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Achievement Of Sustainable Development Goal 6 Through The Jal Jeevan Mission Scheme In The Tribal Dominated Rural Darjeeling Himalayan Region, India

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Abstract: The availability and accessibility of safe drinking water are major challenges for tribal-dominated mountainous regions, which still persist due to undulating terrain, dense forest cover, dispersed settlements, complex socio-economic conditions, etc. To overcome these challenges, Govt. of India has taken an initiative to provide safe drinking water to every rural household through the introduction of the Jal Jeevan Mission (JJM) in 2019. This study aims to assess the impacts of the JJM scheme on the availability, accessibility, reliability and quality of the water supply and its impact on socio-economic conditions, health improvement and the achievement of Sustainable Development Goal (SDG) 6.1. Results indicate that, provision of safe drinking water within the household premises has increased five-fold between 2011 and 2025, which drastically changed the scenario of drinking water supply for this region. It also helped significantly in achieving SDG 6.1 through the provision of a safe and reliable drinking water supply. This scheme has significantly improved the health condition of this region by reducing the occurrence of water-borne diseases since pre-implementation time. Even it helps to save he amount of man-day hours earlier lost due to collecting water from far distances. Overall, it helps to improve women's empowerment by reducing their burden of collecting water from far distances. The spatial variability of the implementation of this scheme also shows that context-specific project planning is required for getting full benefit from these types of infrastructure-related project rather than universal models. Overall, this study shows a positive impact of the JJM scheme on long-term issues related to water supply for this region.

Index Terms **-** Jal Jeevan Mission; Darjeeling Himalayan Region; Health condition; well-being; Safe drinking water; Sustainable Development Goals.

1. Introduction

Water resources are fundamental to sustaining life, supporting agriculture, and maintaining ecological balance. However, growing global population pressures, rapid urbanization, industrialization, and climate change have intensified demands on these resources, leading to widespread water scarcity and a global water crisis. Over-extraction, contamination, and uneven distribution of water exacerbate this challenge, particularly in ecologically sensitive and mountainous regions, posing significant threats to human health, food security, and socioeconomic development and underscoring the need for sustainable water management strategies (du Plessis, 2023; Bănăduc et al., 2022; Mishra, 2023).

Water issues in hilly regions are characterized by unique challenges arising from complex topography, fragile ecosystems, and socioeconomic vulnerabilities. Mountainous regions often experience disrupted natural water cycles, reduced aquifer recharge, and declining spring flows—the primary traditional source of water—due to climate change, land use change, and population pressures (Bănăduc et al., 2022; Bhat et al., 2020; Kiyani et al., 2022). Water quality is also threatened by deforestation, human settlement expansion, and contamination of previously pure water sources (Lone et al., 2021; Patton et al., 2020). In the Indian Himalayan context, steep slopes, dense forests, and scattered rural settlements complicate water collection and distribution systems, while seasonal variability and reduced spring discharge further intensify water stress (Verma et al., 2022; Verma & Jamwal, 2022). These physical challenges are compounded by socioeconomic factors such as tribal dominance, low literacy rates, and limited infrastructure, contributing to persistent problems of unsafe drinking water, increased waterborne diseases, and socioeconomic losses.

The Darjeeling Himalayan Region (DHR) exemplifies these challenges, with local residents reporting regular declines in spring discharges, leading to chronic water scarcity and increased dependence on untreated water sources. Many rural and tribal-dominated areas still rely on traditional sources, resulting in frequent health risks and rising health care costs due to waterborne illnesses.

In response, the Government of India launched the *Jal Jeevan Mission (JJM)* on August 15, 2019, with the objective of providing Functional Household Tap Connections (FHTCs) to every rural household, ensuring a regular and safe supply of potable water directly to homes. The mission, popularly known as *Har Ghar Jal*, aims to deliver at least 55 litres per capita per day (lpcd) of safe water to all rural households across the country through decentralized, community-led implementation and source sustainability measures such as rainwater harvesting and water conservation. The programme also aims to enhance water supply infrastructure, foster community engagement, and promote capacity building for long-term sustainability.

