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Perception and constraints analysis of water footprint: A case of Hebbal Nagawara valley project of Karnataka

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Abstract

In vake of understanding economic impact of Hebbal Nagawara valley project on the beneficiary farmers, this paper is an attempt to enlist and analyse the perceptions and constraints from Chikkaballapur taluka farmers after project inception. For this study, 45 farmers who fall under project benefit area were randomly selected and information on positive and negative externalities aroused after the project implementation in the area was collected. The collected information was analysed using descriptive statistics, tabular analysis and Principal Component Analysis (PCA) tools. The results showed that due to HN valley project, there occurred both positive and negative externalities. Among the six positive externalities listed *viz.*, borewells has replenished, ground water level improved, cropping pattern and intensity has improved along with increased crop yield and they have increased area under irrigation after the project, more than 50 percent yes response was recorded for five among six entities of which highest positive benefit response was given to replenished borewells (93% of respondents). Similarly, among eight negative externalities listed, only one parameter had received "yes" with more than 50 percent of respondents which is given to deteriorated water quality after the project. Further the analysis of these externalities using PCA gave composite index indicating that the positive externalities (0.66) outweighed negative externalities (0.22) which says overall impact of the HN Valley Project on farmers is beneficial rather than harming them. The water samples test reports also shown that heavy metals were found to be Below Detectable Levels (BDL) and most of other elements are within permissible limits. Thus, the findings revealed that the treated sewage water meets all safety requirements and is more beneficial to farming community in the area.

Keywords: HN valley, perception, water foot print, positive externalities, negative externalities

Introduction

Chikkaballapur district is located in the Eastern dry zone of Karnataka. The climatic situations of the district range from mild to severe; temperature ranges between 15.7 °C to 36 °C whereas the average annual rainfall is 621 millimitres (mm), with roughly 30–35 rainy days per year. Almost 67 percent of the rain is received during the South-West monsoon (June-September).

Agriculture is a key profession of the people residing in this district. More than 60 percent of ground water withdrawals are used for the agriculture sector (Hamsa and Srikantha Murthy, 2017). Despite the fact that this district has three rivers (*viz*., North Pennar, South Pennar, and Palar basins), their contribution to irrigation is very negligible. Hence groundwater formed the major source of water.

As of June 2020, Karnataka has a total sewage generation (TSG) of 4,458 MLD. Bengaluru, the capital city of Karnataka, is the fifth-largest metropolitan region, generating roughly 1,440 MLD of sewage (32.30% of Karnataka's TSG) but, the Bengaluru Water Supply and Sewerage Board (BWSSB) has an installed capacity to treat 1,057 MLD only with its 24 STPs. After rigorous treatment and nutrient screening, treated sewage water is sent to various uses like groundwater recharge, agriculture etc. (Anonymous, 2021) [1].

The use of treated sewage water has proven to be immensely helpful worldwide. Globally, even untreated or partially treated wastewater is claimed to be applied to more than 20 m ha of land across the world, with wastewater reuse accounting for around 10 percent of global irrigated acreage (Zhang and Shen, 2019) [10].

Owing to frequent well failures as well as ground water extraction from deeper sources (up to 1500 feet), five of the six taluks of Chikkaballapur district are grouped under the

over-exploitation category. Many farmers are now experiencing critical water scarcity impacts. Hence, to help farmers by recharging groundwater, the Government of Karnataka envisaged the Hebbal Nagawara Valley Project (HNVP) which supplies 440 MLD of secondary treated sewage water to 134 irrigation tanks located across Kolar and Chikkaballapur districts with an outlay of Rs. 948 crores.
With this backdrop, the current investigation was aimed at investigating the externalities that were arrived in the project water-filled irrigation tank areas (HNVP) and enlisting different externality parameters present at field level as well as to judge which externalities had a higher impact.

