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OPPORTUNITIES AND CHALLENGES OF WASTEWATER IRRIGATION: A STUDY OF PERI-URBAN AGRICULTURE OF VARANASI DISTRICT, UTTAR PRADESH, INDIA

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ABSTRACT

The easy availability during whole year and nutrient content of wastewater sludge plays a strong supportive role for increasing use of wastewater in agriculture. Increasing population and urbanization pressurizes food demands, socio-economic and environmental stresses. Urban or Peri-urban Agriculture (UPA) provides a complementary strategy to reduce food insecurity and enhance urban environmental management in the context of rural-urban linkage. It is observed that nutrients contain in wastewater results in higher crop yields and thereby considerably reduces use of artificial fertilizers as well as fertilizers cost. But on the other hand it has an adverse effect that poses health risks directly to farmers and farm - workers. The aim of present study is to examine the opportunities and challenges of wastewater irrigation in UPA. This study tried to estimate the benefits and cost of production as well as health cost due to wastewater through a primary survey among the 382 households in the vicinity of UPA area of Varanasi district. Primary data were collected from 6 wastewater irrigated (WWI) and 6 freshwater irrigated (FWI) villages for the cross-section analysis. Through a case study of the UPA areas tried to establish a relationship between two deferent irrigation water users. The results of the study reveal that wastewater for irrigation has higher benefit-costs ratio compare than freshwater areas. But at the same time higher morbidity rate as well as cost of illness has been found in the WWI areas than compared to FWI areas. Study concludes that there are evidences that wastewater has a potential to reduce the production cost and return approximately 68.03 percent higher than FWI area.

INTRODUCTION

Irrigation with wastewater has become an integral part of urban and peri-urban agriculture in and around world. Basically due to scarcity of freshwater resources many low income countries use wastewater irrigation practise. An estimated twenty million hectares worldwide are being irrigated with wastewater because of high water demand for agriculture and easy acceptance by farmers in comparison to other uses (Jimenez and Asano 2008). Furthermore, wastewater adds nutrients and sludge containing nutrients and promotes productivity. The easy availability and continuous supply throughout the year plays a strong supportive role for farmers' use of wastewater in agriculture. The rapid industrialization and urbanization in developing countries contributed to increase water pollution as well as to human health and environmental degradation. Basically water pollution poses a serious challenge due to its impact on a large number of economic activities (Reddy *et al*., 2009). It is observed that nutrients contain in wastewater result in higher crop yields and thereby considerably reduces use of chemical fertilizers as well as the cost of production. But however this is not a costless benefit, many health and environmental problems associated with wastewater components like pathogens, organic compounds and heavy metals presents, which cause serious health hazards from mild skin itching to cholera. The use of wastewater for irrigation is associated with adverse effects on farmers' health, whose direct contact with contaminated water and its causes produce health cost. The paper considers the effects of such a perennial water resource in peri-urban areas and its effects upon health and livelihood practices of farmers and farm workers. The comparative analysis has been done between Wastewater irrigated areas (WWI) and Freshwater irrigated areas (FWI) at every aspects. This study examines the perception of farmers on the costs, the benefits and the risks of using wastewater in the cultivation.

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Urban and peri-urban agriculture (UPA) can be defined as the growing of plants and animal products within and around urban areas. The rapid urbanization that is taking place goes together with a rapid increase in urban population as well as poverty and food insecurity. Now a day we can see that concept of urban and peri - urban agriculture (UPA) is quite accepted at global level. UPA has potential for recycling urban wastewater, saving on inputs costs, marketing-transport costs and providing livelihood security with employment generation.

Wastewater is an option to link rural-urban agriculture and urban food demand and other forms of resource recovery that provide opportunities to water scarcity and nutrient. Urban agriculture produces an estimated 20 per cent of the global food supply and half of this is grown using wastewater, according to a recent 53-city survey by the International Water Management Institute (Qadir, M., *et al*. 2007; IWMI). Availability of wastewater during whole year makes opportunity to generate great employment for agriculture farmers and labourers to cultivate crops, vegetables, flowers, fodders that can be sold in nearby urban markets.