In the Darjeeling district of West Bengal, efforts under JJM aim to overcome the region's unique Himalayan constraints by expanding piped water supply networks and increasing household coverage. As per the official West Bengal JJM dashboard, a significant proportion of villages report full tap water connection status, reflecting progress in extending infrastructure and improving access at the grassroots level (*e.g.*, 85 villages with 100% tap water reporting in specified regions) even as implementation continues to advance in other areas of the districts of JJM.

Despite notable nationwide progress toward the mission's targets—with millions of rural households already connected and access steadily expanding—implementation in mountainous and tribal regions continues to face significant challenges due to terrain complexity, resource limitations, and governance hurdles,

highlighting the need for region-specific strategies and enhanced stakeholder engagement for sustainable water security that aligns with the principles of Sustainable Development Goal 6 (Clean Water and Sanitation).

Although JJM has significantly expanded access to safe drinking water in rural India, much of the existing research emphasizes broad coverage statistics and quantitative impacts of household tap connections. There is limited empirical evidence on critical aspects such as equity in service delivery, the financial and operational sustainability of water systems, and local community perceptions and governance practices. For example, economically disadvantaged groups often remain underserved despite overall increases in household connections, indicating persistent inequities in access to Functional Household Tap Connections (FHTCs) under the mission (Singh & Naik, 2024).

Therefore, the major objective of this research is to assess the implementation outcomes of the Jal Jeevan Mission with respect to ensuring sustainable access to potable water through FHTCs for rural households, specifically by analyzing progress, challenges, and community engagement mechanisms. This study aims to examine how the programme enhances access to safe and adequate drinking water, evaluates the effectiveness of service delivery strategies, assesses the sustainability of water supply systems, and explores community participation in water governance. A comprehensive understanding of these elements will help identify strengths, limitations, and areas for improvement in the execution of the mission.

The Jal Jeevan Mission is implemented through a decentralized, participatory approach, where village action plans are developed based on local water needs and resource availability. This framework fosters community ownership and active involvement in the management of water supply systems. The mission also integrates long-term sustainability measures—such as rainwater harvesting, water conservation practices, and capacity-building initiatives—to support reliable water resources over time

2. Study area

The Darjeeling Himalayan Region (DHR) consists of eight Community Development (CD) Blocks of the Darjeeling and Kalimpong districts of the West Bengal state of India (Figure 1), characterised by highly undulating terrain, a forest-dominated tribal region with a scarcity of safe drinking water. Hilly Darjeeling district has a 30.734% Schedule Tribe population, and Kalimpong district is showing 31.667% Schedule Tribe population (Census 2011) compared to the average tribal population of West Bengal (5.8%). Availability of drinking water is almost dependent on unprotected springs, which are not sustainable in nature. The female members of the family bear the responsibility of collecting water from far distances, in spite of their involvement in economic development, social development and health development. This scarcity of safe drinking water demands for the implementation of Jal Jeevan Mission (JJM) for providing adequate safe drinking water to every rural household of this region.

