Original Research Article

Externalities and Farmers perception on the use of treated sewage water for Agriculture

Abstract

As global economic growth complicates water challenges, exploring the potential of treating and reusing wastewater in agriculture is crucial for achieving long-term water sustainability. This study investigates the positive and negative externalities associated with using treated sewage water for agriculture through borewell recharge. Primary data was collected employing snowball sampling to select sample of 60 farmers whose borewells had been replenished with treated sewage water. The study also examines farmers' perceptions of using this treated water. The findings reveal that the positive externalities (0.560) outweigh the negative externalities (0.506), as indicated by the externality index derived from principal component analysis. However, an increase in the consumption of fertilizers and pesticides was noted over the past three years following the implementation of the Koramangala-Challaghatta valley project. This paper provides a detailed account of both the positive and negative externalities of using treated sewage water, along with farmers' perception on its reuse and their pesticide use behaviour.

Keywords: Externality, perception, pesticide, fertilizers, recharge

Introduction

Rapid population growth, urbanization, extensive water consumption, and climate change are critical factors depleting freshwater resources. Islam and Karim (2019) project that water consumption will rise faster than population growth in several regions worldwide. Given the current water shortage, wastewater reuse is crucial. Currently, 92% of global water is used for agriculture, with about 70% sourced from fresh water, including rivers and groundwater (Rout and Kattumuri, 2022). Utilizing recycled wastewater is a viable strategy in water-scarce areas. Most treated wastewater (TWW) is typically released into watercourses or used for irrigating parks, lawns, or public spaces, but its use for non-potable applications, like crop irrigation, industrial processes, and groundwater recharge, remains limited. Only a small proportion of TWW is reintegrated into productive uses, presenting an underutilized resource with potential to alleviate water scarcity (Mishra et al., 2023). Israel has increased its agricultural production by 1600 percent through wastewater reuse, setting a global benchmark (Tal, 2016). Extensive studies have examined the impacts of reused TWW on land, agriculture, aquatic bodies, economic viability, and public health (Castro et al., 2014).

India's population is expected to exceed 1.5 billion by 2050, with over 50 per cent living in urban centers. This demographic growth, urbanization, industrialization, and lifestyle changes will increase water use and generate more wastewater. Currently, about 15 per cent of India's water is used for domestic and industrial purposes, projected to rise to 30 per cent by 2050. Urban and industrial water requirements are projected at around 90 and 81 km^3 annually by 2050, respectively. This will lead to a significant increase in domestic and industrial effluents (Minhas et al., 2022). Historically, sewage water was an opportunity for peri-urban agriculture due to its biodegradable content and plant nutrients. However, increasing contamination with toxic metals and organic micro-contaminants has complicated wastewater use. In many Indian urban centers, domestic, industrial, and stormwater are discharged into the same system, complicating wastewater treatment. India's sewage treatment capacity is limited, leading to untreated wastewater being used for irrigation, posing health risks, especially when vegetables irrigated with raw sewage are consumed uncooked. There are also concerns about environmental sanitation and disease prevention among farm workers, and contaminant transfer to urban populations through dairy feed crops irrigated with wastewater (Minhas et al., 2022). High concentrations of bio-toxins have been found in grasses, forages, milk, and animal serum, especially along the Musi river near Hyderabad (Amerasinghe et al., 2013). Despite these concerns, wastewater irrigation supports the livelihoods of millions of peri-urban farmers by reducing cultivation costs. Addressing the quality aspects of wastewater use in agriculture requires a holistic, integrated approach involving public health engineers, agronomists, hydro-biologists, medical professionals, and farming communities to develop safe long-term guidelines.

Karnataka state faces a severe water crisis due to rapid urbanization, population growth, and climate change, depleting groundwater levels and surface water reserves. To address this, the state is exploring alternative water sources, including treated sewage water for agriculture. Treated sewage water provides a sustainable and reliable irrigation source, conserving freshwater resources and enhancing soil fertility with valuable nutrients, thereby boosting crop yields. It also reduces untreated wastewater discharge, mitigating pollution. However, adopting treated sewage water for agriculture poses challenges, including ensuring water quality, addressing potential health risks, and developing adequate infrastructure for treatment and distribution. This study explores farmers' perspectives on sewage water reuse in agriculture, examining its positive and negative externalities in the Koramangala-Challaghatta Valley project area of Kolar District, Karnataka.

