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Interlinking Lakes as a Climate Change Adaptation Strategy to Combat Groundwater Decline in Bhandara District, Central India

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***Abstract*— The groundwater is threatened by climate change and extreme usage. The study concentrates on the reduction in groundwater level at the level of the Bhandara District, also known as the "District of Lakes" in the state of Maharashtra. The paper analyzes how the inter-linking of lakes can be a climate adaptation strategy for raising the level of groundwater. The study researches that inter-linking lakes can enhance recharge by 10-20%, improve drought resilience, and ensure reliable water availability. This is a climate adaptation strategy that aims to achieve a specific goal associated with the manifestation concerning the fulfillment of SDG goals 6 and 13.**

***Index Terms*— Groundwater decline, Groundwater recharge, Climate change, SWAT model, Remote Sensing and GIS, Lake Interlinking.**

I. INTRODUCTION

It is becoming more broadly recognized that one of the main roots of the distraction of hydrological processes in semi-humid tropical regions is weather change, which puts extra burden on already stressed water resources. Climate change is affecting the management and availability of freshwater resources worldwide through rising temperatures, shift in monsoon cycles, and higher evapotranspiration rates. [1; 2]. Groundwater resources, that often constitute a first line of defence during periods of erratic rainfall or drought cycles, are being severely affected because of such variations in climatic conditions (Fig. 1). The level of groundwater resources in South Asia is being seen to decrease at a sharper rate because of high levels of abstraction, low natural rates of recharge and erratic rainfall [3].
Over 65% and over 85% of irrigation and rural water demands in India are fulfilled by groundwater resources, which are a critical component of water resources [4].
Indian subcontinent aquifers are currently being drained seriously because of increased climate change, population pressure, and irrational extraction rates [5].
In India, for instance, groundwater have steadily decreased over the years; this is most visible in regions where agricultural activities rely on this water seriously. Climate change and land use adjustments have also led to a reduction in naturally replenished water in aquifers with increased rates of groundwaters being drawn for human and agricultural consumption [6].

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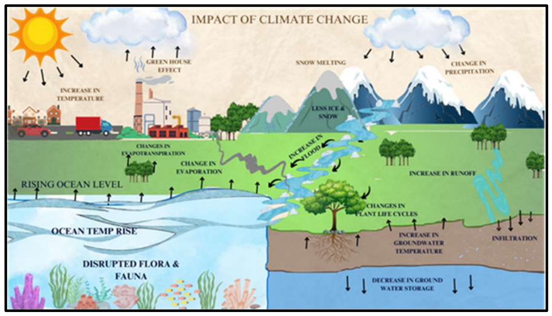


Figure 1. Climate change effect of on groundwater recharge

The same applies to Eastern Vidarbha in the state of Maharashtra, where increased annual fluctuations in monsoons have placed further stress on this dwindling water source [7].

Despite its popularity in terms of the presence of many lakes and traditional tank systems, the Bhandara district has been observed to show a different trend in water availability (Table I). The long-term hydrograph records indicate that groundwater levels are still reducing in some regions of the district, as reported by [8]. Groundwater levels in the Bhandara District in Central India (Maharashtra state) also known as the "District of Lakes," are progressively reducing because of reduced aquifer recharge, reduced intensity of rainfall and increased demand of water being met through bore wells and tube wells. The decline in groundwater levels in this region, which has been reported to worsen, has been accelerated by the decline of the integrated water systems in this district. The groundwater level in this region was previously replenished by the monsoons through an efficiently integrated ground hydrological system, which was very useful in terms of agricultural water requirements [9]. However, this system has been adversely affected by siltation, encroachment, high levels of rapid urbanization and neglect of conventional water channel systems connecting the water bodies in this region in the past decades. The water requirements in this region, which relied on short-term water availability are currently being adversely affected by reduction in groundwater recharge, reduced water infiltration in terms of silted water channels through which water used to percolate easily in the shallow groundwater aquifers.

