



## Evaluating the water resources of the Bhramani River Basin in India

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### Abstract

This research explores sustainable water resource management strategies, focusing on the integration of urban planning and environmental conservation to achieve the Sustainable Development Goals (SDGs). It highlights the need for holistic approaches to balance economic, social, and environmental priorities. The research highlights innovative frameworks like the European Water Framework Directive and Integrated Water Resource Management (IWRM) and highlights the importance of coordinated efforts in water supply, wastewater management, flood prevention, and irrigation. The study also explores the potential of biological wastewater treatment, managed aquifer recharge, and rainwater harvesting as sustainable solutions to mitigate water scarcity and improve climate change resilience. Policy coherence, community engagement, and technological advancements are crucial for overcoming barriers like water pollution, inefficient infrastructure, and institutional gaps. Governance and financing mechanisms are also essential for enhancing water service sustainability, particularly in developing regions like Sub-Saharan Africa. The thesis emphasizes the transformative impact of improved water access on gender equity, poverty alleviation, and overall well-being. The research concludes with actionable recommendations for policymakers, urban planners, and stakeholders to foster sustainable water management practices.

**Keywords:** Agriculture, brahmani river basin, water resources

### Introduction

The term "fresh water" refers to the water that occurs on Earth in its natural form. Everyone uses this potable water for everything from drinking and cooking to cleaning and bathing and even watering their lawns. More people are worried about the quality and quantity of water because of how important it is and how scarce it is becoming as a consequence of pollution, misuse, and climate change. Authorities are unable to meet the demand for water due to a lack of investment or inadequate human capability; as a result, 1.6 billion people reside in places facing economic water shortage. Planning, development, and management of integrated water resources necessitates an evaluation of the existing water resources. Environmental and social-economic systems rely on the availability of water and the management of water resources. A more nuanced view of water resource allocation and management may be possible with the use of combined economic valuation methods. The Adra River Basin system in Spain, the Dong Nai River Basin in Vietnam, and many river basins in California are just a few of the places that have used optimization models that connect basin-wide hydrologic and economic systems. Nevertheless, the current water supply and its potential integration into the larger water supply system at both the sub-basin and basin scales are not taken into account by these models. Water management methods at the river basin size may be rationalized and made successful with the help of the fundamental components and structure described in this study. The Brahmani River Basin in Odisha, India, is the subject of this research because of its historical significance as an agricultural centre and its current status as a number of sites for industrialization. Despite being a basin with an excess of water, it experiences water shortages and floods in certain areas. Within the next several decades, rivalry among water use sectors is likely to heat up. This is

because the river basin is located in three separate states, and each of these states is increasing its demands for agriculture, industrial water, and urban water.

### Literature Review

Dr. Tarunika Jain Agrawal (2017) <sup>[1]</sup> Water resource management is severely underfunded, which is putting a strain on already-scarce water supplies that are under increasing pressure to satisfy rising demand due to factors including population growth, urbanization, and agricultural demands. This research gives an overview of the state of water resource management in India and the policies put in place by the government so far; it also discusses how integrated water resource management is necessary in the country. The primary objective is to bring up a few points that highlight the significance of investigating new ways to fund WRM.

Ali Sdiri (2018) <sup>[2]</sup> Sousse hosted the 2016 International Conference on Integrated Environmental Management for Sustainable Development (ICIEM) from October 27th to the 30th. The purpose of the conference was to facilitate global dialogue on water resource rationalization as a means of environmental protection and preservation.

Arun Lal Srivastav *et al* (2021) <sup>[3]</sup> Climate change is causing declining agricultural output and worsening water quality worldwide. Agricultural output is vulnerable to weather changes, including climatic fluctuations, long-term rainfall patterns, growth shocks, and severe weather occurrences. Drought has increased the proportion of land affected by main crops like wheat, barley, maize, rice, sorghum, and soya bean worldwide since the 1960s. Wheat yield losses are expected in the US, India, and Russia due to rising temperatures. To reduce climate change's negative impacts on water resource availability, watershed management, improved storage capacity, equitable water supply and