Methodology:

Recognizing the significant impact of wastewater on agricultural production and productivity, the Government of Karnataka launched the pioneering Koramangala-Challaghatta Valley Project (KCVP) in November 2016. This unique initiative aims to address sewage water challenges in Bengaluru by using treated sewage water to fill irrigation tanks in the Kolar and Chikkaballapur districts. The KCVP is being implemented in phases, to supply treated sewage water to 126 irrigation tanks across various clusters in the Kolar and Chikkaballapur districts. This project is a crucial intervention to address Bengaluru's growing sewage concerns and to revitalize depleting groundwater levels in the Kolar district. The KCVP thus serves dual purposes: addressing urban wastewater challenges and enhancing agricultural sustainability.

The research was conducted in the Kolar district of Karnataka using a snowball sampling design to select respondents. Primary data were gathered from 60 farm households whose borewells had been recharged following the implementation of the KCVP. Data collection was conducted through personal interviews using a pre-tested, well-structured schedule. Villages were randomly selected based on the areas where tanks were filled under the project. The collected data included detailed information on farmers' perceptions of using treated sewage water for irrigation, the cost of cultivating tomatoes, and the inputs used during the agricultural year 2023-24.

2.2 Principal Component Analysis and Externality Index

2.2.1 Normalisation of data:

The data collected on various variables were subjected to normalization to render them unit and scale-free for comparison. This normalization process followed the methodology outlined in the works of Kale *et al*. (2016), Kumar *et al*. (2016), Ponnusamy *et al.* (2016), and Mahida and Sendhil (2017), regardless of the specific study domain. This approach was applied uniformly to variables exhibiting a positive functional relationship with their respective indicators.

Normalisation has been done as given in equation 1.

Normalisation = (Actual value – Minimum value) / (Maximum value – Minimum value)…….(1)

For variables that exert a negative influence on the respective indicators, the normalization formula (Eq. 2) as follows has been employed:

Normalisation = (Maximum value – Actual value) / (Maximum value – Minimum value) ...(2)

After normalizing the data to ensure observations fall within the range of 0 to 1 for all variables, the next step involves assigning weights to these variables for computing the composite externality index. Typically, three methods are employed for assigning weights, as outlined by Kumar *et al.* (2016), equal weights, expert opinion, and principal component analysis (PCA). Each method presents its own set of advantages and drawbacks. Equal weights may overlook variables that significantly impact the index; expert opinion tends to be subjective and constrained by the availability of experts, the number of variables, and the research timeframe for obtaining responses; while PCA necessitates econometric knowledge and operates under the assumption of linear relationships among variables. In this study, given the utilization of multidimensional data and the advantages offered by PCA compared to other methods, weights were determined through principal component analysis. Unlike studies that solely rely on factor loadings from the first principal component for weight assignment (Kumar *et al.*, 2016) our approach adhered to the Kaiser (1960) criterion, which selects principal components with eigenvalues greater than one, thereby capturing maximum variation in the data. This framework is consistent with Ayyoob *et al.* (2013), Rana *et al.* (2015), Kale *et al.* (2016), and Mahida and Sendhil (2017) as delineated in Equation 3.

$$X_t = \Lambda_t F_t + e_t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

where,

X_t - N-dimensional vector comprising variables that impact the externality.

Λ_t - rx_1 common factor,

F_t - Factor loading, and

e_t - Associated idiosyncratic error-term of order N x 1

The weights from the PCA were calculated as indicated by equation 4.

$$Wi = \sum |Lij| Ej \quad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

where,

W_i - Weight of the i^{th} variable

E_j - Eigen value of the j^{th} factor

L_{ij} - Loading value of the i^{th} variable on j^{th} factor.

The composite externality indexing and categorization involve expressing the calculated weights for each variable, selected across all variables, using the following formula (Eq. 5), resulting in a composite index value for each variable.

$$\text{Index}=\frac{\sum_{i=1}^{n} XiWi}{\sum_{i=1}^{j} Wi}\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

Where,

Xi - Normalized value of i^{th} variable

Wi - Weight of the i^{th} variable

Finally, the composite externality index has been classified into three categories viz., high, moderate and least based on the distribution of composite index value (Ayyoob *et al.,* 2013; Rana *et al.*, 2015; Kale *et al.,* 2016).

The variables considered under positive and negative externalities are presented below:

Positive externalities	**Negative Externalities**
Bore well recharged	Soil quality decreased
Water table increased	Ground water contamination with effluents
Cropping pattern changed	Increased cost of production
Cropping intensity increased	Human health problems (skin diseases, cold and cough and other microbial infections)/Animal health
Yield increased	Crop Yields have decreased
Irrigated area increased	Usage of fertilizers increased
On farm employment increased	Usage of higher pesticides compared to earlier
Increased land value	

3. Results and Discussion:

Details on the study results are presented under the following headings:

3.1 Positive and Negative Externalities associated with use of treated sewage water on Agriculture

Implementation of KCVP in one of the drought prone districts of Karnataka i.e., Kolar has been accompanied with supplying treated sewage water to village tanks, which helped agriculture in the study area through borewell recharge has both positive and negative externalities. Opinion of farmers both positive and negative externality due to the use of treated sewage water is presented in the following section.