As stated in [10], the decline rate of the groundwater of 0.35-0.7 m/year in Bhandara is directly related to the decline in monsoonal rainfall of -3 mm/year and an increased rate of evapotranspiration, mainly in Tumsar, Lakhandur, and Pauni talukas. Approximate annual decline of 0.5 meters in all monitoring wells shows the decline in pre-monsoon water levels. It has been seen that the Vidarbha region has been experiencing the decline of ground waters due to irregular rainfall and higher irrigation demands [11]. One major problem associated with water resources management is symbolized by the rising paradox between the presence of plenty of water systems in the district and the continuously dwindling levels of groundwater. With the rising occurrences of climate-related extremes, ranging from prolonged dry seasons to flash floods, there has been an increasing advocacy for the adoption of nature-based solutions for restoring the natural hydrological regimes [12].

From this justification, it is evident that the research focuses on interlinking of lakes in the Bhandara district in an effort to combat climate change impact with aim to augment groundwater recharge. This research makes use of climate change combat approach through techniques such as remote sensing and GIS in conjunction with Soil and Water Assessment Tool model (SWAT).

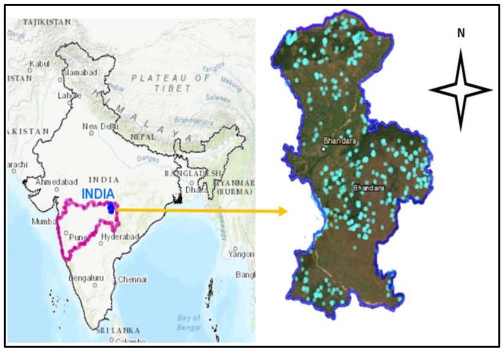
II. Materials and Methods

A. Study Area

The proposed study area Bhandara lies in eastern Maharashtra covering 3,717 km² within the Wainganga river basin. The district lies between 20°38’–21°36’ N latitudes and 79°27’–80°06’ E longitudes, with altitudes ranging from 263 to 315 m (Fig. 2.). With more than 400 lakes in district and a 1200 mm average rainfall, the district once had a robust recharge network. The Wainganga, Bavanthadi, Chulbandh, Godora and Sur rivers are the major watercourses (Fig. 3). However, fragmentation, siltation, and urbanization have weakened lake connectivity, limiting aquifer recharge.

B. Data Collection

- Field inspections undertaken to check the present condition of lakes, note any encroachments, and examine the layout and connections of canals.



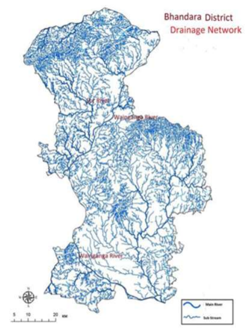


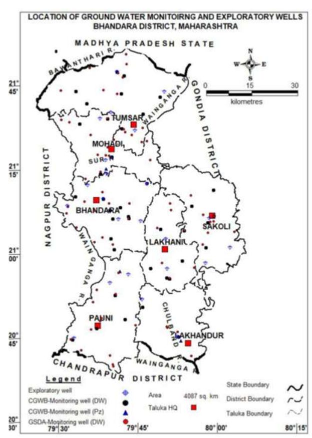
Figure 2. Location Map of Bhandara district Figure 3. Drainage Map

- Meteorological information such as daily rainfall, temperature, humidity, wind speed and evaporation will be obtained from the IMD Pune for Bhandara station.
- Groundwater levels and well observation records collected from the Central Ground Water Board (CGWB) (Fig. 4) and the Maharashtra State Groundwater Survey and Development Agency (GSDA).
- Digital Elevation Model (DEM) obtained from National Remote Sensing platforms such as NRSC and Bhuvan.
- The National Bureau of Soil Survey and Land Use Planning (NBSSLUP) provided soil map, land use–land cover map.

C. Groundwater Scenario in Bhandara District

The groundwater availability and development status is shown in Fig. 5 with annual rainfall of Bhandara district (Fig. 6).

The tahsilwise details of the shallow aquifer groundwater availability and use of Bhandara district is given in Table I. it shows that overall total recharge potential of Bhandara district is about 858.04 MCM/Year. In addition, the overall total utilization level of groundwater (irrigation, industry and domestic purpose) is 30.42 %.