Wastewater based peril-urban agriculture is also quite familiar in Varanasi. There are two rivers Varuna and the holy river Ganga, both flow surrounding the city and these are main natural resource of all water needs. Urban and peri-urban agriculture in Varanasi has concluded that UPA make very significant contributions to city nutrition, household food security, employment and environment. Although it does not presently appear to be official recognition of UPA in Varanasi, city farming is widespread and is tolerated as an important response to the economic and social condition faced by many poor individuals. Famers cultivate mainly two crops wheat and rice during the monsoon and predominantly vegetables during winter. The average range of landholding among wastewater farmers in peri-urban areas of Varanasi was 0.03-13.33 acre.

As a consequence of the high global food demand, it is not surprising that, worldwide, the biggest user of wastewater (treated or not) is agriculture (Jimenez *et al*., 2008). The future availability of water for irrigation is likely to decline, due to the impacts of climate change and competition from other users (urban, industrial). An important factor which makes wastewater valuable is that it is a reliable source of water, as it is available all year round because demand by various users like domestic and industrial are increasing its results sewerage water is also continuous increasing.

The supply of water in the city ensures the supply of wastewater because the depleted fraction of domestic and residential water use is typically only 15–25% with the remainder returning as wastewater (Scott *et al*., 2004). The rapid growing population, accelerating industrialization and intensification of agriculture and also urbanization exert heavy pressure on our limited freshwater resources. The projection for India report that it will require 1,447 cubic kilometres ($km^{3)}$ of water of which 74% is identified for irrigation, while the rest is for drinking water (7%), industry (4%), energy (9%) and others (6%) (CPCB report 2009). Thus availability of wastewater permits higher crop yields, year-round production, and increases the range of crops that can be irrigated, particularly in urban and peri-urban areas. Where vegetables are the main commodity produced with wastewater, there can be a significant aggregate benefit for the society in terms of a more balanced diet. In the case of Accra, for example, more than 200,000 people eat vegetables produced with wastewater every day (Amoah *et al*., 2007). Use of wastewater for irrigation and aquaculture is a common practice in India, but is usually part of the informal sector which does not receive much recognition from the government (Buechler *et al*., 2002, Buechler and Mekala 2005).Varanasi district is an advanced agricultural as well as industrial hub. The main industries are engaged in manufacturing of metal products, textiles and dyeing and printing, chemicals and electrical apparatus etc. (F. Marshall *et al*., 2010). In Varanasi, an estimated 200 million liters daily or more of untreated human sewage is discharged into Ganga as well as Varuna rivers (Steve hamner *et al*., 2006).

Wastewater using farmers are likely to believe and consider the benefits greater than the risk. Because of this they might continue using wastewater in agriculture. But they are not aware about the major risks which are associated with wastewater. The wastewater quality not only affects the human health but it also reduces the agricultural productivity. Wastewater changes the soil properties resulting into various hazards to the crops. Contamination of soils and crops due to wastewater irrigation are widely reported from different parts of the world. It has been reported that 45% of wastewater irrigated areas in China are contaminated with heavy metals at the most serious level. Not only in China, this has been a problem in several other countries like Germany, France and India as well (Ingwersen and Streck, 2006; Dere *et al*., 2009; Singh and Kumar, 2006). In the Varanasi F. Marshall *et al*., (2006) found in their study zinc, lead, copper, cadmium, manganese and nickel above the permissible level after the sample test of soil of wastewater irrigated areas. Anita singh *et al*., (2010) also found in their study which was concentrated in the Varanasi urban and peri-urban areas, heavy metals in soil was highest Zn followed by Ni, Cu and Cd.

The present study is conducted to estimate wastewater use in agriculture activities while farmers are unaware of its consequences on their health. The study considers the effects of such a perennial water resource in peri-urban areas and its effects upon health and livelihood practices of farmers and farm workers. The comparative analysis has been done between Wastewater irrigated areas (WWI) and Freshwater irrigated areas (FWI) at every aspects. This study examines the perception of farmers on the costs, the benefits and the risks of using wastewater in the cultivation. Health cost estimates and considered a lower bound of the actual costs incurred by the households and it does not include all the social costs incurred.

Objectives of the study

1. To examine the opportunities and challenges of wastewater irrigation with the help of a cross-sectional survey.
2. To estimate the health cost associated with wastewater.
3. To compare and evaluate the feasibility of wastewater use for irrigation purpose in cost-benefit frame work.