Methodology

Sampling framework and data source

The present study was carried out in Chikkaballapur district of Karnataka. Using a random sampling technique, 45 samples farmers having borewells were chosen from each Chikkaballapur and Sidlaghatta taluk and they were interviewed using a well-structured pre-tested schedule for collecting required data. The water testing included three samples from the treatment area and one sample from the control area; drawn from the inlet of irrigation tanks, another from the borewells that were completely dry before HNVP but are now fully recovered after the project, and one more from the borewells that were functioning before but improved in water yield after the project to check if the HN valley's treated sewage water had impacted the water quality means. For comparison, one groundwater sample was also pooled from the control area farmers borewells.
Further, the obtained data from the farmers was analysed using Descriptive Statistics (mean percentages), tabular analysis (frequencies) and Principal Component Analysis (PCA).

Principal component analysis (PCA)

PCA method was initiated by Pearson in1901, and was developed by Hotelling in 1933. In the present study PCA is used to study the externalities associated with HNVP. In this study, Statistical software for data science (STATA) was used to work on the PCA.

Normalization

The indicators were measured on different scales for each parameter, both positive and negative externalities were normalized (Ramesh, 2020) [4]. The parameter that has a positive functional relationship with the irrespective index was normalized using the equation below.

$$\text{Normalization} = \frac{(\text{Actual Value} - \text{Minimum Value})}{(\text{Maximum Value} - \text{Minimum Value})}$$

Assigning weights to the parameters

The weights were assigned to the indicators after normalization on the basis of their extent of influence on the externalities. With the assumption of a linear relationship between the variables, the PCA approach assigns the weights (Kaiser, 1960) [13] As a result, in this investigation, the PCA approach was used. Here's how it works:

$$X_t = \Lambda_t F_t + e_t$$

Where,
Xt = Indicates N-dimensional vector of variables influencing externalities
Λ_t = represents the r ×1 common factor
F_t = represents the factor loading
e_t = represents the associated idiosyncratic error-term of order N ×1

The following equation was used to calculate the weights from the PCA.

$$W_i = \Sigma |L_{ij}| E_j$$

Where,
W_i = represents the weight of the i th variable
E_j = represents the eigen value of the j^{th} factor
L_{ij} = represents the loading value of the i^{th} variable on j^{th} factor

Composite externality index (Positive and Negative)

The positive and negative externality composite indexes were computed individually using their respective indicators and weights in the equation below.

$$\text{Index} = \frac{\sum_{i=1}^{n} X_i W_i}{\sum_{i=1}^{n} W_i}$$

Where,
X_i = represents the normalized value of i^{th} variable
W_i = is the weight of i^{th} variable

Categorization of externalities

Finally, positive and negative externalities composite index were categorized into two groups high and low on the basis of mean and standard deviation.

Results and Discussion

Perceptions of HNVP sample farmers on HN valley influences

The farmers' modest perspectives on the HN Valley Project were examined in the following parts to identify the most important aspects among them.

Table 1: Positive perceptions of the respondents in the HNVP area

Sl. No.	Parameters	Frequency	
		Yes (%)	No (%)
1	Borewells have been replenished	42 (93)	3 (7)
2	The level of the water table has improved	39 (87)	6 (13)
3	The cropping pattern has been improved	24 (53)	21 (47)
4	The cropping intensity has been increased	23 (51)	22 (49)
5	Crop yields have escalated	33 (73)	12 (27)
6	Increased the area under irrigation	11 (24)	34 (76)

Note: HNVP: Hebbal-Nagawara Valley Project area (Treatment area)

According to the findings (Table 1), around 93 percent of respondents claimed that their borewells had been refilled after the HN Valley Project implementation. For 87 percent of the sample farms, the water table levels have shown an improvement (*i.e.*, the water is now available at near depth; *i.e.*, as an example, before to the HNVP project, the average depth of ground water table was somewhere around 1000 feet which has now became 600-700 feet indicating significant improvement in the ground water table), and about 73 percent of the farmers reported that, the crop yields were improved (might be due to adequate water availability, nutrient status of water and higher fertilizer use efficiency), 24 percent of the sample farmers have extended the area under irrigation (due to guaranteed year-round water resource), about 24 farmers supposed that the changes in cropping patterns have occurred whereas, cropping intensity was increased for 23 farmers (cultivating perennials along with annual crops).