distribution policies, and river health can be achieved. Boosting agricultural productivity can guarantee food security by creating resistant crops, effective water management in irrigation, climate-smart agriculture strategies, and promoting indigenous knowledge. Technological intervention, such as software applications, water management strategies, temperature measuring devices, soil health analysis tools, and nutrient management systems, can help farmers manage their farms sustainably. Lakhwinder Kaur (2016) [4] There are a number of pressing issues in Punjab that need to be addressed, according to the current research titled "Water Management Strategies for Sustainable Agriculture." These include the falling water table in central Punjab, water-logging and brackish water in the south-western sections, and unpredictable rainfall and water run-off in Khandi districts. Water scarcity is a major concern for farmers. Current problems and concerns with agricultural water management were covered in this article, along with the environmental impacts of agronomic methods. Laser land levelling, planting wheat in beds, transplanting paddy in the second half of June, using direct seeded rice, zero tillage, water saving cropping systems, mulching, protected cultivation in poly-houses and low tunnels, micro irrigation, rainwater harvesting, and tensiometer-aided irrigation are just a few of the many ways that water resources could be more efficiently used. In order to preserve our limited natural resources, we need to diversify our cropping systems and embrace shorter breeding types. Also included are the policy actions made by the government to slow the decline of groundwater levels.

Shan-E-Hyder Soomro *et al* (2024) [5] Freshwater is crucial for human survival and development, as it spans all spheres of society, economy, and environment. The industrial sector uses around 20% of available freshwater globally, prioritizing production efficiency over conservation and efficiency. Recent research suggests a positive correlation between investing in technology upgrades for industrial water treatment and reuse and a long-term, lucrative return on investment. This research aims to operationalize sustainability in water management within Pakistan, helping business leaders and entrepreneurs optimize operations and meet sustainability standards set by national and international organizations. To ensure viable industrial water use, a comprehensive water management plan considering financial, social, and environmental aspects is necessary. The study's global reach is expected to help businesses optimize their operations and meet sustainability standards in the face of globalization.

**Research Methodology**

**Data Collection and Its Analysis**

Table 3.6 shows the results of the analysis of rainfall, discharge, evapotranspiration, groundwater, population (both urban and rural), irrigation (Kharif and Rabi), and industry data gathered from various sources between 1990 and 2012 for each sub-basin in the research region.

**Use of land**

The land use statistics were derived from data obtained at the district level in the states that make up the co-basin. Both the overall basin and individual subbasins have had their data processed. National Remote Sensing Agencies (NRSA, 2000) in Hyderabad additionally used IRS-1D LISS

III satellite imagery to confirm the land use data. Based on the results of the latter investigation, Table 1 displays the total land usage in the basin.

**Table 1: Brahmani Basin Land Use Pattern (km2)**

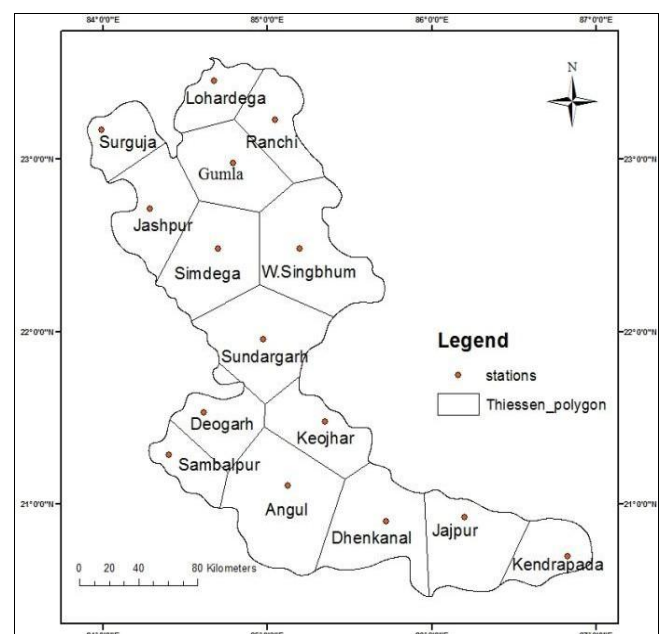
Land use	Area
Geographical Area	39,268
Forests	15,101
Permanent pastures	1,323
Land not available for cultivation, waste and fallows	9,805
Land under reservoirs	607
Culturable land (Cultivated Land, Culturable wastes & Fallow)	21,805
Net sown area	12,432