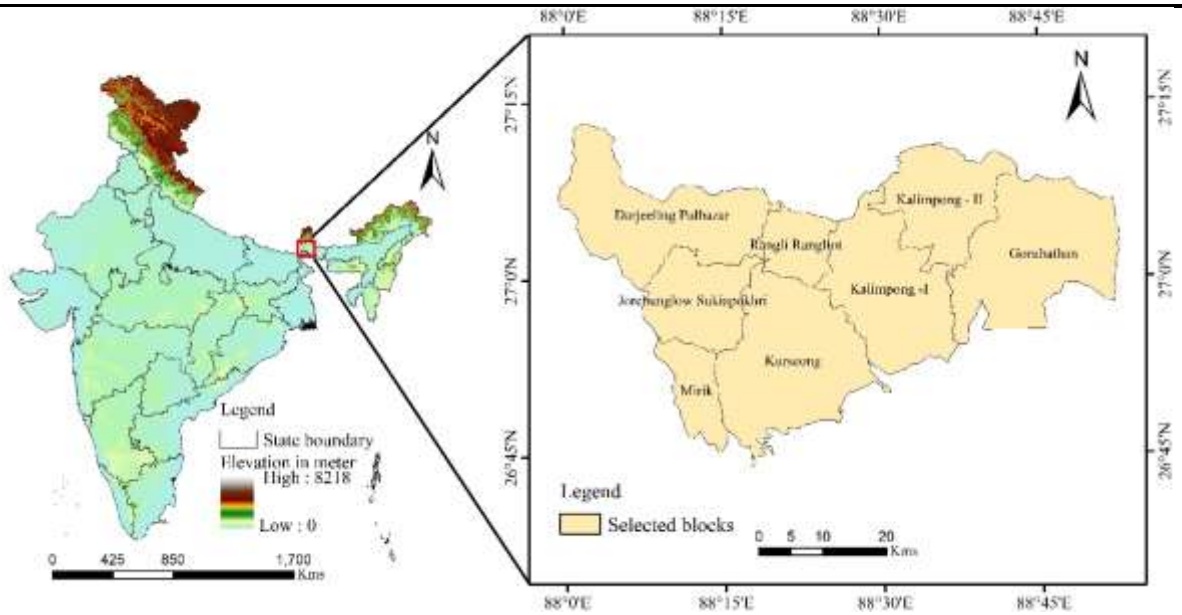

Figure 1: Location of Darjeeling Himalayan Region C.D. Blocks.

2.1.Data and Methodology

2.1.1. Data used

Primarily, this study is based on secondary data collected from two sources, as listed in Table 1. Both data indicate the availability of safe drinking water within the premises. Along with the use of secondary data from two main sources, some household-level survey data are also used as a case study to understand the achievement level of SDG 6.1 in this selected tribal-dominated Darjeeling Himalayan Region of India.

Table 1: Details of the data source used for this study.

JJM implementation phase	Year of data	Source of the data
Pre-implementation	2011 (2011 population census)	Census of India 2011 (https://censusindia.gov.in/)
After implementation	2025	Jal Jeevan Mission Dashboard (https://ejalshakti.gov.in/jjmreport/JJMIndia.aspx)
After implementation	2025	JJM impact data collected through the household-level survey

2.2. Methodology

2.2.1. Sampling strategy

Sampling strategy is an important step in achieving accurate results, especially in primary field survey-based studies. A stratified random sampling technique is selected for this study to conduct household-level data collection. Firstly, the total number of samples (398) is estimated based on Yeamen's (1967) formula with a 5% margin of error (Eq. No. 1). Then, the total number of samples is divided into different Community Development blocks of the Darjeeling Himalayan Region (DHR). Then these estimated samples are divided

into different categories of villages based on the Jal Jeevan Mission (JJM) implementation percentage. Further, the households are selected randomly to collect household-level information.

$$n = \frac{N}{1+N(a)^2} \text{..... (Eq. No. 1)}$$

Where n is the sample size of the population

N=Household number

α= Margin of error

1= Constant

2.2.2. Questionnaire framing

A structured question is framed to assess the implementation status and the effect of the Jal Jeevan Mission (JJM) scheme on the changing socio-economic and human well-being aspects of the tribal dominated DHR. The questionnaire is divided into sections for assessing different aspects of JJM impacts. Blocks 0 to C comprise questions related to basic demographic and household information. Blocks D and E discuss the implementation status and water demand-supply aspects of the study area. Health-related impacts and economic impacts are assessed in Blocks F and G, respectively. This framed structured question is then used to collect field-based data from 398 rural households of the DHR area for assessing the impacts of JJM on different socio-economic aspects.

2.2.3. Analysis of the data

The collected household-level data is subjected to various statistical analyses to obtain results regarding the impacts of JJM on different socio-economic aspects of the tribal-dominated rural DHR.

2.2.3.1. Statistical analysis

Both the descriptive and inferential statistical techniques are used on the collected data. Descriptive statistics such as frequency distribution, cross tabulation etc, are applied on the field collected data to understand the nature of the data and also to understand the nature of the studied problem of the study area. Similarly, different inferential statistical techniques such as the Chi-Square test, McNemar's test, are applied to understand the relationship between JJM implementation and socio-economic changes of the DHR. A combination of both descriptive and inferential statistics ultimately helps to understand the impacts of JJM on socio-economic conditions and the achievement of SDG 6.1.

Chi-square test is a non-parametric hypothesis test used to assess the association between two variables, which is calculated using Eq. no. 2.

$$x^2 = \frac{\sum (O-E)^2}{E} \text{..... (Eq. No. 2)}$$

Where, x^2 is the Chi-Square test value, O is the observed value, and E is the expected value.