MATERIALS AND METHODS

Study area

The study is conducted at the Peri-urban areas of Varanasi (25° 18' N latitude and 83° E longitude and 76m above the sea level) located in eastern Gangetic plain of India. The study areas selected are Dinapur (northeast of the city centre) and Bhagwanpur sewage treatment plant (BSTP) and others fresh water areas were taken for the differentiate research problem. At Dinapur site the irrigation of the agricultural field done by water discharged from a Dinapur sewage treatment plant (DSTP) of 80 million litters' day (MLD) capacity installed in 1986. Varuna river water also has taken as an indirect wastewater because many sewage and industries like Bharat Heavy Electrical Limited (BHEL) others chemical factories discharge their waste water directly into the river. Coraut, Pisaur, and Daniyalpur village's maximum farmers and farm workers directly intake Varuna river water for irrigation purpose. There are six freshwater irrigated villages also selected. For maintaining socio – economic status freshwater irrigated villages have selected around 2-3 km distant from wastewater irrigated village. In the freshwater irrigated area main source of irrigation water is groundwater (submersible and well) which is also used as drinking water. Therefore in both areas (WWI and FWI) we tried to maintain equal socio – economic status only irrigation water quality is different.

Source and Type of Data: This is a data intensive study processing primary data. Since the research work focuses both quantitative and qualitative aspects it is built upon both quantitative and qualitative data. First hand information through primary survey has been collected. Primary data is based on the household survey conducted in the study area seeking on socio demographic economic agricultural and health status of the study population.

Sampling and Sample Size

The villages were purposively selected based on the self observation and result of the previous studies. The villages are as following- Bhagwanpur, Dinapur, Berhauli, Daniyalpur, Pisaur, Coraut as a WWI villages and Kotwa, Ramna, Tikari, Chamaw, Bhawanipur and Chhitauni as a FWI villages. Two villages Deenapur and Bhagwanpur were selected due to sewage treatment plant (STP) because these STP's partially treated water used by farmers of the villages for irrigation purpose. The freshwater irrigated (FWI) villages have been taken as a control area and wastewater as affected areas. After selecting villages through random sample selection a total of 382 households 191 from WWI and 191 from FWI Villages have selected and interviewed for the study from May 2015 to September 2015. For the selection of households within village stratified random sampling with serpentile method has been followed. For the selection of households use of irrigation water (wastewater and freshwater) has been the stratum used.

The questionnaires are used to obtain demographic and socioeconomic information as well as benefits and risks about wastewater irrigation. Same questionnaire has been used for both (WWI and FWI) areas. In order to obtain the required information, close and open ended questions are presented to the respondents. Household survey conducted in the study area for seeking the information of socio-demographic, economic, agricultural and health status of the study population. The table 1 gives the details about samples.

Table 1 Distribution of Households Sample

Village	Total households	Sampled households
Deenapur (WW)	601	45
Bhagwanpur (WW)	95	7
Berhauli (WW)	118	13
Pisaur (WW)	816	62
Daniyalpur (WW)	535	40
Coraut (WW)	313	24
Kotawa (FW)	834	35
Ramana (FW)	1284	53
Tikri (FW)	782	32
Chamaw (FW)	133	6
Bhawanipur (FW)	650	27
Chhitauni (FW)	905	38
Total	**7066**	**382**

WW = Wastewater, FW = Freshwater

Data Analysis

Cost benefit analysis (CBA): In the CBA framework the study intended to capture the costs and benefits like gain in farmer income due to regular availability of irrigation water in the dry and summer days and the nutrient value of wastewater similarly additional input cost in agriculture like more seed cost and pesticide and insecticide cost. On the other hand wastewater impose health cost on farmers exposed to it in terms of additional diseases and morbidity caused over the baseline health status of similar population who are not exposed to the hazards of wastewater. Use of farm economics and related information obtained through the household survey is used here for estimating the costs and benefits of wastewater irrigation.

Through comparative cross-sectional method within two groups (WWI and FWI) various indicators have been analysed. The following indicators were compared:-

1. Comparison of use of chemical fertilizers in deferent seasons.
2. Comparison of agricultural inputs such as seed, fertilizer, irrigation, pesticides and labours costs.
3. Comparison of availability (frequency of irrigation) of irrigation water.
4. Comparison of average per acre production.
5. Comparison of prevalence of diseases and health expenditures.
6. Comparison of net benefits of farm income.