**Water Resources**

Both the Sankh and Koel rivers have gauge and discharge (G&D) sites; the Sankh has a drainage area of 3,160 km2 while the Koel has a drainage area of 9,160 km2. Panposh (drainage area 19,448 km2), Gomlai (drainage area 21,950 km2), and Jenapur (drainage size 33,955 km2) are the three G&D sites along the major Brahmani River. Figure 4 shows where the G&D locations are. The basin's renewable water resources are assessed by the Central Water Commission (CWC)1 to be 21,920 million cubic meters per year. Both surface and underground water sources are included in this. "CWC" in 1988

**Rainfall data**

A tropical monsoon climate is basically what the whole Brahmani River basin experiences. Winter, summer, and the wet season are clearly defined. Sea breezes influence the weather in the narrow coastal strip to a lesser extent than the altitude impact does at the higher elevations of hills and plateaus. Extreme heat in the summer may reach 47 degrees Celsius, while winter lows are 4 degrees Celsius. The basin receives an average of 1305 mm of precipitation each year, with extremes of 969 mm and 1574 mm. Crops and plants in the basin are adequately watered during the monsoon months (June to September) by the aggregate precipitation.



**Fig 1a: The Brahmani River basin's rainfall stations and the Thiessen polygons that correlate to them**

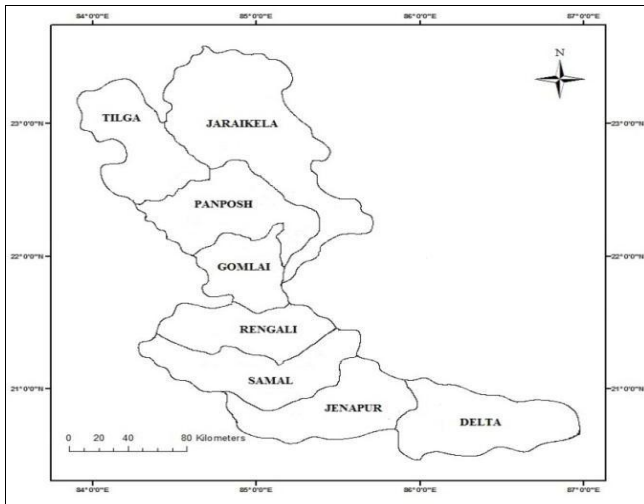


Fig 1b: Segments of the Brahmani River

The Thiessen weights of all the rain gauge stations in the Brahmani River basin are listed in Table 1.

Sl.No.	Rain gauge station	weightage of each station	S.No.	Rain gauge station	weightage of each station
1	Lohardega	0.0370	9	Sambalpur	0.0445
2	Gumla	0.0611	10	Keojhar	0.0908
3	Ranchi	0.0660	11	Deogarh	0.0524
4	Simdega	0.1023	12	Angul	0.0879
5	W. Singbhum	0.1171	13	Dhenanal	0.0457
6	Surguja	0.0384	14	Jajpur	0.0619
7	Jashpur	0.0452	15	Kendrapada	0.0415
8	Sundargarh	0.1081			

All of the data sets that were collected between 1990 and 2012 were used to determine the rainfall trends. There has been a noticeable decline in rainfall at many rain gauge sites, including Lohardega, Ranchi, Gumla, West Singbhum, Surguja, Jashpur, and Sundargarh. Figure 2 shows that there is a continuous trend at the Sambalpur, Deogarh, Keojhar, Angul, and Dhenkanal rain gauge stations, as well as at the Jajpur and Kendrapada stations.