The treated sewage water streaming down the channels and the standing water in the irrigation tanks had a significant impact on groundwater recharge. Standing water in the tanks creates pressure that speeds up seepage and percolation, allowing for faster groundwater recharge. The findings of the current investigation were in conformity with Chandrakanth and Arun (1997) [11], Al-lahama *et al.* (2003) [12] and Ramesh (2020) [4].

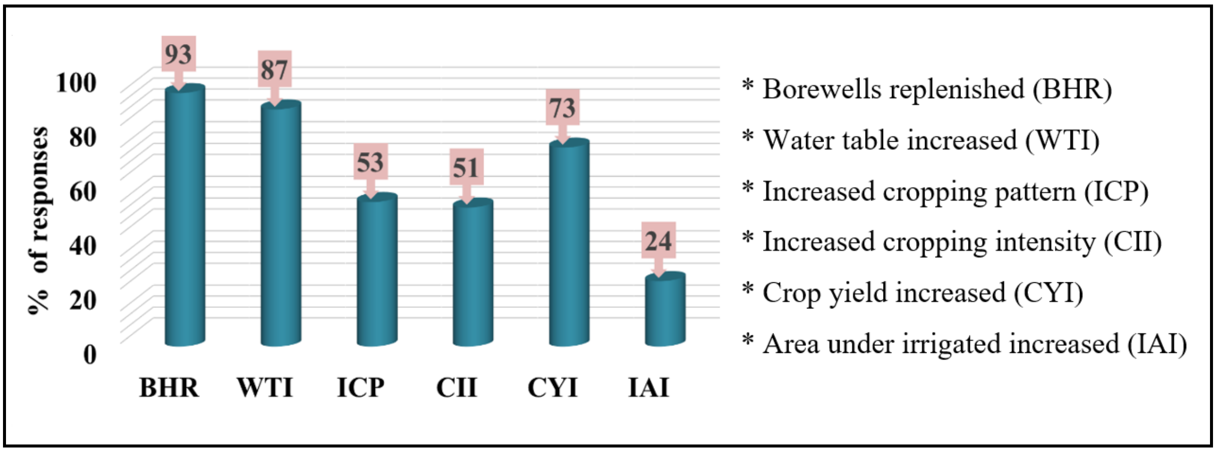

Fig 1: Positive externality parameters and farmers responses in the HNVP area

The description for each of the positive externalities in the fig.1, is as follows:

BHR: Borewells replenished means that the water level in the borewells has increased. This is a positive impact because it means that farmers have more access to water for irrigation.

WTI: Water table increased means that the level of groundwater has increased. This is also a positive impact because it means that farmers have more access to water for irrigation and drinking.

ICP: Increased cropping pattern means that farmers are growing a wider variety of crops. This is a positive impact because it can help to reduce risks and improve yields.

CII: Increased cropping intensity means that farmers are planting more crops per unit area. This is also a positive impact because it can help to increase yields.

CYI: Crop yield increased means that the amount of output from the crops has increased. This is the most significant positive impact of the HNVP project, as it has a direct impact on farmers' income.

IAI: Area under irrigated increased means that the area of land under irrigation has increased. This is a positive impact because it means that more farmers have access to water for irrigation.

Some of the positive benefits of HN valley to the farmers is depicted below in the plate1 with pictures for the better understanding of the situation in the HNVP area.

Plate 1: Depicting positive benefits to HNVP area by HN valley project

The data in Table 2, revealed that nearly 58 percent of the respondents alleged that the water quality got deteriorated in the HNVP area or borewells as well (The water which was sweet to taste earlier is more of salty now). About 16 percent of farmers of the HNVP area were used to drink their own borewell water before the project, but now, they have switched to buying purified water after project implementation to avoid risks of pollution or in the fear of ill-health and 20 percent of the respondents reported that their crop yields have decreased owing to increased pest and disease diseases as well as low quality of water all of which led to reduced crop yield. It also seen that, their number of irrigations for the crops has increased after HNVP which results in over moisture in soil as well as humid micro-climate which favours better climatic condition for fungal growth as well as increased growth and occurrence of pest and diseases which finally lead to reduced crop yield as well as increased costs on pesticides, fungicides etc). An extent of 9 percent and 7 percent of sample farmers testified the increased human and animal health complications, respectively.