RESULT AND FINDINGS

Table 2 Use of fertilizer as per acre per season

Area	Rabi (Kg/acre)	Kharif (Kg/acre)	Summer (Kg/acre)	Total
WWI	77.34	63.13	13.72	154.19
FWI	156.28	152.78	39.15	348.21
Total	120.24	111.73	27.50	259.47

Source: Computed from Household Survey

Table 2 described about the use of chemical fertilizers such as urea, DAP etc. Result revealed that use of chemical fertilizers is several times higher in the FWI areas in the comparison with WWI areas. It is three times higher in the rabi and summer and more than two times higher in the kharif as well. Result of table provides interesting insight and it is proving that wastewater has good amount of nutrient contents for soil in the study areas. Farmers of WWI area have observed that due to wastewater irrigation growth rate of plants increased without applying more fertilizers. Therefore in the WWI less required for the fertilizer use as compared in the FWI. It is observed that total per year per acre use of fertilizer is also more than double in FWI in comparison with WWI. Though it has been proved that wastewater irrigation is very beneficial in respect of fertilizer cost reduction because fertilization involved the high agricultural inputs costs.

Table 3 Comparison of Inputs cost incurred by household in a year

Inputs	WWI area		FWI area	
	Cost/acre (Rs.)	**Valid No.***	**Cost/acre (Rs.)**	**Valid No.***
Seed	2600.41	190	3320.87	191
Fertilizer	2423.22	188	4946.67	191
Irrigation	6014.36	189	12399.12	191
Pesticide	1624.49	143	2690.40	149
Hired Labours	3150.33	62	4946.67	81
Total	15812.81		28303.73	

Source: Computed from Household Survey

*Valid number refers to the households who have actually incurred the annual inputs cost for particular items.

The above table is showing the annual per acre inputs cost. Results reveal that overall cost of production is relatively higher in freshwater irrigated area compare than wastewater irrigated area. It is estimated that main inputs cost of production are irrigation and fertilizer in both areas. It is analyzed that per acre cost of irrigation water and fertilizer for WWI area 2 times less (Rs. 6014.36 and Rs. 2423.22) than FWI area (Rs.12399.12 and Rs. 4946.67). The low seed cost is due to high germination or growth of seed in the WWI area, which require farmers to use less seed rate. It is seen that per acre seed cost of FWI area 21.69% higher than WWI area. Per acre pesticides cost also has resulted less in WWI area (Rs. 1624.49) compare than FWI area (Rs. 2690.40). This could be due to nutrient contain or toxic element of wastewater which may impose negative impact on insects. As an input cost hired labour cost is included. In both areas mostly family members of the households engaged in all kinds of agricultural activities and few farmers used hired labour. High per acre labourer cost is also observed in the FWI in the comparison with WWI areas. Therefore results of inputs cost are clearly proved that use of wastewater for irrigation reduced about 51 percent per acre per year inputs cost particularly for irrigation and fertilizer cost.

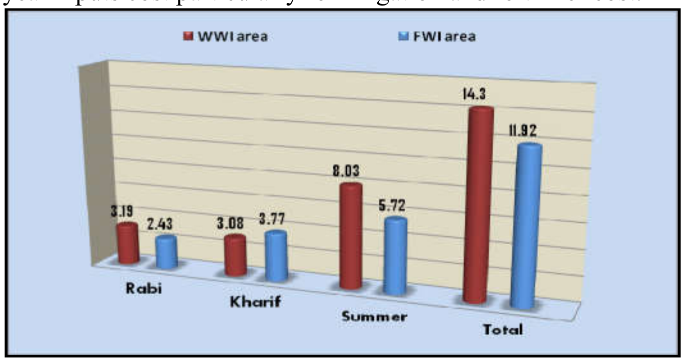

Figure 1 Average frequency of irrigation as per acre per season

Source: Computed from Household Survey

Above figure shows the average frequency of irrigation as per acre per season. Result is clearly presenting to the current situation of irrigation in the study areas. From the figure it can be observed that frequency of the irrigation is several times higher in the WWI in comparison with the FWI areas. Season wise availability of irrigation water is comparatively higher in rabi and summer in the WWI as compared than FWI areas. In the kharif season because of rainy season frequency of irrigation is higher in FWI in comparison with WWI areas. Overall per acre frequency of irrigation is 14-15 times in WWI and 11-12 times in FWI areas. A result of figure is proving that availability of wastewater is higher than freshwater.