McNamer's test is a statistical test performed to understand the association between pre and post-events based on a binary response, calculated based on Eq. No. 3.

$$m^2 = \frac{(|b-c|-1)^2}{b+c} \text{..... (Eq. No. 3)}$$

Where m^2 is the McNemar test value, b and c are the number of discordant pairs in the 2×2 contingency table.

2.2.3.2. Calculation of SDG 6.1 indicators

Member countries of the United Nations (UN) in 2015 framed 17 Sustainable Development Goals (SDGs) and associated SDG targets to be achieved by 2030 for providing a sustainable future to the world. Out of these 17 SDGs, SDG 6 talks about the provision of Clean Water and Sanitation to all by 2030. This SDG is further divided into 6 targets, and the first target is to achieve universal and equitable access to safe and affordable drinking water for all by 2030. Which is further divided into two indicators. Details of the two indicators and their measurement procedure are given below.

Indicator 6.1.1: Proportion of population using safely managed drinking water services

The population using safely managed drinking water indicator is calculated using the Eq. No. 4.

$$6.1.1(\%) = \left(\frac{Population\,using\,safely\,managed\,drinking\,water\,services}{Total Population}\right)\times 100 \quad \text{….. (Eq. No. 4)}$$

Here, safely managed drinking water includes three criteria: 1) available when needed, 2) located within premises and 3) free from contamination. These three combined calculate the proportion of the population using a safe drinking water source. In the case of Census 2011 data, 1) Tap water from a treated source, 2) Covered well, and 3) Hand-pump are considered as the sources of safely managed drinking water, whereas, in the case of JJM data, Functional Tap Water Connection (FTWC) is considered as the safely managed drinking water source for calculating SDG indicator 6.1.1.

Indicator 6.1.2: Percentage of rural population having improved source of drinking water.

The percentage of the rural population having improved source of drinking water is calculated using Eq. No. 5.

$$6.1.2(\%) = \left(\frac{Rural\ population\,using\,improved\,drinking\,water\,sources}{Total\ rural\ population}\right)\times 100 \quad \text{…… (Eq. No. 5)}$$

Here, piped water, borewell/tubewell, protected well source is considered as an improved drinking water source in the case of census 2011 data, and FTWC is considered as the improved source of drinking water in the case of JJM provided data. Based on both of these datasets, SDG indicator 6.1.2 is calculated to understand the changes in the achievement of SDG 6 through the implementation of the JJM scheme.

3. Results

3.1. Level of water security before JJM implementation

Tribal dominated rural Darjeeling Himalayan region (DHR) has been facing several safe drinking water issues for a long time, with its main source of drinking water from unprotected springs. The people of this region collect their water from far distances and for collecting water from far distances results in a loss of huge man-day hours. Mainly, female members of the households are responsible for collecting water from far distances, and where safe drinking water is not available nearby, they have to purchase their required water, spending a huge amount of money. Details of the water source for the DHR area are given in the Table, as obtained from the Census of India 2011 data (Table 2). Data showing that nearly 91.6% of the households are accessing water from untreated sources, with a maximum percentage of 95.7% for Rangli-Rangliot C.D. block of

Darjeeling district and the lowest percentage of 89.3% in Gorubathan C.D. block of Kalimpong district. This scenario of an unsafe drinking water source brings more attention to this area for providing safe drinking water through the provision of FTWC to every rural household through the JJM scheme.

Table 2: Sources of drinking water for the selected eight C.D. blocks of DHR before the implementation of the JJM scheme (Census of India, 2011).

District Name	Tehsil Name	Main Source of Drinking Water										
		Tapwater from a treated source	Tapwater from un-treated source	Covered well	Un-covered well	Hand-pump	Tubewell/ Borehole	Spring	River/ Canal	Tank/ Pond/ Lake	Other sources	Water from untreated sources
Darjiling	Darjeeling Pulbazar	5.3	25.5	0.7	1.8	0	2.1	57.9	0.8	3.8	2.1	**91.9**
	Rangli Rangliot	2.9	27.2	0.7	0.4	0	0.7	63.5	1	2.6	0.9	**95.7**
	Jorebunglow Sukiapokhri	4.9	38.9	1.4	0.8	0	0.4	51.5	0.3	0.7	1.1	**93.3**
	Mirik	8.7	15.5	0.4	1.2	0.1	0.8	72.6	0	0.5	0.1	**90**
	Kurseong	6	32.5	1.2	9.2	0.6	2	41.7	1.2	2.3	3.3	**90.2**
Kalimpong	Kalimpong -I	7.9	22.1	0.3	1.5	0.1	0.9	60.3	1.3	2.2	3.4	**90.8**
	Kalimpong - II	7.6	31.8	0.6	0.2	0	0.2	54.4	0.6	3.5	1.2	**91.6**
	Gorubathan	7.4	26.8	1.8	6.9	0.4	1.1	47.3	3.8	2.5	2	**89.3**