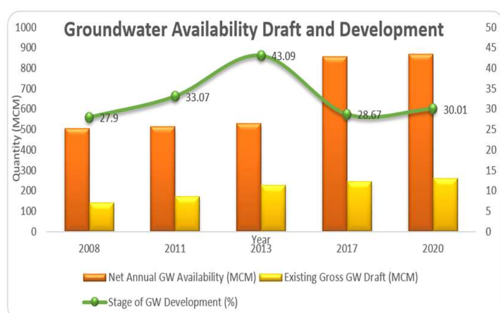


Figure 4. Location of Ground water monitoring wells Figure 5. Groundwater Availability and Development Status

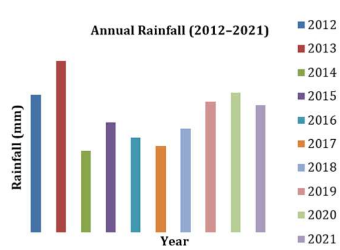


Figure 6. Temporal Analysis of Annual Rainfall (2012–2021)

TABLE I. SHALLOW AQUIFER GROUNDWATER AVAILABILITY AND USE IN BHANDARA DISTRICT (2020)

Tahsil / Administrative Area	Recharge Potential (MCM/ year)	Groundwater Use for Irrigation (MCM/ year)	Ground-water Use for Industry (MCM/ year)	Groundwater Use for Domestic Purposes (MCM/ year)	Total Groundwater Withdrawal (MCM/year)	Domestic Water Allocation (Projected 2025, MCM/ year)	Balance Ground-water Available (MCM/ year)	Utilisation Level (%)	Resource Status
Bhandara	83.16	28.31	0.11	6.68	35.14	6.69	48.01	42.22	Safe
Lakhandur	366.33	27.29	0.00	4.28	31.53	4.28	334.72	8.61	Safe
Lakhani	56.32	27.11	0.04	4.29	31.52	4.29	24.74	56.00	Safe
Mohadi	57.11	28.21	0.11	4.40	32.74	4.40	24.32	57.32	Safe
Pauni	147.22	49.62	0.00	4.93	54.61	4.92	92.61	37.04	Safe
Sakoli	68.52	30.43	0.02	5.22	35.75	5.24	32.75	52.14	Safe
Tumsar	79.11	32.92	0.00	6.42	39.42	6.48	39.63	49.82	Safe
Overall	857.77	223.89	0.28	36.22	260.71	36.30	596.78	303.15	Safe

D. Interlinking Lakes as a Climate Change Adaptation Measure

Conceptual Framework of SWAT Model

The modeling framework will employ SWAT model in QGIS environment. SWAT is a physically based hydrological model that has been widely used in surface and subsurface hydrological processes simulations of land use, soil, and climatic conditions. In SWAT-based watershed studies, specifically for lake linking and groundwater recharge assessment, the development of Hydrologic Response Units (HRUs) constitutes a very crucial step because HRUs are fundamental spatial units for process simulation in each sub-basin. Therefore, they help in addressing the heterogeneity of hydrologic processes in a simple way. SWAT model required spatial inputs and climate inputs. Spatial input includes DEM, Land Use/ Land Cover map (LULC), soil map and slope map and climate input includes daily meteorological data (Table II).

TABLE II. INPUT DATA FOR SWAT MODEL

SWAT Model Data	
DEM Soil map Land use/Land cover map Slope map	Spatial Data
Daily Meteorological Data	
River runoff	

SWAT-CUP is external software used in combination with the SWAT model for automatic calibration, validation, sensitivity analysis and uncertainty analysis. It helps link SWAT simulated results to observed data (stream flow, sediment, groundwater, nutrients) and optimizes SWAT model parameters using SUFI-2 algorithm to enhance accuracy and address uncertainty of predictions made. Some of the statistical measures used to judge the model's efficiency will be NSE, RMSE, R2, and PBIAS.

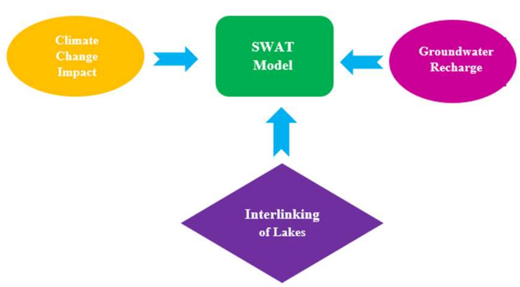


Figure 7. Conceptual framework of SWAT model in study

In order to evaluate groundwater recharge and offer a thorough analysis of runoff and water balance, SWAT will model surface hydrological processes. 25 years of historical hydrological and meteorological data, divided into warm-up, calibration and validation phases will be utilized to perform calibration and validation with the help of SUFI-2.

