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Spatio-Temporal Analysis of Water Resources and Population Trends in Marathwada, Maharashtra

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Abstract: ***Climate variability, unsustainable agricultural practices, and overexploitation of groundwater resources - the main causes of the severe and worsening water crisis in Maharashtra's drought - prone Marathwada region. With an emphasis on fickle rainfall patterns, rising drought frequency, and the prevalence of water - intensive crops like sugarcane that intensify water scarcity, this study offers a thorough assessment of the region's water resource problems. The socioeconomic effects, such as agricultural hardship and an increase in farmer suicides, are also highlighted in the paper. This study looks at the success of the Jal Shakti Abhiyan campaign, which encourages rainwater harvesting, watershed development, and community - based water management as sustainable solutions and uses insights from the nearby Vidarbha region. Better awareness, technical training, aquifer regulation, irrigation efficiency, crop diversification, and climate adaptation planning are a few of the practical suggestions made by the study.***

Keywords: Marathwada, Groundwater Depletion, Drought, Water Management, Vidarbha, Rainwater Harvesting, Spatio - Temporal Analysis

1. Introduction

The Indian state of Maharashtra contains the Marathwada region, which has a history of water stress and drought. Its water profile has been sullied over the past few decades by fluctuating monsoons, diminishing groundwater levels, and rising demand brought on by urbanization and agricultural growth. In order to highlight important trends, pinpoint underlying causes, and emphasize the necessity of efficacious intervention, this paper analyses the water situation in Marathwada using quantitative data from surveys and projections.

2. Study Area

2.1 Latitudinal Profile

Marathwada is a major component of the upper Godavari River basin and holds a central geographic position within the state of Maharashtra. Geographically, it is located between latitudes 17° 35' N and 20° 41' N and longitudes 74° 40' E and 78° 16' E. Marathwada's central location in peninsular India adds to its significance as an agroclimatic and socio - economic zone.

The region has a relatively compact and elongated territorial shape, spanning a vertical North - South stretch of about 330 kilometres and a horizontal East - West extent of about 395 kilometres. With a total area of 64, 434 square kilometres, Marathwada is a significant administrative and planning unit that makes up around 20.95% of Maharashtra's overall geographic area.

The region is situated in a zone of climatic transition, bestriding the drier interior zones to the east and the relatively wetter western regions. Since many of the rivers, streams, and watershed areas that make up the Godavari system originate or pass through this area, its location in the upper Godavari basin further emphasizes its hydrological significance. Geological limitations, topographical difficulties, and an uneven and restricted distribution of rainfall limit the region's hydrological yield despite its potential.

Additionally, the region's semi - arid climate and increased temperature variability are influenced by its latitudinal location. It receives less rainfall due to its proximity to the tropic zone and its position in the Western Ghats' rain shadow, but the vast plateau terrain encourages drastic seasonal temperature variations.

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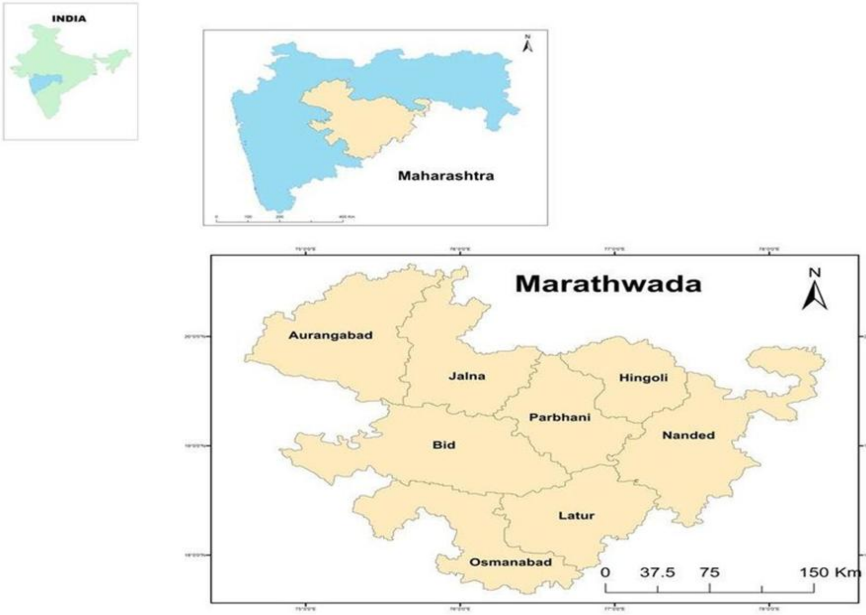

Figure 1: Location of Marathwada

2.2 Physical Profile

Marathwada, also called the Aurangabad Division of Maharashtra, is bounded to the south and southeast by the Indian states of Telangana and Karnataka. The Maharashtra divisions of Vidarbha, Nashik, and Pune geographically enclose it. Its climatic and hydrological profile is greatly influenced by its location within the rain shadow zone of the Sahyadri (Western Ghats) and Ajanta Mountain ranges, which makes it vulnerable to frequent droughts and water scarcity.