3.2. Present status of tap connections through the JJM scheme

The worst unsafe drinking water scenario of the DHR area has drastically changed through the implementation of the JJM scheme in this region. Nearly 50.14% of the rural households of the DHR area have already been covered with FTWC provided by the JJM scheme, with the provision of 55 liters of safe drinking water per person per day (Table 4).

Table 4: C.D. block-wise JJM implementation status for selected C.D. blocks of Darjeeling and Kalimpong district.

District	**Name of the block**	**Total household**	**JJM connected HH**	**% of connections**	**C.D. Block average**
Hilly Darjeeling	Darjeeling Pulbazar	30768	14308	43.58	47.08
	Mirik	18529	8224	44.38	
	Rangli Rangliot	19180	10326	53.84	
	Jore Bungalow	44413	25223	56.79	
	Kurseong	49684	18281	36.8	
Kalimpong	Kalimpong I	26325	13307	50.55	55.26
	Kalimpong II	21026	11999	57.06	
	Gorubathan	17204	10010	58.18	
Total		**227129**	**111678**	**50.1475**	

All eight C.D. Blocks of the DHR area are showing significant progress in providing FTWC in spite of having several physical and administrative difficulties in this region. Kalimpong (55.26%) district is showing higher progress in terms of FTWC provision than Darjeeling district (47.08%). Gorubathan C.D. Block of Kalimpong district has the highest percentage of FTWC with 58.18%, followed by Kalimpong-II and Kalimpong-I C.D. Block, whereas in the case of Darjeeling district, Jorebunglow C.D. Block with 56.79% is showing the highest percentage of FTWC implementation, followed by Rangli-Rangliot, Mirik, Darjeeling-Phulbazar and lastly Kurseong C.D. Block (Table 5). Large area coverage and dispersed settlement distribution of the Kurseong district are mainly responsible for the lowest amount of FTWC of this C.D. Block. This increased percentage of safe FTWC in rural households has increased the water security level of this region and should reduce dependency on unsafe drinking water sources, having a positive impact on man-day-hour saved, improved health condition, economic condition and improved human well-being of this region.

Table 5: C.D. block-wise number of villages under different levels of JJM implementation.

Class	JJM implementation percentage of total villages							
	Darjeeling Pulbazar	Mirik	Rangli Ranglio t	Jore Bungalo w	Kurseon g	Kalimpong I	Kalimpong II	Gorubatha n
75-100	14.89	15.00	29.03	36.00	2.78	36.54	23.08	28.95
50-75	4.26	10.00	9.68	8.00	11.11	15.38	23.08	18.42
25-50	6.38	10.00	6.45	2.00	16.67	17.31	5.13	10.53
5-25	6.38	10.00	22.58	6.00	6.94	5.77	2.56	10.53
0-5	68.09	55.00	32.26	48.00	62.50	25.00	46.15	31.58

3.3. Improvement of water security in the DHR through JJM

Darjeeling Himalayan Region (DHR), historically dependent on unsafe and unreliable sources of water, has experienced a drastic change in terms of water security after the implementation of the JJM scheme in 2019. Although the progress is lower than the national average and West Bengal state average, significant progress has been made for this highly undulating, forest-dominated tribal region, where water scarcity was a major issue. Earlier to the implementation of the JJM scheme, more than 90% of the households were dependent on untreated sources of water, which has drastically changed and presently, more than 50% households in this region are accessing safe water within their premises. These changes in water security positively impacted the utilization of man-day hours, health condition, economic condition and overall well-being of the people.

