reality, the farmer is likely to respond somewhere in between, by letting production fall a little and increasing inputs somewhere X_1 to X_2 . Either way, the farmer suffers an economic loss in the

form of decreased profits. Under the first option he loses the value of lost output. In the second option, the costs of production increase as a result of having to increase other inputs. This provides us two measures for valuing the degradation of land: the value of lost output, or the cost of additional resource inputs. Both affect farm profit.

$$\pi = PQ - c(Q)$$

Where, π = profit, P = price (which is assumed to be fixed by the market), Q = production, c = cost of inputs (which depends on the production, Q)

Figure 1.2: Graphical Representation of Production Change



Source: Adopted from Gunatilake 2003.

1.8 Chapterisation

The present study covers five chapters. First chapter discusses extent and dimensions of river water pollution and its impact on agriculture production and productivity by reviewing previous literatures. This chapter also establishes the foundation of the present study by identifying research gaps in the existing literature, developed objectives and hypothesis. Lastly, data sources and estimation methods are discussed to estimate the impact of river water pollution on farm productivity and income. The Second chapter assesses socioeconomic characteristics of sample farmers and compares them with Maharajganj district and Uttar Pradesh. The third chapter

estimated the impact of polluted water on farm production and productivity in one village and compared with the variables in a non-polluted village. The fourth chapter captures farmers' perception on river pollution and measures taken by the Government, while major findings, conclusions and policy recommendations are made in the fifth chapter.

1.9 Major Findings of the Study

First chapter Entitled “**Extent and Dimensions of River Water Pollution**” discussed about importance of water in human life, and then discussed the extent and dimensions of river water pollution all over the world. After review of detailed literature on water and its role in agriculture, farmers' perception on use of wastewater, polluted river water for irrigation, study has identified the research gap that none of the previous study captured farmers' perception on river water pollution in Maharajganj and also none of previous study has calculated farm production and income loss due to use of polluted water of Rohin River. Hence, the present study bridges this gap by selecting two villages in Maharajganj district. Thereafter, objectives and hypotheses are framed. Lastly, data sources and estimation method (i.e., productivity change) method is discussed in detailed.

Second chapter entitled “**Socio-Economic Background of Maharajganj District and Study Villages**” deals with socioeconomic conditions of population belonging to the Uttar Pradesh and Maharajganj in general and population belonging to the sample villages in specific. The findings are as follows. **First**, Maharajganj district is relatively backward compared to Uttar Pradesh as far as socioeconomic conditions are concerned. **Second**, majority of population in Maharajganj and sample villages are belonging to the Hindu religion. **Third**, among the social groups, farmers belonging to the General Caste are in better economic position in terms of mean land size,

income, expenditure. Similarly, all other economic indicators are in favour of farmers belonging to the General Caste. **Fourth**, farmers belonging to the Scheduled Caste are living in bottom of the society with minimal resources including land size and income. **Fifth**, half of the population across the social groups is working in agriculture, it means changes in agriculture productivity or loss in agriculture leads to livelihood insecurity. **Sixth**, unemployment rate varies from 8 to 13% across the social group, and among the social groups, population belonging to the Scheduled Caste is relatively more unemployed. **Seventh**, good news is that majority of farmers have access of sanitation and safe drinking water within the premises. **Lastly**, more than 80% of females are working in agriculture, while only 32% of males are working in agriculture.