Basaltic formations from the Deccan Traps dominate the physiographic terrain of Marathwada, which forms a part of the Deccan Plateau. The deep black cotton soil that results from the weathering of these basaltic rocks is nutrient - rich and conducive to agriculture. Nonetheless, there are significant regional variations in the properties of the soil. Although the deep, moisture - retaining black soil of much of Marathwada is advantageous, some talukas (sub - district level administrative units), such as Udgir, Ausa, and Ahmedpur in the Latur district, have lower - quality soil. These soils become compacted and hard during extended dry spells, which reduces their permeability and hinders groundwater recharge and rainwater percolation. Water scarcity is made worse in these places by the combination of steep terrain and low infiltration capacity.

Cotton, sugarcane, soybeans, wheat, turmeric, and various pulses are among the main crops grown in the area, which is primarily an agricultural area. The production of crops that require a lot of water, like sugarcane, is especially problematic because it puts a great deal of strain on the already scarce water supplies. Water demand is further increased by the numerous water - intensive industries that are located in Marathwada in addition to agriculture, particularly sugar mills and cotton processing facilities.

Marathwada is located in the semi - arid tropical zone. Extreme weather is common in the area; summer highs in May can reach 43°C, while winter lows in December can drop to about 11°C. The monsoon season, which runs from June to September, sees the majority of the year's rainfall, which varies greatly. For example, Parbhani experiences about 48 rainy days with an average of 890 mm of rainfall per year. However, because of its location in the Western Ghats' rain shadow, Marathwada typically receives between 600 and 700 mm of rainfall.

Marathwada's southern plateau has an average elevation of about 381 meters above sea level. Together with unpredictable rainfall patterns, this high terrain makes the area more susceptible to drought and makes it more difficult to manage water resources effectively and recharge aquifers.

2.3 Political Profile

The Marathwada region is a significant historical and administrative division of the Indian state of Maharashtra. Jalna, Aurangabad, Parbhani, Hingoli, Nanded, Latur, Osmanabad, and Beed are its eight districts. The divisional headquarters and the region's main administrative centre are both located in Aurangabad. Tehsils, also known as talukas, are sub - district - level administrative units for governance, resource distribution, and statistical tracking. These eight districts are further subdivided into 76 tehsils.

Every district in Marathwada has distinct economic, geographic, and demographic traits. In contrast to Beed and Osmanabad, which are still primarily agrarian districts, Aurangabad and Nanded are more urbanized and industrialized. Latur has a noteworthy history in education and cooperative movements, while Jalna is renowned for its seed industries.

Oilseeds and pulses are grown in the central agricultural zones of Hingoli and Parbhani. Although these districts collectively create a strong sense of regional identity, they also face a variety of difficulties with regard to population distribution, agricultural practices, and the management of water resources.

In terms of administration, the Marathwada region is essential to state - level planning and governance. The 76 tehsils play a key role in the execution of water conservation projects, drought relief programs, and rural development plans. More localized data collection, decision - making, and focused policy interventions are made possible by this decentralized structure, which is particularly crucial for handling the intricate water - related problems that the area faces.

3. Research Objectives

a) To evaluate the Marathwada region's water resource availability's temporal and spatial dynamics.
b) To examine the patterns of water resource distribution and sector - wise use
c) To investigate the connection between drought occurrence and agricultural practices
d) To determine and assess suitable water management technologies for semi - arid areas
e) To suggest the Vidarbha area as a template for water - saving techniques in similar agroclimatic zones

4. Research Methodology

In order to evaluate the spatiotemporal trends in the availability of water resources and demographic shifts in the Marathwada region, this study uses a quantitative, data - driven methodology. The study mostly uses secondary data sources, such as

- Census data (2011) to examine trends in urban - rural distribution and population growth
- Records from the Groundwater Surveys and Development Agency (GSDA) used to evaluate trends in groundwater depletion.
- Meteorological data to analyse climate conditions and rainfall variability
- Indexes derived from remote sensing, like the Vegetation Health Index (VHI), used to track vegetation stress and the severity of drought.
- Marathwada Water Supply Master Plan of Maharashtra Jeevan Pradhikaran (MJP)

The components of demographic growth, the population's spatial distribution, and the sensitivity of water consumption patterns under various growth scenarios are all examined with the aid of these projections.