Table 4 Average annual production as per acre/quintal

Produce	WWI	FWI	Differences	Total
Wheat	5.37	7.43	-2.06	12.8
Paddy	2.47	3.20	-0.73	5.67
Vegetables	**24.47**	**20.67**	**3.8**	**45.14**
Oilseeds	0.53	0.33	0.2	0.86
Pulses	0.26	0.53	-0.27	0.79
Maize	1.04	0.49	0.55	1.53
Flower*	9509.64	237.91	9271.73	9747.55

Computed from Household Survey, *Flower measured as per garland/acre

Above table is showing per acre annual production in the WWI and FWI areas. In the wastewater production of the flower (Marigold) is growing as commercial crop. In the table an average size of garland (Approximately 10-15 flowers) has been taken for measurement purpose for both (WWI and FWI) areas. Other hand vegetables is also cultivating for the supply to near urban markets. WWI is growing 3.8 quintal/acre more per year because its water availability in the summer makes possible to cultivate in summer season. If compared with other product such as wheat, paddy and pulses FWI is several times higher than WWI areas. Maize is also a common crop of study areas and WWI area cultivated 50% more than FWI area production. Paddy, vegetables and flower are water intensity crops. Result shows the positive impact on vegetables and flower and negative impact on paddy of wastewater irrigation. Farmers of the WWI areas observed that when they irrigate paddy crop with wastewater the maximum crops become putrefy. Therefore they prefer to cultivate vegetables and flowers to supply in the near local markets. Remaining crops such as wheat, oilseeds, pulses and maize cultivated for self consumption. The productivity is significantly deference in both areas.

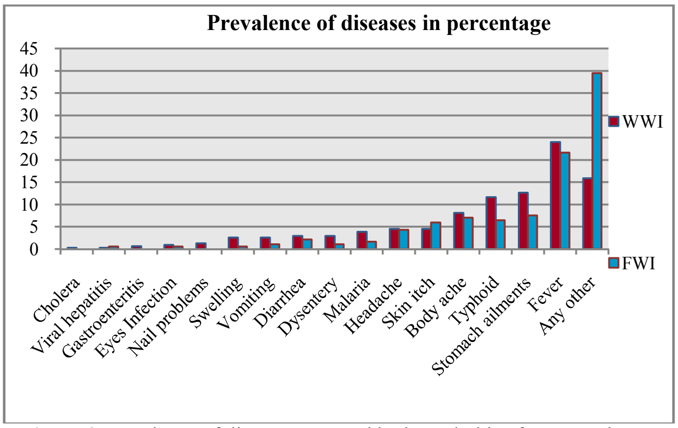

Figure 2 Prevalence of diseases reported by households of WWI and FWI areas

Computed from Household Survey

The figure shows intensity of prevalence of diseases. The prevalence of different diseases by exposure to wastewater is presented in figure. Skin itch, nail problems and eye infection represent the situation at the time of interview. For diarrhea, dysentery and the open health question a recall period of three to six months was used, while for typhoid, cholera, stomach ailment, malaria and gastroenteritis a recall period of six month to one year was used. The result of the health information analyzed for the prevalence of pathogens like viruses, bacteria, protozoa and helminthes by exposure to wastewater reuse. Figure 2 shows that there are significantly different in rate of prevalence of pathogens exposure to wastewater irrigated several times higher than that freshwater irrigated exposure. Result of following figure revealed that water borne diseases such as Typhoid, diarrhea, stomach ailment, dysentery, vomiting etc. several time higher in WWI than FWI area. Only Skin itching was found less than FWI area. It is observed that fever is a most common illness has found in both WWI and FWI areas. Thus fever cannot be considered as a wastewater exposure indicator. Overall percentages of above result of table clearly proved that wastewater irrigation is very hazardous than freshwater irrigated area.

Table 5 Annual health cost of illness incurred by per household (Rs.)

Health cost	WWI (191 HH)	FWI (191 HH)	Differences	Total (382 HH)
Direct	10894.94 (72.34)	5732.01(78.84)	5162.93	8313.50
Indirect	4164.96 (27.66)	1538.02 (21.16)	2626.94	2851.50
Total	15059.90	7270.03	7789.87	11133.02

Source: Computed from Household Survey,
In the bracket shows the percent of total health cost.