Table 1: Perceived Positive Externalities of Treated Sewage Water Usage in Agriculture (n=60)

Sl. No.	Particulars	Number	% total
1	Bore well recharged	60	100.00

2	Water table increased	30	50.00
3	Cropping pattern changed	42	70.00
4	Cropping intensity increased	34	56.67
5	Yield increased	06	10.00
6	Irrigated area increased	36	60.00
7	On farm employment increased	38	63.33
8	Increased land value	36	60.00

Positive externalities in usage of treated sewage water for Agriculture

To assess the effects of treated sewage water on agriculture via borewell recharge in the study area, most relevant statements were chosen in consultation with experts in the field of impact assessment like researchers, scientist and even beneficiaries during the pre-testing of schedule and administered to respondents to collect the opinions and results are presented in Table 1. Cent percentage of famers in the region opined that borewells on their farms and in the region have recharged and given better water output and even some of the failed bore wells started yielding water. Accordingly, fifty percent of respondents, opined that the groundwater table in the region has been increased. During the survey, they even expressed that depth of water availability was around 1500 feet but now farmers in the region are getting water at about 600-850 feet depth of digging. More than three-fourth (70%) of the respondents expressed that cropping pattern in the region has changed due to water availability. Now-a-days more emphasis is towards the vegetable and commercial crops than foodgrains. But remaining (30%) farmers opined no cropping pattern change as they continue to grow same crops. Sixty percent of the respondents reported that additional land was brought under cultivation, and with the availability of irrigation, more area was irrigated, leading to increased cropping intensity. The majority of farmers (90%) in the study area felt that the project implementation did not affect crop yield levels, which remained the same. However, due to the increased area under cultivation, on-farm employment rose, as expressed by 63.75 percent of the sample farmers. These results align with the findings of Ramesh (2019) and Chandrakanth and Arun (1997), who reported changes in cropping patterns, increased cropping intensity, and the generation of additional employment opportunities for beneficiary farmers.

Table 2: Perceived Negative Externalities of Treated Sewage Water Usage in Agriculture(n=60)

Sl. No.	Particulars	No.	%
1	Soil quality decreased	34	56.67

2	Ground water contamination with effluents	38	63.33
3	Increased cost of production	32	53.33
4	Human health problems (skin diseases, cold and cough and other microbial infections)/Animal health	22	36.67
5	Crop Yields have decreased	32	53.33
7	Usage of fertilizers increased	44	73.33
8	Usage of higher pesticides compared to earlier	54	90.00

Perceived Negative externalities in using treated sewage water for Agriculture

Negative externalities associated with use of treated sewage water are documented in the above Table 2. Since the project was implemented eight years ago, there has been little evidence of adverse effects (negative externalities) observed. However, when farmers use water directly from the tanks filled with treated sewage water have noticed effects like soil acidity and leaching, and decreased yields mainly with tuber crops. In addition, farm fields which are situated beside the tanks are being water stagnated in the villages like Narasapura and Uddapanahalli villages.

The opinions of respondents expressing negative externalities showed that farmers reported less of negative effects than the positive effects of using treated sewage water for irrigation. Study area is known for growing of vegetables, Hence this increased access to irrigation water through recharged groundwater has led to further intensive vegetable cultivation. As these vegetables are more of fertilizer and pesticide demanding crops due to their susceptive nature on one hand, continuous cultivation of these crops on the same land year after year. This has led to higher usage of PPC (90.00%) and fertilizers (73.33%) and thus soil quality has decreased (56.67%) in the study area. The more serious issue reported by the respondents was of that treated water may pollute ground water (63.33%) and decrease the water quality. During survey people in the region complained that the supplied water is not being correctly treated but it has been subjected to only primary and secondary filtration. Thus, people in the region are requesting for tertiary treatment. Fifty percent of the farmers expressed that crop yields levels have decreased as these tanks became good habitat for many flies and insects, so they are attacking on the surrounding farms of tanks. More than one-third of respondents expressed that bad smell and breeding of flies in the tanks, filled with this treated water causing allergies, skin rashes and some other health issues with people and even animals when animals drink water from these filled tanks. Similar findings were reported by Ramesh

(2019) study on the economic impact of using treated sewage water for irrigation in Koramangala-Challaghatta Valley Project area in Kolar district of Karnataka.