5. Marathwada

5.1 Population profile

As per the 2011 census, Marathwada has a total population of 1.87 crore. The region has experienced significant demographic changes over recent decades, particularly in the urban - rural composition.

Table 1: Decadal urban and rural population increases 1981 - 2011

Category	1981	1991	2001	2011
Urban Pop	1,978,281	3,042,564	4,140,433	5,072,074
Rural Pop	7,750,501	9,919,559	11,488,815	13,659,798
Urban/Rural (%)	26%	31%	36%	37%
Urban/Total (%)	20%	23%	26%	27%
Rural/Total (%)	80%	77%	74%	73%
Total Pop	9,728,782	12,962,123	15,629,248	18,731,872

Over the three decades between 1981 and 2011, Marathwada's rural and urban populations have steadily increased, as Table 1 illustrates. Nonetheless, the rate of urban population growth has been noticeably higher, indicating a slow but noticeable urbanization trend. Rural - to - urban migration brought on by industrialization, improved job prospects, and urban infrastructure development may serve as the push factors of this change.

Table 2: Urban and rural population projections for decades 2020 - 2050

Category	2020	2030	2040	2050
Urban Pop	62,35,933	77,87,787	97,12,180	1,20,62,224
Rural Pop	1,53,10,988	1,75,48,418	2,02,50,393	2,34,85,454
Urban/Rural (%)	41%	44%	48%	51%
Urban/Total (%)	29%	31%	32%	34%
Rural/Total (%)	71%	69%	68%	66%
Total Pop	2,15,46,921	2,53,36,205	2,99,62,573	3,55,47,678

According to the data in Table 2, Marathwada's urban population is predicted to grow by an astounding 93% between 2020 and 2050, while the rural population is predicted to grow by 53% during the same time frame. Urban areas have an average annual growth rate of 2.5%, while rural areas have an average growth rate of 1.5%. These numbers show the pressure that urban centres will continue to face in the future with respect to housing, public infrastructure, and water supply.

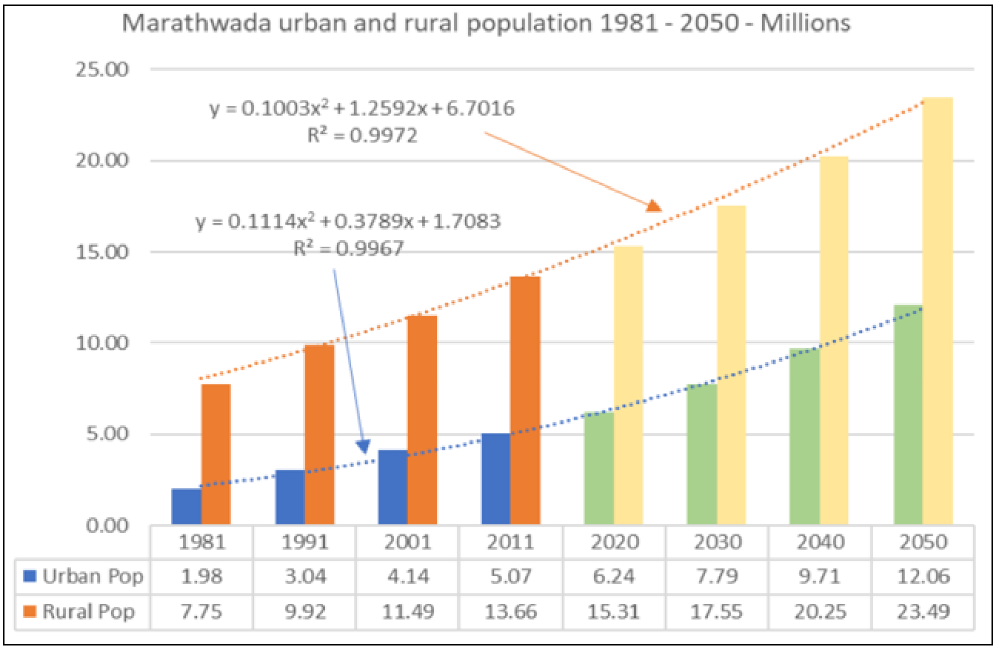

Figure 2: Marathwada - past and projected figures of urban and rural populations 1981 - 2050 (colours yellow and green in figures 1 - 3 represent projections)

Figure 2, which depicts the historical and anticipated population distribution from 1981 to 2050, provides a visual representation of this disparity between urban and rural growth. The trend line indicates that the population gap between rural and urban areas is closing, and if current trends continue, there may be a demographic equilibrium by 2050.