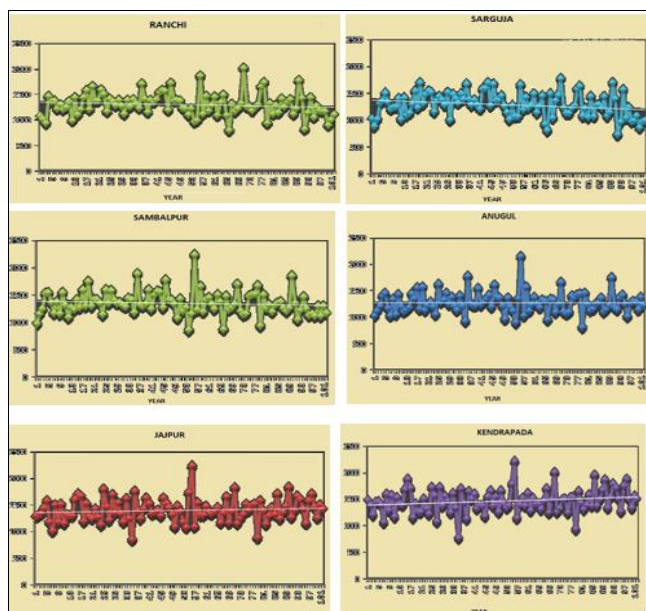


Fig 2: Increasing, decreasing and no rainfall trends of representative stations

**Groundwater data**

Groundwater data is crucial for managing water resources, including surface water, groundwater, existing bodies of water, canal water, and rainfall. The Central Ground Water Board and the Water Resources Department have compiled data showing that only 27.88% of the 1980.33 MCM of accessible groundwater has been utilized, with Joda in the Keonjhar district having the highest utilization rate of 62%. Kendrapada district has the least groundwater depletion, while Surguja district has the most.

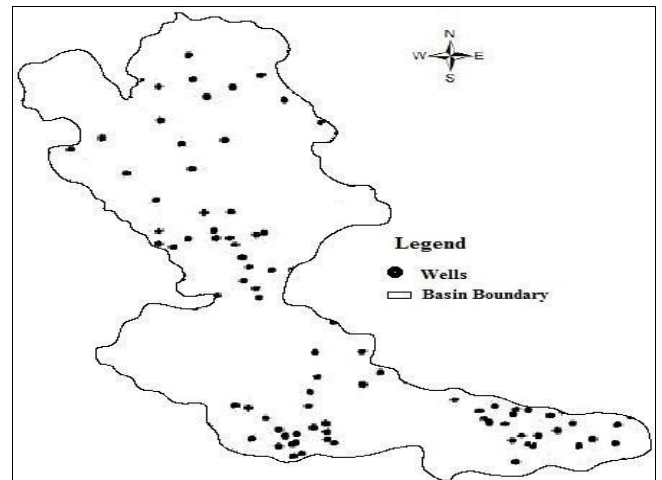


Fig 3: Well placement in the Brahmani basin (NRSC)

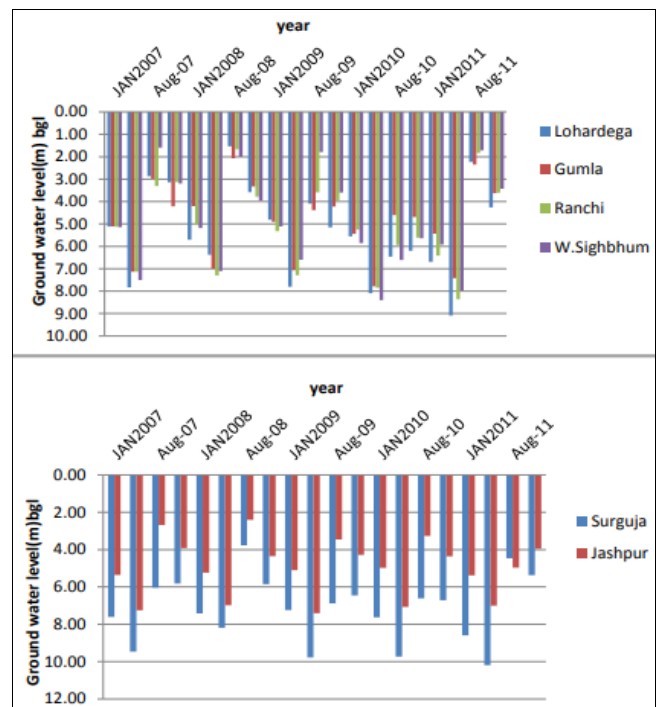


Fig 4: The levels of groundwater at various wells

**Model Formulation**

Methods for estimating and developing links between water resource demand and supply at the basin and sub-basin scales are detailed in this section. A relatively basic equation often describes the connection between supply and demand, or inflow:

$$Inflow - Outflow = Supply - Demand = Storage \ (I) \ Or$$

$$\frac{\text{Inflow}}{\text{time}} - \frac{\text{Outflow}}{\text{time}} = \frac{\text{Supply}}{\text{time}} - \frac{\text{Demand}}{\text{time}} = \frac{\text{Storage}}{\text{time}} \quad (2)$$