Sekar (2001) [14] assessed the negative externalities on human and animal health in the Coimbatore district of Tamil Nadu and range of human health problems *viz.*, diarrhoea, headache, jaundice, allergies, skin rashes, premature birth or abortion, low milk supply, and animal population decline have all been documented in cattle and revealed that, the additional cost of ₹382.9 was incurred per family for human and animal health over a year. Similarily, Rusan and Hinnawi (2007) [5], Muhammad (2015) [6], Akbar (2016) [2], Tarantino *et al.* (2017) [2], Vinod *et al.* (2017) [2], Narayanan and Getachew (2020) [9] and Ramesh (2020) [4] also recorded and calculated health-economics of such negative externalities because of use of treated sewage water.

Table 2: Negative perception of the respondents in the HNVP area

Sl. No.	Parameters	Frequency	
		Yes (%)	No (%)
1	Water quality has deteriorated.	26 (58)	19 (42)
2	Switched over to buy drinking water	7 (16)	38 (84)
3	The crops yields have dropped	9 (20)	36 (80)
4	Human health anomalies has increased	4 (9)	41 (91)
5	Increased animal health complications	3 (7)	42 (93)
6	Occurrence of transportation issue	5 (11)	40 (89)
7	Water-logged field/s	6(13)	39 (87)
8	Quality of the produce has decreased	8 (18)	37 (82)

Note: HNVP: Hebbal-Nagawara Valley Project area (Treatment area)

These findings are on par with the study conducted by Quy-Toan, D., Shareen, J., and Samuel (2014) [15] who revealed that letting domestic pollution into rivers has a real health cost; infants appear to be very vulnerable to water pollution in their first month of life. The average effect of a one-percent increase in faecal coliforms is an additional 3-5 deaths per 100,000 births in a given month. Kazuki (2022) [16], who stated that soil infiltration rates determine the pollution risk of groundwater. The Swatch Bharath Mission (SBM) led to the degradation of water quality in rivers. Although the overall net health impacts were positive, the rising faecal coliform levels caused a negative externality on health.

According to few farmers, in the long run, groundwater pollution (by nutrient enrichment, heavy metals), soil pollution (by salt accumulation), change in crop type (*i.e.*, Salt deposition; salt tolerating crops, exhaustive crops like maize, sorghum), health issues may occur but, as of now, not much of negative incidents were noticed. About 13 percent of the respondents reported that their agricultural lands were water-logged making them unfit for cultivation and nearly 18 percent of respondents alleged for reduced produce quality.