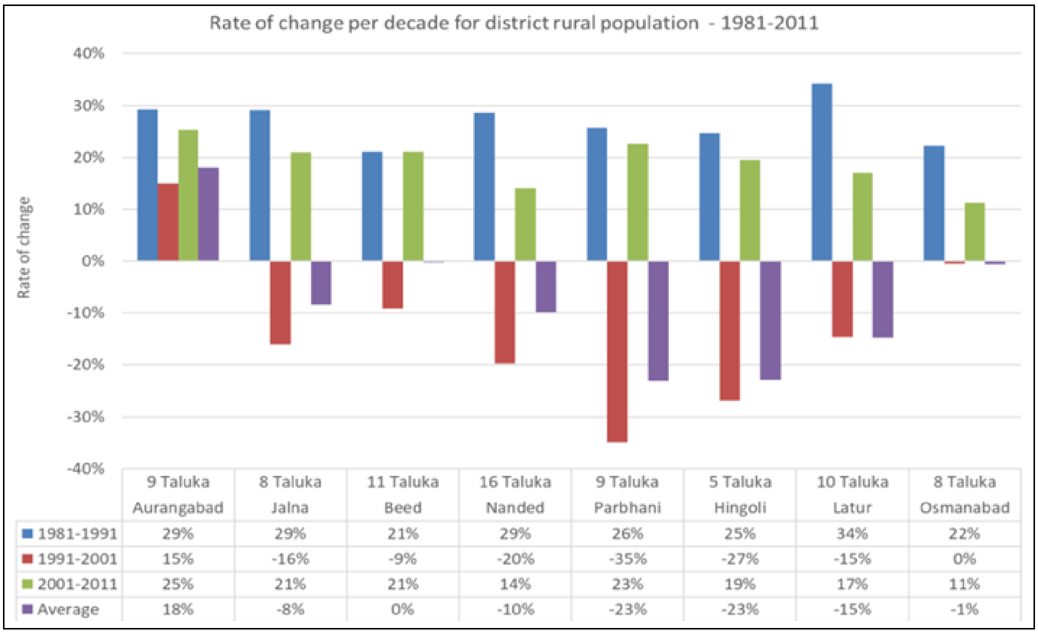

Figure 3: Growth rate in rural population, per district, for the period 1981 - 2011

Figure 3, which plots the percentage increase across different districts for the years 1981 to 2011, offers a detailed look at rural population growth at the district level. Localized planning for water resources can be initiated with the aid of the analysis of Marathwada regions, as shown above, that are subject to identify as comparatively greater demographic pressure zones.

Table 3: Urban and rural population projections - relation

	2020	2030	2040	2050
Urban Pop	62,35,933	77,87,787	97,12,180	1,20,62,224
Rural Pop	1,53,10,988	1,75,48,418	2,02,50,393	2,34,85,454
Urban/Rural (%)	41%	44%	48%	51%
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Total Pop	2,15,46,921	2,53,36,205	2,99,62,573	3,55,47,678

Table 3 provides a comparative review of the anticipated demographic trends, which highlights the differences between rural and urban growth patterns for the future.

In conclusion, Marathwada is experiencing rapid urbanization and a substantial demographic shift. The need for integrated, forward - looking water resource planning that caters to both rural and urban populations is all the more important now.

5.2 Water Profile

The dynamics of the Indian monsoon have a significant impact on the Marathwada's water profile. After emerging from the Indian Ocean, monsoon clouds travel north - eastward after entering India via Kerala. The Konkan region along the coast experiences heavy precipitation because the clouds are blocked by the Sahyadri ranges as they approach Maharashtra. As the monsoon moves into the rain - shadowed interior of Maharashtra, including Marathwada, it loses moisture as it crosses the Ghats, resulting in much less rainfall.

A sharp decline in groundwater levels in Marathwada has been visible due to uncontrolled extraction.70 out of 76 talukas reported a drop in groundwater tables, with more than 25 talukas reporting drops of more than two meters, according to the Groundwater Surveys and Development Agency (GSDA).

In talukas with low soil permeability, like Udgir, Ausa, and Ahmedpur, where water percolation is inherently limited by compact soil and topographic steepness, this depletion is most severe.