Although there is a huge variation in terms of the implementation of the JJM scheme in different blocks of Darjeeling and Kalimpong districts, they are showing both progress and persistent challenges in the implementation. Kalimpong district indicates a higher level of implementation with 55.265 households covered with FTWC, whereas Darjeeling district shows a relatively lower implementation proportion with

47.08%. This higher level of implementation shows a better infrastructural penetration and implementation efficiency in spite of having different physical and managerial difficulties. The proportion of villages under the higher implementation stage (75%-100%) across all the C.D. Blocks demonstrated a measurable penetration of JJM infrastructure for this study area.

Along with the improvement in infrastructural facilities, these have also shown significant progress in assuring water security by providing safe drinking water within the premises for those households that previously collected their water from unsafe sources, such as springs from far distances. It has also reduced the chance of climatic vulnerability of accessing water, especially during dry seasons, reduced the burden of collecting daily water from far distances, improved health conditions and economic conditions. Overall, the implementation of JJm scheme for this study area has played a transformative role in enhancing water security for this water scarcity region and has helped to progress in achieving SDG 6.1.

Figure showing that some parts of the study region have clustered areas of higher JJM implementation, analysed through the calculation of Local Indicators of Spatial Autocorrelation (LISA), calculated using GeoDa software (Figure 2). This clustered higher implementation status shows a higher level of success for a few regions.

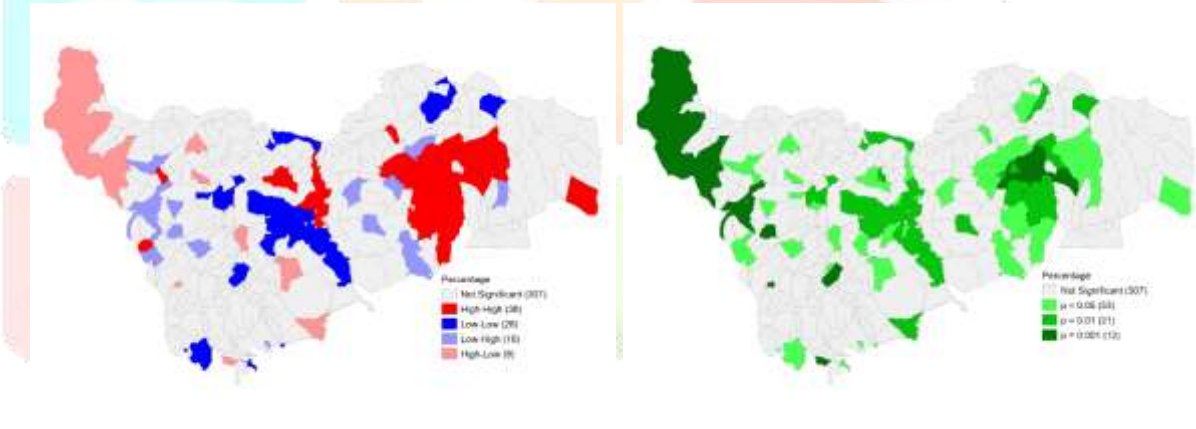

Figure 2: Spatial patterns of village-level JJM implementation shown through LISA analysis.

3.4. JJM Implementation and the achievement of SDG 6 in the DHR

Implementation of the JJM scheme has a huge impact on the achievement of SDG 6.1, which was the main target of implementing this important water supply-related scheme taken by the Government of India. SGD indicator 6.1.1 focused on assessing the achievement of SDG through the provision of safely managed drinking water to every rural household, has seen a drastic increase from 6.58% to 47.08% after the implementation of the JJM scheme for the Darjeeling district, whereas this increase is much higher for the Kalimpong district, which changes from 8.7% in 2011 to 55.26% in 2025. In the case of SDG 6.1.2, Darjeeling district shows a sharp increase from 7.64% in 2011 to 47.08% in 2025 (Table 6).

Table 6: Achievement of SDG 6.1 in different C.D. blocks of DHR between 2011 and 2025.