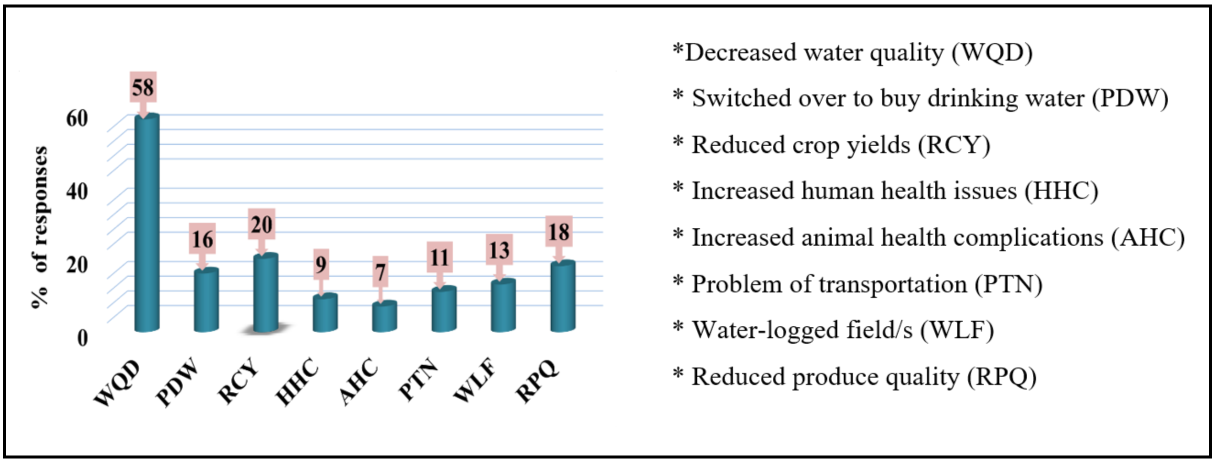

Fig 2: Negative externality parameters and farmers' responses in the HNVP area

The description for each of the negative externalities in the fig2, is as follows:

WQD: Decreased water quality can lead to health problems, such as diarrhea and cholera. It can also make it difficult to grow crops and raise livestock.

PDW: Switching to buying drinking water can be expensive for farmers, especially those who are already struggling to make ends meet.

RCY: Reduced crop yields can lead to financial losses for farmers. It can also make it difficult to feed their families and provide for their basic needs.

HHC: Increased human health issues can also be expensive for farmers, as they may need to pay for medical treatment. They may also lose time from work due to illness.

AHC: Increased animal health complications can also be expensive for farmers, as they may need to pay for veterinary care. They may also lose livestock due to illness or death.

PTN: Problems with transportation can make it difficult for farmers to get their crops to market.

WLF: Water-logged fields can damage crops and make it difficult to farm. They can also create breeding grounds for mosquitoes and other pests.

RPQ: Reduced produce quality can make it difficult for farmers to sell their crops at a good price. It can also lead to financial losses.

Plate 2: Depicting some negative impacts of HN valley project

Thus, overall, the graph shows that the HNVP project also had a negative impact on some farmers in the project area. According to those farmers, these negative impacts can have a serious impact on the lives of farmer families in a long term.

Analysis of factors of externalities

The Principal Component Analysis (PCA) weights for positive and negative externalities are indicated in Table 3. Eigenvalues describe the proportion of variance contributed by each of the eigenvectors so that the importance of attributes can be recognized. The PCA weights are assigned based on correlated attributes towards the overall positive or negative externality. The higher the PCA weight of a parameter/ attribute, the more relevant it is considered.

In the case of positive factors, the increased yield was a prime factor of importance for the farmers (1.32) followed by increased water table levels (1.3), borewells recharge (1.18) and increased area under irrigation (1.15) while, change in cropping intensity (0.79) was of least importance.

In the case of negative externality factors, the decrease in the quality of produce (1.45) was a major concern for the farmers, followed by deteriorated water quality (1.36), waterlogging (1.22) and reduced crop yields (0.32). The results of the current study are in accordance with the findings of Ramesh (2020) [4].

The weighted mean and standard deviation for the positive and negative externalities are also presented in the table 3. The findings reveal that the attribute having the highest weighted mean was 'improved water table' with a value of 1.12 followed by 'borewells recharge' (1.10) while, the lowest mean value of positive externality parameters was observed for 'increase in irrigated area (0.28)'. Among negative externalities, the major factor was 'deteriorated water quality' (0.77) followed by the reduction in the quality of produce (0.25). waterlogging in the farmer's field (0.16) making it unfit for cultivation, switched over to buy the drinking water (0.15) while, the reduction in crop yield, human health glitches as well as the issues of transportation have been reported with a mean value of 0.08 and the rest 0.03 has been recorded for 'animal health issues'.