Physical factors and basin features may further extend the aforementioned correlations for surface water and ground water balance studies. Another way to express the equation is as:

$$\sum_{t=1}^n [P_{basin} + Q_{in,us} + Q_{nps,ssf} + Q_{nps,irf} + Q_{ps,indf} + Q_{ps,munf} + Q_{ob} + Q_{gw}]_t - \sum_{t=1}^n [I_{abs} + I_{fil} + E_{tp} + D_{ir} + D_{ur} + D_{rr} + D_{id} + D_{soil}]_t = \sum_{t=1}^n (Q_{out,ds})_t + \frac{Q_s}{t} \quad (3)$$

- $P_{basin}$  = Rainfall of the basin in m<sup>3</sup>;
- $Q_{in,us}$  = Inflow discharge at upstream in m<sup>3</sup>;
- $Q_{nps,ssf}$  = Inflow discharge from sub-surface flow in m<sup>3</sup>;
- $Q_{nps,irf}$  = Inflow discharge as irrigation return flow in m<sup>3</sup>;
- $Q_{ps,indf}$  = Inflow discharge from Industries in m<sup>3</sup>;
- $Q_{ps,munf}$  = Inflow discharge from Municipality in m<sup>3</sup>;
- $Q_{ob}$  = Inflow discharge from other basins in m<sup>3</sup>;
- $Q_{gw}$  = Inflow discharge from groundwater in m<sup>3</sup>;
- $Q_s$  = Storage of discharge in reservoir in m<sup>3</sup>;
- $I_{abs}$  = Initial abstraction losses in m<sup>3</sup>;
- $I_{fil}$  = Infiltration losses in m<sup>3</sup>;
- $E_{tp}$  = Potential Evapo-transpiration losses in m<sup>3</sup>;
- $D_{ir}$  = Demand for irrigation in m<sup>3</sup>;
- $D_{ur}$  = Demand for population and livestock in urban area in m<sup>3</sup>;
- $D_{rr}$  = Demand for population and livestock in rural area in m<sup>3</sup>;
- $D_{id}$  = Demand for industries in m<sup>3</sup>;
- $D_{soil}$  = Demand for soil's field capacity in m<sup>3</sup>;
- $Q_{out,ds}$  = Outflow discharge at downstream in m<sup>3</sup>;
- $t$  = Time in days

The outflow discharge of a river system is the amount of water that remains in the river after meeting all of the needs of the basin region, as illustrated clearly in Equation (3).

### Model for Agricultural Sector Water availability for agriculture

The following relationships are used to estimate the gross availability for the agriculture sector: As it pertains to water-based farming

$$WA_{agrf} = \int_{t=1}^n (P_{basin} + C_1 * Q_{gw} + Q_{nps,ssf} + Q_{nps,irf})_t \quad (4)$$

In irrigation-based farming

$$WA_{aglr} = \int_{t=1}^n (P_{basin} + C_2 Q_{in,us} + C_3 Q_{ob} + C_4 Q_{gw} + Q_s + Q_{nps,ssf} + Q_{nps,irf})_t \quad (5)$$

$WA_{agrf}$  = Water supply required for rain-fed regions for agriculture in m<sup>3</sup>

$WA_{aglr}$  = Water supply required for irrigation regions for agriculture in m<sup>3</sup>