To define the possible effects of future climate variability on groundwater recharge, hydrological responses will be simulated under RCP4. and RCP8.5 pathways using climate projection data in a validated SWAT model. SWAT will be used to evaluate the groundwater recharge through lakes and based on this, lakes will be interlinked (Fig. 7).

Out of listed 54 lakes, 32 lakes were visited and ground truth data collected (Table III).

TABLE III: LIST OF THE LAKES IN BHANDARA DISTRICT

Tahsil	Village	Lake Name	Geographical Location (Latitude, Longitude)
Bhandara	Amgaon	Amgaon	21.1404 N, 79.7482 E
Bhandara	Mandangaon	Mandangaon	21.2031 N, 79.7239 E
Bhandara	Dodamazari	Dodamazari	21.1556 N, 79.7571 E
Tumsar	Pawnarkhari	Pawnarkhari	21.5375 N, 79.7064 E
Tumsar	Karli	Karli	21.4964 N, 79.6614 E
Mohadi	Betekar Bothali	Betekar Bothali	21.4277 N, 79.5494 E
Mohadi	Dongargaon	Dongargaon	21.3435 N, 79.6563 E
Pauni	Adyal	Adyal	20.7721 N, 79.6058 E
Pauni	Katurli	Katurli	20.9219 N, 79.7623 E
Pauni	Pilandri	Pilandri	20.9300 N, 79.7800 E
Pauni	Nerla	Nerla	20.57 N, 79.41E
Pauni	Konda	Konda	20.52N, 79.41 E
Sakoli	Ekodi	Ekodi	21.1495 N, 79.9395 E
Sakoli	Walmazari	Walmazari	21.1435 N, 79.9948 E
Sakoli	Pindkepar	Pindkepar	21.1304 N, 79.9838 E
Sakoli	Parsodi	Parsodi	21.0563 N, 80.0610 E
Sakoli	Khandala	Khandala	21.0179 N, 79.9710 E
Sakoli	Lawari	Lawari	21.0527 N, 80.0270 E
Sakoli	Umari	Umari	21.0536 N, 80.0416 E
Sakoli	Pathari	Pathari	21.1042 N, 80.0144 E
Lakhani	Wakal	Wakal	20.8940 N, 79.8208 E
Lakhani	Kaneri	Kaneri	20.9930 N, 79.8527 E
Lakhani	Channa	Channa	21.0361 N, 79.8092 E
Lakhandur	Pimpalgaon	Pimpalgaon	20.7559 N, 79.9184 E
Lakhandur	Chapral	Chapral	20.7148 N, 79.9120 E
Lakhandur	Indora	Indora	20.7002 N, 79.9550 E
Lakhandur	Dighori	Dighori	20.8803 N, 79.9458 E
Lakhandur	Dahegaon	Dahegaon	20.8125 N, 79.9133 E

III. RESULTS AND DISCUSSION

The expected outcomes are hypothesized as research is still at the stage of data collection and processing of raw data. At this preliminary stage, SWAT ran with DEM (Fig. 8) for creation of DEM of Bhandara district by using delineated district boundary (Fig. 9 and Fig. 10), Drainage map (Fig. 11), Contour Map (Fig. 12) and sub-basin map (Fig. 13) for Bhandara district.

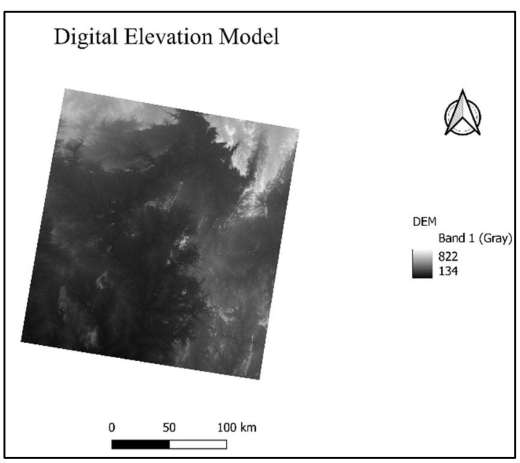


Figure 8. Digital Elevation Model (DEM)