Table 3: Analysis of externalities parameters

Variable	CL1	CL2	PCA Weight	Mean	SD
Positive externalities					
Borewells have been replenished	0.61	0.03	1.18	1.10	0.30
The level of the water table has improved	0.47	-0.34	1.30	1.12	0.45
The cropping pattern has been improved	0.15	-0.45	0.83	0.44	0.42
The cropping intensity has been increased	0.31	-0.17	0.79	0.40	0.40
Crop yields have escalated	0.50	0.31	1.32	0.96	0.59
Increased the area under irrigation	0.15	0.72	1.15	0.28	0.50
Negative externalities					
Water quality has deteriorated.	-0.24	0.61	1.36	0.77	0.68
Switched over to buying drinking water	-0.03	0.64	1.00	0.15	0.36
The crop yields have dropped	-0.01	-0.21	0.32	0.08	0.27
Human health anomalies have increased	0.48	-0.01	0.93	0.08	0.27
Increased animal health complications	0.26	0.01	0.51	0.03	0.13
Occurrence of transportation issue	0.18	-0.26	0.72	0.08	0.23
Water-logged field/s	0.58	0.08	1.22	0.16	0.42
The quality of the produce has decreased	0.52	0.32	1.45	0.25	0.56

Note: HNVP: Hebbal-NagawaraValley Project Area (Treatment area)
CL: Component loading SD: Standard deviation

Table 4: Positive and negative externalities' composite index (CI) for the HNVP area

Sl. No.	Composite Index	Mean
1	**Positive externalities**	0.66 [0.21]
a	High	31 (69)
b	Low	14 (31)
2	**Negative externalities**	0.22 [0.19]
a	High	15(33)
b	Low	30(67)

Note: HNVP: Hebbal-Nagawara Valley Project area (Treatment area)
Figures in the squared brackets represent the standard deviation of positive/ negative externality parameters
Figures in the parenthesis represent, the percentage of respondents to the total samples in the HNVP area; 45

To arrive at a judgment on the overall impact of the HN Valley Project on HNVP farmers, a composite index for positive and negative externalities was calculated and presented in Table 4. In the HNVP area, the cut-off score (mean value) for positive externalities was 0.66 with a standard deviation of 0.21 whereas, for the negative externalities this score was 0.22 with a standard deviation of 0.19.

Further, the sample farmers of the HNVP were grouped into two categories based on the cut-off score of CI. The farmers who scored more than the cut-off CI were grouped as the 'high/ matches pairs' category and those with scores less than the cut-off CI were grouped as the 'low/ clerical pairs category

In the case of positive externalities, about 69 percent (31) of respondents belong to the high group. While, in the case of negative externalities, 67 percent (30) belong to the low category. This clearly indicates that the positive externalities outweigh the negative externalities. Ramesh (2020) [4] in his study has also revealed that the supply of treated sewage water to irrigation tanks of the Kolar district has resulted in higher positive benefits than negative impacts and Akbar (2016) [2] in his study exposed that wastewater use in irrigation has increased the incidence of human and animal health anomalies. The results of the current study are thus in line with Ramesh (2020) [4] whereas it is contrary to the findings of Akbar (2016) [2].

The water testing included three samples (table 5) from the treatment area and one sample from the control area. In the treatment area, one sample was drawn from the inlet of irrigation tanks, another from the borewells that were completely dry before HNVP but are now fully recovered after the project, and one more from the borewells that were functioning before but improved in water yield after the project to check if the HN valley's treated sewage water had impacted the water quality means. For comparison, one groundwater sample was also pooled from the control area farmers borewells.

The results of the tested water samples from table 5., indicated that, the heavy metals were found to be Below Detectable Levels (BDL) in all of the samples, while all other measured elements were relatively lower in the control area sample. The findings revealed that the treated sewage water meets all safety requirements and that the water in the control area was of higher quality than that in the treatment area. The results of current study is In line with the investigation of Rusan and Hinnawi (2007) [5] on long-term effect of wastewater irrigation of forage crops on soil and plant quality parameters and the outcome of their research was that, treated sewage water for irrigation had more benefits in terms of soil and plant nutrient enrichment while least effect in terms of heavy metals and they concluded that proper management of wastewater for irrigation and periodic monitoring of soil and plant quality parameters are required to ensure successful, safe, long-term wastewater irrigation.