District	C.D. Block	SDG 6.1.1		SDG 6.1.2	
		Percentage of households			
		2011	2025	2011	2025
Darjeeling	Darjeeling Pulbazar	6	43.58	8.1	43.58
	Mirik	3.6	44.38	4.3	44.38
	Rangli Rangliot	6.3	53.84	6.7	53.84
	Jore Bungalow	9.2	56.79	9.9	56.79
	Kurseong	7.8	36.8	9.2	36.8
Kalimpong	Kalimpong I	8.3	50.55	9.1	50.55
	Kalimpong II	8.2	57.06	8.4	57.06
	Gorubathan	9.6	58.18	10.3	58.18

3.5. Impact of JJM on health conditions

The implementation of the JJM scheme in the selected study area has a positive impact on health conditions, as revealed by the analysis. The Chi-Square result ($\chi^2 = 11.686$, df = 5, p = 0.039) indicates that the occurrence of disease before availing the JJM connection was dependent on the source of water, which is also supported by the higher percentage of 'yes' responses to the occurrence of waterborne diseases for piped water and springs, which were the main sources of water for these households. But more significantly, the households using public taps are getting more affected by waterborne diseases (Table 7).

Similarly, the McNeimer test result (p = 0.000 (two-sided)) shows that the implementation of the JJM scheme has a very significant impact on disease occurrence, and this result is supported by a 31.7% household response of reduced medical expenses after availing JJM connections.

Both the results obtained from the household level survey indicate a highly positive impact of JJM tap connection on improved health conditions of the selected study area.

Table 7: Impacts of different water sources on the occurrence of water-borne diseases.

Source of water	Occurrence of disease before JJM (Number of households)	
	No	Yes
Packaged water	24	6
Piped water	105	38
Public tap	31	15
Protected spring	131	25
Protected dug well	3	3
River pond	15	2

3.6. Impact of JJM on economic condition

Earlier, the people of DHR collected their daily water from far distances, as they had to collect their water mainly from springs, which was a time-consuming and costly process and also a difficult task, especially for the female members who were responsible for collecting water. But the implementation of the JJM scheme provides FTWC within the premises for a larger proportion of people in this area, helping to save some time from water collection. Nearly 64.1% of the respondents have responded that they are saving time earlier

invested in collecting water from far distances. On the other hand, nearly 49% of the respondents are utilising this saved time for more income generation through the involvement in different household-level business activities such as horticulture, homestay tourism, and animal husbandry (Table 8). Especially, female members of these households are investing their time in household-level income generation, as they are mainly responsible for collecting water from far distances. Even 55% respondent have reported that their household income increased significantly due to the availability of water through JJM provided FTWC.

Table 8: Response regarding the economic impacts of JJM scheme in the study area.

Economic issues	Responses (%)	
	Yes	No
Positive impact of JJM on the economic condition	58.8	41.2
Time saving due to the JJM water connection within the premises	64.1	35.7
The JJM water connection induces savings in time to generate more income	48.7	50.8
Changes in total income after taking the JJM connection	55.2	44.8
Satisfaction with more income generation after taking the JJM connection	44.7	55.3
Availability of job facilities for investing saved time	46.2	53.8

The impact of JJM implementation on the economic prosperity of connected households is also assessed through the Chi-Square test analysis between the variables, time saving due to availing water through JJM connections, investment of saved time for collecting water from far distances before taking JJM connection, satisfaction with the changes in income due to the availability of water within premises through JJM scheme and the availability of job opportunities in the market for investing saved time from collecting water from far distances. Details of the Chi-Square test results are given in Table 9, which indicates that the availability of the JJM connection has an association with time saving from collecting water and income change, and availability of job opportunities in the market. All these associations are significant.

Table 9: Chi-square test results for assessing the association between JJm parameters and economic benefits.

Variables	χ^2	df	p-value	Cramér's V
Time saving × Investing time	85.042	1	<0.001	0.46
Investing time × Income satisfaction	80.183	1	<0.001	0.45
Job opportunity × Income satisfaction	109.32	1	<0.001	0.52

4. Discussion

4.1. Improvement in water security in the DHR through the JJM scheme

This study is conducted to understand the changing impacts of the JJM scheme in the transformation of water security of tribal dominated hilly areas of the Darjeeling Himalayan Region (DHR). The results demonstrate that more than 50% of the households in the hilly Darjeeling and Kalimpong districts are accessing water within their premises, whereas this scenario was totally different, and more than 90% of households in this

region were collecting their water from untreated sources, especially from springs having a high chance of being contaminated and a higher chance of seasonal unavailability of water (Bhat et al., 2020; Verma & Jamwal, 2022). But the introduction of JJM-based FTWC plays a vital role in ensuring water availability, accessibility, reliability and quality, which has changed this water supply from a communal and fragile source to a formalised supply system. This scenario of the impacts of the JJM scheme is also experienced in other mountainous regions of India, showing a strong positive impact of the JJM scheme in providing adequate, safe water to every rural household of hilly regions having water scarcity for a long time (Singh et al., 2022; Mishra, 2023).