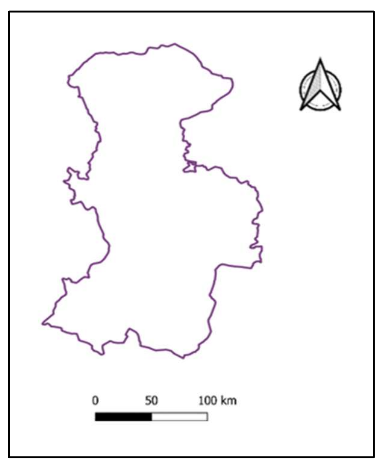
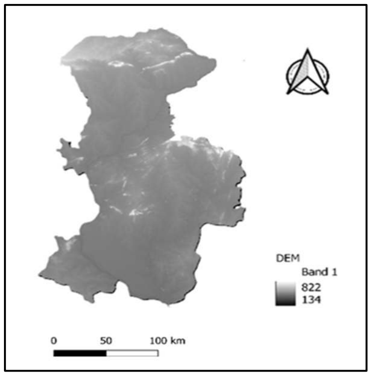


Figure 9. Digitized Bhandara district boundary



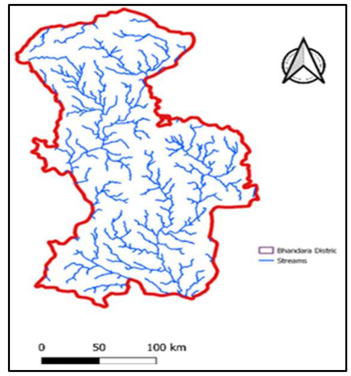
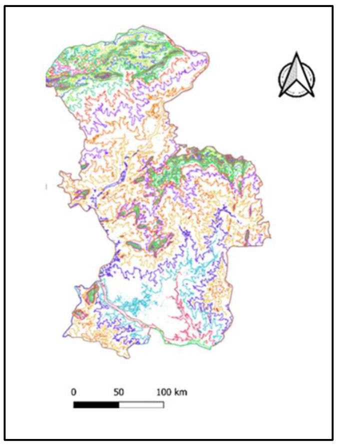


Figure 10. Digital Elevation Model (DEM) of Bhandara district   Figure 11. Drainage Map (SWAT)



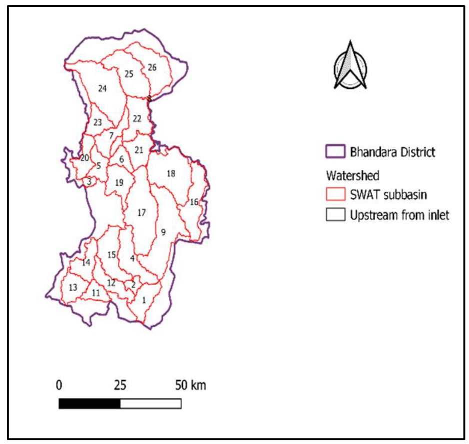


Figure 12. Contour Map (SWAT)   Figure 13. Sub-basin Map (SWAT)

There shall be an increase in groundwater recharge by 10-20%, drought-resistant capacity, and reduced dependence upon deep aquifers. The distribution of excess water in a scientifically interconnected manner may reduce the chances of floods, associated with the guarantee of water availability in the drought periods (Fig. 14, Table IV). Assessments of the system's climate-resilience level with diverse expected emissions shall become easier with the integration of climate projections into the system. Irrigation system improvements leading to improved farm livelihoods, with access to clean drinking water, shall improve food security outcomes.

A. Implications for Policy

The proposed framework is also consistent with the state-level regulations of Maharashtra regarding groundwater and the Indian National Water Policy (2023). The proposed framework is also consistent with SDG Goals 6 and 13 because it promotes local initiatives for eco-hydrological measures.