Health economic cost includes all expenditure on the treatment and prevention of diseases incurred by households in a year. The above table is showing differences of average health economic cost of WWI and FWI villages. It is seen that the cost of illness which includes both medical expenditure (direct cost) and wage loss (indirect cost) incurred by the family are Rs. 10894.94 and Rs. 4164.96 for WWI area and 5732.01 and 1538.02 for FWI area per household per year. The average cost of illness per household across all villages in year is about Rs11133.02. Average indirect cost (wage loss) clearly revealed that days of illness were mostly time higher in WWI area in comparison with FWI area due to water born long term diseases. In case of WWI area total per household average cost is Rs. 15059.90 as compared to FWI area where it is Rs. 7270.03. The direct cost of WWI area is 47.38% more than FWI area cost, while the indirect cost of WWI area is accounted 63.07% more than FWI area and total average cost is also 51.72% more than FWI area cost. This is showing a substantial economic or welfare loss for the households in the WWI and FWI area. There can see the interesting result in the WWI villages, average cost of illness several time more than double that of FWI villages, average cost of illness. The total average cost of illness revealed that the cost of illness measures between WWI and FWI villages are significantly difference. It is proved that the wastewater irrigation produces the more cost of illness comparatively freshwater irrigation.

Table 6 Annual net return (benefit) of agriculture income (Rs.)

Location	Cultivated Income/acre	Cost of Inputs/acre	Net return/acre
Wastewater	95513.98	15812.81	79701.17
Freshwater	75734.72	28303.73	47430.99
All	171248.70	36019.54	135229.16

Source: Computed from Household Survey

Comparing the cost of production and output (income) value, it has been observed that due to low cost of production net benefits of cash input are high for wastewater irrigated area. Other side comparing overall cost of production, in freshwater irrigated are 44.13 percent higher than wastewater irrigated area. Higher costs in freshwater area were due to greater fertilizer use and higher or expensive irrigation water cost. It is estimated that fertilizer cost for fresh water use area was 51.01 more as compared to wastewater irrigated area. Average per acre cultivated or agriculture income in wastewater irrigated area is 20.70 percent (19779.26) higher than freshwater irrigated area. Net return is also about 40.48% higher in wastewater irrigated area as compare than freshwater irrigated area. Share of net benefit from overall villages is for wastewater irrigated area is 58.93% and for freshwater irrigated is 35.07%. Above results are showing the actual economic impact of wastewater irrigation and net benefit concludes that wastewater more beneficial than cost production of inputs as compare than freshwater.

CONCLUSION

1. Results of prevalence of diseases have revealed that wastewater born diseases like typhoid, malaria, vomiting, dysentery, nail problems, swellings, gastroenteritis and even cholera are several time higher than freshwater irrigated area. It is presenting risks or negative impact of wastewater irrigation.
2. The average per household cost of illness for the study area is Rs. 11133.02. In case of indirect (wage or productivity loss) cost WWI area is accounted 63.07% higher than FWI area due to higher number of days of illness. The total per household average health cost in WWI area was Rs. 15059.90 which is equivalent to 6 to 7 days of wages income loss per month for a male and 12 to 13 days of wages income loss for a female worker when estimated at average wage rate or Rs. 200 for males and Rs. 100 for females of study area. This is a big leakage for benefit of wastewater irrigation which is reducing to the annual net benefit of agriculture income. This is the big challenge for farmers and farm workers to overcome this health cost and increase their net benefits.
3. Wastewater irrigation is cheaper than fresh water. It was found that ground water was about two times more costly than the wastewater. It was also estimated that frequency of the irrigation is several times higher in the WWI in comparison with the FWI areas. This is showing the availability of wastewater particularly in summer season. It gives opportunity to WWI farmers that they grow more vegetables and sale at high rate in the near urban markets.
4. Overall per acre cost of production is estimated several times higher in FWI area as compare than WWI area. Cost of production in FWI area is higher for all agriculture inputs for example fertilizer, seed, irrigation

and pesticides and hired agricultural labour cost in a year. It is observed that net return or benefit of per acre inputs is high for wastewater irrigated area. Net per acre return or income of WWI area is approximately 68.03 percent higher than FWI area.

5. Study concludes that if farmers of WWI areas will increase awareness regarding their health or adopt precautionary thing during irrigation with wastewater than they can increase their net cultivated income. Study also suggests that if government make a policy to provide health education for farmers or provide precautionary tools like gloves, mask etc. then it can also decrease health cost rapidly. Other hand if government sets up treatment plants for treating wastewater up to standards recommended for irrigation is most importance not only due to health reasons but also for improving agricultural productivity. Therefore, availability of wastewater is a beneficial in the water scare regions and gives significantly higher yields for the same amount of inputs used by FWI areas.

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