Spatial variation in the implementation status of JJM FTWC also helps to identify the roles of undulating terrain, dense forest, dispersed settlements, etc, for the implementation of these important water supply-related schemes. It also echoes that these special regions required context-specific planning and a project for getting a higher level of success rather than following an overall planning process.

On the other hand, JJM has accelerated the achievement of SDG 6.1, which focuses on the universal and equitable access to safe and affordable drinking water, especially for mountainous regions, which also lags behind in achieving SDGs than the plain areas. A five-fold increase in SDG 6.1.1 and 6.1.2 values has shown that it is not only an incremental change but also a structural change in the access to safe drinking water for the mountainous DHR region. This increase in both indicators sharply indicates that JJM provided FTWC has improved the safety and service quality in terms of drinking water provision.

The JJM scheme not only enhances the safety and service quality of water supply provision in this region, but also enhances the economic and health conditions of this region by providing drinking water supply within the premises. It is evidenced from the results that the occurrence of water-borne diseases has reduced after taking JJM FTWC within their premises, and also demonstrated that it saved a huge amount of man-day hour loss, which was earlier invested in collecting water from far distances. Not only has it helped toward enhancing women's empowerment by reducing their burden for collecting water from far distances. They are investing their saved time from water collection for economic growth, socialisation, and education and enhancing their overall quality of life.

Overall, this JJM scheme has shown that if infrastructure intervention can be effectively managed and properly planned and maintained, it can bring huge changes in society, especially for disadvantaged regions like tribal dominated hilly forested regions of DHR. Also, the lagging of this region compared to other regions of the state of West Bengal shows that context-specific planning is essential rather than overall planning models for achieving higher success for these types of infrastructure augmentation projects.

4.2. Challenges and way forward of water security in DHR

JJM has helped to provide a safe and reliable drinking water supply within the premises of rural households of DHR for a significant proportion, but still, the implementation of this scheme is facing several issues, such as undulating terrain, dispersed settlements, operational issues, decreased spring discharge, connectivity issues, etc., for the full implementation of this scheme. So, for achieving universal coverage of this scheme for this region, special attention should be given to the last-mile connectivity issue for remote and sparsely distributed settlement areas. Even more emphasis should be given to spring rejuvenation, rainwater

harvesting, and community-led monitoring and maintenance and awareness generation. Inclusion of local knowledge through the incorporation of local people within this project planning may be the best way out for get the full benefit of this important water supply-related scheme.

4.3. Limitations of the study

Despite assessing the role of the JJM scheme in providing safe drinking water for a water scarcity region, this study has some limitations that should be mentioned for a better understanding of the study and for the future scope of this study. Firstly, this study is conducted based on cross-sectional data, which is taken only at a time, limited to assessing the impacts over a long time. Secondly, health outcomes and economic impacts are assessed based on self-reported responses without cross-verifying them with other methods. So future study can be done for a more micro-level, that is, for the village level, with some other source of data. Even a longitudinal study can be performed by incorporating data from different years.

Conclusion

The study clearly assesses the impacts of the JJM scheme on the improvement in availability, accessibility, reliability and quality of supplied water within the premises for forest and tribal dominated hilly terrain, DHR. The drastic improvement in the supply of safe drinking water within the household premises from nearly 10% to more than 50% for the DHR region between 2011 and 2025 shows the effectiveness of this scheme for this region. This scheme also helps in achieving SDG 6.1 for this region to a significant level through the provision of safe drinking water to every rural household. Along with the infrastructure development, it also helps to improve the health, economic and human well-being condition of the people of this region. Saving of lost man-day hours earlier invested for collecting water from far distances helped them to generate more income and also helps for the self-development of the family members, especially for the female members of the family, as they are the main responsible persons for collecting water from far distances. Similarly, the results related to the spatial variability of implementation and impacts of this scheme also show how context-specific planning should be taken to get the full benefit from water supply-related infrastructure development projects.

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