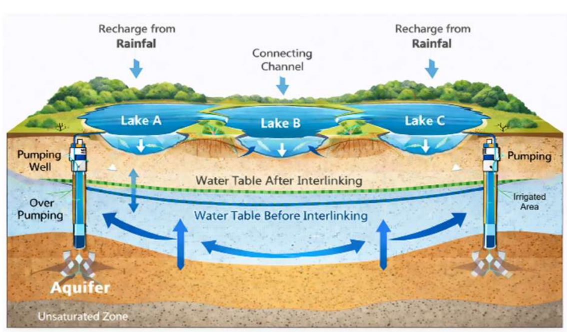


Figure 14. Conceptual schematic diagram showing effects of lake interlinking for groundwater recharge

TABLE IV. ANTICIPATED ALTERATIONS IN GROUNDWATER DYNAMICS DUE TO LAKE INTERLINKING

Hydrological feature	System of isolated lakes (pre-interlinking)	Conceptual interconnected lake system
Connectivity of surface water	Lakes operate on their own	Lakes operate as a network
Aquifer-lake interaction	Restricted to nearby seepage areas	System-wide distributed recharge
Timing of recharge	Temporary and seasonal	Continual and multi-seasonal
Pattern of groundwater flow	Regional and uneven	System-wide and integrated
Reaction of the water table	Gradual deterioration	Stability or partial recovery
Water availability during the dry season	Regular desiccation of lakes	Increased surface water persistence
Pumping responsiveness	High drawdown in the nearby area of wells	Decreased drawdown as a result of recharge backing

IV. CONCLUSION

The cumulative effects of unpredictable rainfall and heavy water use are putting more strain on Bhandara's groundwater resources. Depletion of groundwater is a reflection of both human and climate stress. Linking lakes with SWAT, RS, and GIS support provides a reliable model for improving recharge. By improving surface water accumulation and underground flow, the analysis demonstrates that connecting existing lakes by means of scientifically based design can improve groundwater recharge. A workable solution for increasing water availability in the face of shifting climate conditions is to combine conventional lake systems with modern hydrological and geospatial methods. In India's lake-dominated and water-stressed areas, this strategy provides a flexible and sustainable framework for managing water resources.

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REFERENCES

[1] IPCC, "Climate Change 2021: The physical science basis," Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (V. Masson-Delmotte, P. Zhai, A. Pirani, et al., Eds.). Cambridge, U.K.: Cambridge University Press. https://doi.org/10.1017/9781009157896

[2] K. S. Meshram and M. S. Kadu, "Interlinking of Lakes to Combat Impacts of Climate Change," IOP Conf. Ser.: Earth Environ. Sci. 2023, 1193. https://doi.org/10.1088/1755-1315/1193/1/012012

[3] J. S. Famiglietti, "The global groundwater crisis," Nature Climate Change, 2014, 4(11), 945–948. https://doi.org/10.1038/nclimate2425

[4] P. N. Rajankar, D. H. Tambekar and S. R. Wate, "Groundwater quality and water quality index at Bhandara District," Environmental Monitoring and Assessment, 2011, 184(4), 2209–2218.

[5] M. Rodell, J. S. Famiglietti, D. N. Wiese et al., "Emerging trends in global freshwater availability," Nature, 2018, 557(7707), 651–659. https://doi.org/10.1038/s41586-018-0123-1

[6] Central Ground Water Board, "National compilation on dynamic ground water resources of India, 2023," Ministry of Jal Shakti, Government of India. https://cgwb.gov.in/cgwbpnm/public/uploads/documents/17056512151889452705file.pdf

[7] M. K. Dhavalikar, "Cultural heritage of Maharashtra: Studies in archaeology, art and architecture," New Delhi, 2012: Aryan Books International.

[8] N. S. Kudnar, N. L. Kushwaha, and M. Rajashekhar, "Impact of rainfall and groundwater on agricultural crops and drinking water in the Bhandara District, India," 2024, Springer. https://doi.org/0.1007/978-981-97-8363-2_11

[9] S. R. Kashiwar, U. R. Dongarwar, and M. C. Kundu, "Statistical evaluation of rainfall time series in concurrence with groundwater resources of Bhandara District, Central India," 2022, Academia.edu, https://doi.org/10.1007/s40340-022-00201-9

[10] G. A. Gaurkar, "Groundwater levels in Bhandara District: Status, challenges, and management strategies," Journal of East-West Thought, 2025, 15(2), 55–68. https://doi.org/10.7492/7cp65b15

[11] Groundwater Surveys and Development Agency (GSDA), "Groundwater level and quality assessment report: Bhandara District," 2024, Government of Maharashtra, Pune.

[12] D. Pandey, "Environmental vulnerability of Bhandara and Gondia districts of Maharashtra State, India," Proceedings of the National Seminar on Water & Environment., 2011.