Table 5: Water sample test reports for the study area (as of 17th September 2021)

Sl. No.	Tested element	Unit	Tank inlet point	Completely recovered borewell	Improved borewell	Control area borewell
01	pH	----	7.94	7.28	6.80	6.82
02	EC	µs/cm	207.00	215.70	206.30	108.40
03	Ca+Mg	mg/L	6.35	7.65	10.88	7.70
04	Ca	mg/L	3.30	7.05	5.95	4.48
05	Mg	mg/L	3.05	0.60	4.93	3.23
06	Co_3	mg/L	0.94	1.10	1.22	1.14
07	HCO_3	mg/L	3.24	2.80	4.70	2.44
08	Cl	m.eq/L	24.80	21.55	21.80	16.80
09	Na	m.eq/L	0.17	0.14	0.12	0.05
10	K	m.eq/L	0.04	0.03	0.01	0.01
11	Po^{4-}	mg/L	0.03	0.03	0.02	0.03
12	So^{4-}	mg/L	0.12	0.10	0.11	0.06
13	Zn	mg/L	0.03	0.05	0.08	0.06
14	Cu	mg/L	0.12	0.13	0.12	0.11
15	Fe	mg/L	0.34	0.29	0.38	0.29
16	Mn	mg/L	0.04	0.14	0.04	0.04
17	Pb	mg/L	BDL	BDL	BDL	BDL
18	Cr	mg/L	BDL	BDL	BDL	BDL
19	Ni	mg/L	BDL	BDL	BDL	BDL
20	Cd	mg/L	BDL	BDL	BDL	BDL

Source: Soil science laboratory, College of Sericulture, Chintamani

Note: BDL: Below detectable levels, µs/cm: microsiemens percentimeter m.eq/L: milliequivalents per liter, mg/L: milligrams per liter

Conclusion

The current research was conducted in Chikkaballapur district, situated in the Eastern dry zone of Karnataka, sheds light on the multifaceted impacts of the Hebbal Nagawara Valley Project (HNVP) on the agricultural sector, highlighting both positive and negative externalities. Based on the various studies reviewed, it is evident that the use of wastewater for agricultural purposes has both positive and negative externalities that significantly impact agriculture, health, and the environment. One of the most noteworthy results of this research is the positive impact of HNVP on the agricultural community. The findings of this study underline the critical importance of the HNVP in addressing the water scarcity issues faced by farmers in the region. Notably, the project has led to borewell replenishment for 93 percent of respondents, improved water table levels for 87percent, and enhanced crop yields for 73 percent. The availability of treated sewage water through HNVP has not only recharged groundwater but also allowed for an expansion of the area under irrigation, resulting in improved cropping patterns and intensities. These positive outcomes are crucial for the sustainability and prosperity of the agriculture-dependent community. However, the research also reveals that there are adverse consequences associated with the project. A portion of farmers reported deteriorating water quality, increased reliance on purchasing purified water, reduced crop yields, and health issues. These negative externalities though relatively minor at present, raise concerns about the potential long-term impacts on groundwater and soil quality demanding careful monitoring and mitigation to ensure the long-term sustainability of the project.

Further, the Principal Component Analysis (PCA) helps to understand the relative importance of these positive and negative externalities and revealed that the positive externalities significantly outweigh the negative ones, underlining the project's overall benefits to the farming community. The high percentage of respondents falling into the "high" category for positive externalities compared to the "low" category for negative externalities suggests that, on balance, the HNVP has had a positive impact on the farmers in the region.

The sample water quality tests indicated that the treated sewage water met safety requirements, with heavy metals remaining below detectable levels assuring the water quality. However, as some of the research studies indicated that, there will be a more negative impacts in long-run, it is very essential to enhance sewage water treatment from secondary to tertiary method for the safeguard of farming communities as well as environment. Overall, the HNVP has proven to be a vital initiative in Chikkaballapur district, promoting sustainable agricultural practices and groundwater recharge. The research findings emphasize the importance of continued monitoring and adaptive management to address emerging challenges and maximize the long-term positive impact on both agriculture and the environment.