Chapter three entitled “**Water Contamination and Agricultural Productivity in the Surveyed Villages**” dealt with how the use of polluted river water impacted on agriculture productivity in the sample village i.e., Rajabari. Two crops namely rice and wheat are included into the estimation. The findings from this chapter are as follows. **First**, area, production and productivity of both crops shows that Taraini village where no water contamination exists, is in better position compared with Rajabari village where water contamination exists. The productivity of paddy crop is also more than two times higher in Taraini village (i.e., 19.86 quintals per acre) than that of in Rajabari village (i.e., 8.84 quintals per acre). Likewise, the wheat productivity in Taraini village is also relatively two and half time higher (18.14 quintals per acre) than that of Rajabari village (i.e., 7.78 quintals per acre). **Second**, inequality in terms of production and productivity also exists across the crops. The mean production of paddy and wheat crops by marginal holdings is 6.45 & 6.68 quintals, while mean production by large holdings is three times higher (i.e.,

195.5&185.67 quintals). The crop productivity figures revealed that marginal farmers are lagged behind the small, semi-medium, medium and large farmers. They are highly susceptible from contaminated water with limited land for cultivation along with less employment opportunities in allied and non-farm sector. **Third**, similar results in Rajabari village are also observed that farm productivity of marginal farmers is relatively lower compared to large farmers. **Fourth**, the cost of cultivation for paddy crop in Rajabari village is 7,752INR per acre, while it is relatively lower in Taraini village i.e., 6,329INR. Further, cost of cultivation for wheat crop is 10,576INR in Rajabari village, while it is only 9,614INR in Taraini village. **Fifth**, farmers belonging to the Rajabari village are spending relatively higher to grow crops compared to farmers belonging to the Taraini village. **Sixth**, due to contamination of the output, they are getting relatively less value of 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 declining crop productivity but also lowering farm returns. **Seventh**, the per acre cost of cultivation of paddy and wheat under marginal landholdings is 7,927INR & 11,007INR, while cost of cultivation for large farmers is relatively less i.e., 3,847INR & 4,743INR. This shows that marginal farmers are investing relatively more compared to large farmers to grow wheat and paddy crops. With higher cost of cultivation for marginal farmers, marginal farmers are also not getting remunerative prices for their farm produce. Due to this, their farm output value is also lower compared to large farmers. **Eight**, the net returns for large farmers are 16,835 per acre for large farmers, while marginal farmers are only getting 4,283INR for paddy crops. Similar results also depict wheat crops across land holdings. **Ninth**, the costs of livestock management is relatively higher in water contaminated village i.e., Rajabari compared with Taraini village. In Rajabari village

rearing cost is 6000INR, while it is only 5788INR in Taraini village. Further, disease cost is also relatively higher in Rajabari village (i.e., 910 per livestock) compared to Taraini village (i.e., 836 per livestock). Total cost on per livestock in Rajabari village is 6910INR, while it is only 6623INR in Taraini village. **Lastly**, farmers in Rajabari village are getting income from livestock (i.e., 25, 300INR), while farmers belonging to the Taraini village are getting income from livestock (i.e., 28,167INR) which is relatively less compared to Rajabari village.

Fourth chapter entitled “**Farmers’ Perception on Water Contamination in Study Villages**” dealt with farmers’ perception on river water pollution. The major findings from this chapter are follows. **First**, the majority of farmers belonging to the Rajabari (contaminated village) village perceived that water contamination in the river catchment area is a reality and on the other hand, none of farmer belonging to the Taraini village (no contamination) perceived that water contamination do not exist in the village. **Second**, farmers also perceived that due to the absence of waste-water regulations, industries are dumping waste-water into the river at the upper part in Nepal. They further perceived that main reason of water contamination is industrial development in the catchment area. **Third**, farmers belonging to the General Caste (GC) are relatively more aware on water contamination compared to other social groups. Farmers belonging to the GC community (82%) have responded that industries in Nepal are dumping industrial waste into the river and this polluting to the river water. On the other hand, only 55% of farmers belonging to the Scheduled Caste (SC) community perceived in the Rajabari village¹. More than 75% of farmers belonging to the GC community perceived that reverse boring is a common phenomenon in the upstream country, i.e., Nepal. **Fourth**, farmers belonging to the

¹The present study excluded Taraini village from the estimation. The reason is that river pollution is not associated with the Taraini village.