$t$  = Time in days

$C_1, C_2, C_3$  and  $C_4$  = Coefficients for different variables

### Water requirement for agriculture

Keep in mind that estimating the crop water needs for various crops at different times is necessary for the availability of water in agricultural regions that rely on irrigation or rainwater. A number of variables affect how much water crops need, such as the way they are sown, the length of time between harvests, the coefficients of the

crops, the amount of water that may be evaporated by rain, and the amount of water that seeps into paddy fields. According to Amarsinghe *et al.* (2005), the estimated crop water demand (Cwr) for paddy crops is:

$$WR_{paddy} = A_p * [\sum_{i=1}^m \{ \sum_{j=1}^n (K_{p(i,j)} * E_{tp(i,j)} - R_{e(i,j)}) - \sum_j^n P_{p(i,j)} \}] \quad (6)$$

as well as the projected water needs of other crops:

$$WR_{other} = A_p * [\sum_{i=1}^m \{ \sum_{j=1}^n (K_{o(i,j)} * E_{to(i,j)}) - \sum_j^n P_{o(i,j)} \}] \quad (7)$$

$WR_{paddy}$  = Rice crop water need in cubic meters for the *i*th cell (area of the plot) and the *j*th time period (days)

$WR_{other}$  = Quantity of water needed by different crops in cubic meters for the *i*th cell (area of the plot) and the *j*th time period (days)

$K_p(i, j)$  = Crop coefficient for paddy for the *i*th cell (plot area) and the *j*th time period (days)

$K_o(i, j)$  = Factor pertaining to different crops for the *i*th cell (area of the plot) and the *j*th time period (days)

$E_{tp}(i, j)$  = The evaporation-transpiration rate for the plot area of the *i*th cell for the *j*th time period in days, expressed in cubic meters

$E_{to}(i, j)$  = Equation (i) shows the evapotranspiration rate for the *i*th cell (the plot area) for the *j*th time period (days) in cubic meters.

$R_e(i, j)$  = Maximum precipitation in cubic meters for the *i*th cell (the size of the plot) and the *j*th time period (the number of days)

$P_p(i, j)$  = For the *i*th cell (plot area) and the *j*th time period (days), the percolation during the paddy crop is expressed in m<sup>3</sup>.

$P_o(i, j)$  = For the *i*th cell (plot area) and the *j*th time period (days), percolation during other crops is measured in m<sup>3</sup>.

To get the real water withdrawal for irrigating the farmland, you need to incorporate the efficiency of the water supply from canals and groundwater in equations (4) and (5). The fourth, fifth, sixth, and seventh equations may be rewritten and balanced as

$$WA_{agrf} = \int_{t=1}^n (P_{basin} + C_1 * Q_{gw} + Q_{nps,ssf} + Q_{nps,irf})_t * (Eff) = WR_{other} = A_p * [\sum_{i=1}^m \{ \sum_j^n (K_{o(i,j)} * E_{to(i,j)}) - \sum_{j=1}^n P_{o(i,j)} \}] \quad (8)$$

and

$$WA_{aglr} = \int_{t=1}^n (P_{basin} + C_2 Q_{in,us} + C_3 Q_{ob} + C_4 Q_{gw} + Q_s + Q_{nps,ssf} + Q_{nps,irf})_t * Eff =$$

$$WR_{paddy} = A_p * [\sum_{i=1}^m \{ \sum_{j=1}^n (K_{p(i,j)} * E_{tp(i,j)} - R_{e(i,j)}) - \sum_j^n P_{p(i,j)} \}] \quad (9)$$

$WA_{agrf}$  = Absolute water supply required for rain-fed regions for agriculture in m<sup>3</sup>

$WA_{aglr}$  = Absolute water supply required for irrigation regions for agriculture in m<sup>3</sup>

Eff = Summation of all efficiency for the water supply (rainfall + ground water

the effectiveness of pumping and irrigation, the flow from upstream as pumping, and the flow from other basins

When estimating transportation costs, it is essential to take into account the following factors: irrigation efficiency at the basin level, canal conveyance efficiency, watercourse conveyance efficiency, field channel efficiency, and field application efficiency.

### Conclusion

In order to boost agricultural output, aquaculture, and industrial growth, the Brahmani River basin must

implement integrated water resources management. As things are, the idea of consumptive usage is nonexistent, and relatively little water is being used for various reasons. The model's efficiency and coefficients enable users to maximize water demand for various purposes while considering conservative estimates of supply. By adjusting the coefficients, the model can be applied to other basins and simplified when certain variables are removed. Alternate futures can be achieved by expanding home, industrial, and agricultural regions and their corresponding needs.

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