This study contributes valuable insights to the field of agricultural economics and resource management, offering lessons that can inform similar projects in regions facing water scarcity and agricultural challenges as well as offering guidance for policymakers and stakeholders seeking to balance the benefits and challenges associated with large-scale irrigation projects in water-scarce regions.

Hence, transforming urban wastewater, once a menace to the environment and natural groundwater, into a lifeline for rural agriculture is a remarkable feat. By implementing advanced sewage treatment technologies, we not only curb pollution in our cities but also nurture the dry lands of rural areas, where water scarcity is a perennial challenge. Through this innovative approach, the precious resource that was once lost to pollution is now a catalyst for growth. This harmonious transformation represents a true Win-Win scenario paving for harmonious and healthy planet.

References

1. Anonymous. Report by BWSSB, Government of Karnataka (GoK); c2021.
2. Akbar. Wastewater use in irrigation: bane or boon? A study from peri-urban Bengaluru. Research paper, Azim Premji University, Bangalore; c2016.
3. Hamsa KR, Srikantha Murthy PS. An economic analysis of net returns from major crops in central dry zone of Karnataka under different valuation approaches. Int J Agric Environ Biotechnol. 2017;10(5):598-601.
4. Ramesh N. An economic impact assessment of supplying treated sewage water to irrigation tanks on farming in Kolar district under KC valley project [M.Sc. (Agri.) Thesis]. Bangalore: Univ Agric Sci; c2020.
5. Rusan MJ, Hinnawi S. Long term effect of wastewater irrigation of forage crops on soil and plant quality parameters. Desalination. 2007;215(1-3):143-52.
6. Muhammad I. Economic impacts of wastewater irrigation in Punjab. J Agric Res. 2015;49(2):5-14.
7. Tarantino E, Disciglio G, Gatta G, Libutti A, Frabboni L, Gagliardi A, *et al*. Agro-industrial treated wastewater reuse for crop irrigation: implication in soil fertility. Chem Eng Trans. 2017;58:979-84.
8. Vinod K, Chopra AK, Sachin S, Jogendra S, Roushan KT. Irrigating okra with secondary treated municipal wastewater: observations regarding plant growth and soil characteristics. Int J Phytoremediation. 2017;19(5):490-9.
9. Narayanan K, Getachew A. Investigating suitability of treated wastewater for agriculture in Hawassa, Sidama region, Ethiopia. Int J Agric Res Innov Tech. 2020;10(2):59-65.
10. Zhang Y, Shen Y. Wastewater irrigation: past, present, and future. WIREs Water; c2019, 6(3)
11. Chandrakanth MG, Arun V. Externalities in groundwater irrigation in hard rock areas. Indian J Agric Econ. 1997;52(4):761-71.
12. Al-Lahhama O, El-Assi NM, Fayyad M. Impact of treated wastewater irrigation on quality attributes and contamination of tomato fruit. Agric Water Manage. 2003;61:51-62.
13. Kaiser HF. The application of electronic computers to factor analysis. Educational and psychological measurement. 1960 Apr;20(1):141-51.
14. Uppuluri P, Sekar R. Experiences with specification-based intrusion detection. In International Workshop on Recent Advances in Intrusion Detection Berlin, Heidelberg: Springer Berlin Heidelberg; c2001. p. 172-189.
15. Do QT, Joshi S, Stolper S. Pollution externalities and health: A study of Indian rivers. In 10th Annual Conference on Economic Growth and Development, Indian Statistical Institute, Delhi; c2014.
16. Kazuki Y, Gao FJ, Yamakawa M, Hirabayashi M, Kazuki K, Kajitani N, *et al*. A transchromosomic rat model with human chromosome 21 shows robust Down syndrome features. The American Journal of Human Genetics. 2022 Feb 3;109(2):328-344.