Table 3: Eigenvalues and principal component analysis (PCA) weights of related parameters

Variable	Eigen value 1	Eigen value 2	PCA Weights
Positive externalities			
Bore well recharge	0.352	0.618	1.880
Change in Cropping pattern	0.387	0.578	1.940
Water table increased	0.186	-0.204	0.840
No. of milch animals increased	0.470	-0.331	1.900
On farm employment	0.480	-0.216	1.780
Irrigated area increased	0.488	-0.294	1.910
Negative externalities			
Water quality deterioration	0.154	-0.498	1.053
Decreased yield	-0.003	0.673	0.991
High pest intensity	0.669	0.144	1.621
Human/Animal health problems	-0.136	0.467	0.971
Soil quality deterioration	0.253	-0.202	0.829
High fertilizer consumption	0.669	0.144	1.621

The results in Table 3 present the Principal Component Analysis (PCA) weights associated with positive and negative externalities. The findings indicate that the most significant factor contributing to positive externalities is the change in cropping pattern, with the highest weight of 1.940, followed closely by the increase in irrigated area at 1.910. The availability of irrigation water throughout the year also leads to a higher number of milch animals, with a weight of 1.910. These three variables have the greatest influence on positive externalities. On the other hand, the most significant negative externality is high pest intensity combined with high fertilizer consumption, with a weight of 1.621. This is followed by water quality deterioration, with a weight of 1.053. These results highlight the notable impact of these variables on the negative externalities within the study area.

Table 4: Composite externality index for use of treated sewage water (n=60)

Composite Index	Mean	Std. dev.
Positive externalities	**0.567**	**0.285**
High (Index>(Mean+0.5*Standard deviation))	>0.709	

	(55.00)	
Moderate (Mean-0.5*standard deviation) <index> (Mean + Standard deviation)	0.424-0.709 (10.00)	
Low(Index<(Mean-0.5*Standard deviation))	<0.424 (35.00)	
Negative externalities	**0.506**	
High (Index>(Mean+0.5*Standard deviation))	0.627 (43.33)	
Moderate (Mean-0.5*standard deviation) <index> (Mean + Standard deviation)	0.385-0.627 (16.67)	**0.242**
Low(Index<(Mean-0.5*Standard deviation))	0.385 (40.00)	

Figures in the parenthesis indicate percentage of respondents to total sample size

The calculation of the Composite Index for both positive and negative externalities involved utilizing parameters such as bore-well recharge, changes in cropping pattern, cropping intensity, yield increase, expanded irrigation area, water quality deterioration, as well as issues related to human and animal health. The Composite Index results, as presented in Table 4, indicate a mean index of 0.560 and a standard deviation of 0.285 for positive externalities. Conversely, negative externalities exhibit a mean index of 0.506 with a standard deviation of 0.242.

Further categorization of externalities is based on the mean and standard deviation values. Approximately 55 per cent of the sampled farmers fall into the high positive externalities index category, with only 10 per cent in the moderate positive externality category, and the remaining 35 per cent classified under low positive externalities. In contrast, 43.33 per cent of the sample farmers are categorized as having high negative externalities, 16.66 per cent fall into the moderate category, and another 40 percent are placed in the low negative externality index category.

The cumulative positive externality value is approximately 0.560. This is attributed to the borewell recharge, which has led to increased cropping intensity and year-round water availability. Consequently, respondents have expanded their milch animal holdings, resulting in a positive externality that surpasses the negative externality in the region. The negative externality index was determined to be 0.506, slightly lower than the positive externality index.

Despite this marginal difference, respondents express concerns about the perceived poor quality of treated water, anticipating potential long-term groundwater pollution in the region.

Furthermore, areas where treated water is stored have experienced soil acidity and water logging, prompting elevated fertilizer consumption and heightened pest infestation on nearby farms. This, in turn, has led to increased pesticide expenditures. In summary, the prevailing positive externalities outweigh the negative externalities associated with the use of treated sewage water in the region. Initially a drought-prone area where only plantation crops like niligiri thrived, the introduction of treated sewage water from Bangalore has transformed the cropping pattern. The region now supports a diverse range of crops, enhancing the livelihoods of local farmers.

Conclusion:

The adoption of treated sewage water has brought substantial positive externalities, transforming agriculture in the once-drought-prone region. The study highlights the importance of changes in cropping patterns and increased irrigation in fostering positive impacts. However, challenges such as soil quality deterioration and potential groundwater contamination underscore the need for continuous monitoring and improvement in water treatment processes. The Composite Externality Index indicates a higher prevalence of positive externalities, but attention must be given to addressing negative externalities. Balancing these positive and negative impacts is crucial for sustainable agricultural development in the region.

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