large landholdings are relatively more aware of river pollution compared to farmers belonging to the marginal landholding followed by small, semi-medium and medium landholdings. More than 80% of large farmers are responded the dumping and mixing industrial waste in the water bodies are key pollutants responsible for river water pollution, while only 45.50% of marginal farmers are perceived. Majority of farmers are agreed that reverse boring is polluting groundwater. **Fifth**, farmers across the landholdings have perceived that industrial activities in the upstream areas are increasing pollution levels in the river over the years. **Sixth**, the intensity of water contamination is relatively high in Rajabari village compared with Taraini village. Where, more than 70% of farmers belonging to the Rajabari village perceived that colour of water have changed, while only 12.50% of farmers perceived that colour of water is changed in Taraini village. **Seventh**, it is observed that 54.50% of farmers belonging to the Rajabari village responded that vegetation growth is nowadays slowing due to use of contamination water for irrigation, while only 10.15% of farmers belonging to the Taraini village responded the same. **Eighth**, more than 80% of farmers belonging to the Rajabari village responded that the nutrient content in farm produce has declined, while only 12.25% of farmers belonging to the Taraini village have responded. **Ninth**, more than 80% of farmers belonging to the Rajabari village have reported that joint pain is common health issue throughout the years and this is due to drinking untreated water, while only 15.50% of farmers belonging to the Taraini village reported joint pain health issue. **Tenth**, 85.75% of farmers belonging to the Rajabari village have reported that jaundice problem is common during summer season, while only 10.25% of farmers belonging to the Taraini village have reported. Likewise results also observed in case of cholera, dysentery, typhoid and Diarrhea. **Lastly**, nearly 90% of farmers belonging to the Rajabari village boiled water before

use, while only 10.87% of farmers belonging to the Taraini village boiled water. Further, about 95.50% of farmers belonging to the Rajabari village have used household methods to treat water and make it safe for drinking, while only 4.50% of farmers belonging to the Taraini village have used household method to treat water. In totality, higher exposure from contamination water on health motivates farmers to adopt indigenous and modern water treatment methods to make water safe.

1.10 Conclusions

Environmental degradation (Water degradation) is a serious problem all over the country. The present study assessed farmers' perception on polluted river water in agriculture productivity and farm income. The study captured farmers' perception on river water pollution in the sample village i.e., Rajabari. The results confirmed that polluted water not only declined farm productivity but also increased health expenditure in the Rajabari village. Farmers are well aware of river pollution and they are taking several curative and preventive measures to deal with river pollution. The results from the present study are also matched with the past studies conducted by Khai and Mitsuyasu (2013: 248-256) confirming that wastewater is adversely impacting to the farm productivity.

1.11 Limitations of the Study

The present study is very important for the regional policy planning. Though, the present study tried to capture all the aspects of river water pollution in its impact on agriculture productivity in with and without scenario but, there are few limitations that can be bridge in the future study. First, the present study is covered only two villages in Rohini river catchment area. For representative and robust analysis, more villages should be included in the analysis. Second, the present study covered only

100 selected households from two villages namely Rajabari and Taraini. Hence, generalization cannot be possible with small sample size.

1.12 Recommendations

Water contamination is major challenges for agricultural productivity and it is harmful for environment. Government should be taken solid steps against water contamination. In catchment area of Jharain or Rohini River water contamination level is high and it is affecting adversely to agricultural productivity, livestock, and health and formers income. The major source water contamination is Sunwal and Nawal Parasi city in Nepal. Sunwal and Nawal Parasi are highly industrialized city so they dump toxic and acidic wastes into Jharain River, the toxic and acidic wastes possess to India and damages different manners to formers, agriculture, livestock and health. The problems of contamination of water are international issues between India and Nepal. So on first priority, dialogue between India and Nepal must be done to solve these problems. Second, priority is to implementation of various types of environmental awareness programme, and scientific assessment, installation of treatment plant, well connected sewer system and needs to organize local voluntary groups.