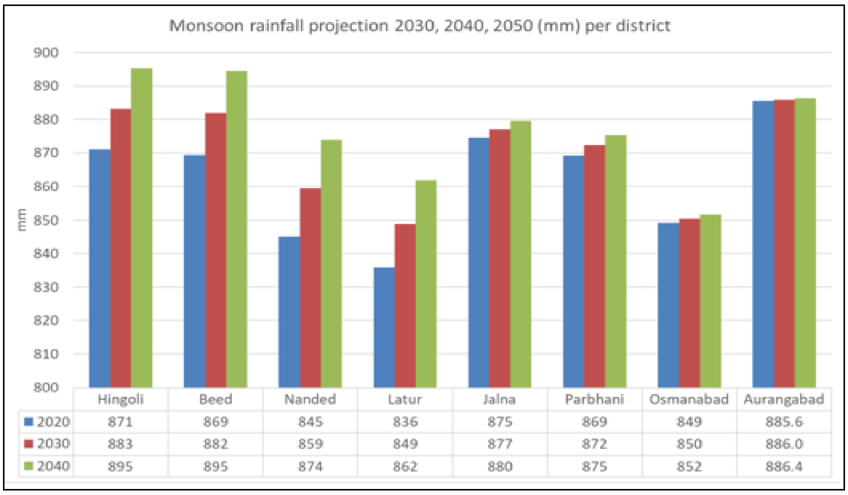

Figure 4: Average monsoon rainfall projections per district

Table 4: Projected increase in monsoon rainfall per district for the years 2030, 2040 and 2050.

			Projected Increase in Monsoon Rainfall (% increase from baseline)			Projected Monsoon Rainfall (mm)		
#	District	Normal Monsoon Rainfall for Marathwada (mm)	2030	2040*	2050	2030	2040*	2050
1	Hingoli	708.8	22.9	24.6	26.3	871	883	895
2	Beed		22.65	24.425	26.2	869	882	895
3	Nanded		19.22	21.26	23.3	845	859	874
4	Latur		17.93	19.765	21.6	836	849	862
5	Jalna		23.4	23.75	24.1	875	877	880
6	Parbhani		22.64	23.07	23.5	869	872	875
7	Osmanabad		19.8	19.98	20.16	849	850	852
8	Aurangabad		24.95	25	25.05	886	886	

The average monsoon rainfall forecasts by district are shown in Figure 4. According to these forecasts, the region may experience an unequal rainfall distribution, which could have a substantial impact on surface and groundwater recharge.

Table 4, which displays gradational projected increases in monsoon rainfall for the years 2030, 2040, and 2050, provides more information. Despite being encouraging, these increases are counterbalanced by uneven distribution and growing dry spells.

Table 5: Rural water demand and supply projections 2020 - 2050

		2020	2030	2040	2050
Demand Year	(Mm³)	224	352	407	471
Supply Year (Mm³)	(Mm³)	257	402	459	528
Supply Day Max	(Mm³/day)	0.85	1.32	1.51	1.74

Table 6: Urban water demand and supply projections 2020 - 2050

		URBAN			
		2020	2030	2040	2050
Demand Year	(Mm³)	263	334	435	543
Supply Year (Mm³)	(Mm³)	302	381	491	608
Supply Day Max	(Mm³/day)	0.99	1.25	1.62	2

According to Table 5, Marathwada's rural water demand will increase gradually as a result of population expansion and agricultural demands, but the supply would not be able to keep up. The disparity widens by 2050, particularly in regions with groundwater stress. Rural water insecurity will increase in such conditions.

Due to rapid urbanization, Table 6 shows a more pronounced increase in urban water demand, which is expected to nearly double by 2050. Even though supply capacities are predicted to increase, they still fall short of demand, which raises the possibility of shortages in cities as well.

Both tables demonstrate growing deficits, and unless major interventions are put in place, critical shortfalls are anticipated after 2035.

Table 7: District - wise water demand projections for 2020 - 2050 (in M3)

District Name	2020	2030	2040	2050
Aurangabad	18,14,39,339	23,84,48,730	29,84,51,834	37,25,45,004
Jalna	5,25,90,536	7,15,61,079	8,42,73,604	9,87,35,657
Beed	6,86,07,899	9,29,27,665	10,62,58,584	11,94,74,869
Nanded	10,30,58,020	13,99,13,427	17,01,21,307	20,68,58,270
Parbhani	5,58,42,037	7,33,41,380	8,60,10,936	9,75,33,872
Hingoli	2,98,89,911	4,00,50,298	4,72,06,460	4,90,10,048
Latur	8,66,68,393	11,39,98,649	13,34,02,400	16,10,94,684
Osmanabad	4,54,52,600	5,96,01,824	6,70,40,164	7,60,39,250
TOTAL	62,35,48,733	82,98,43,051	99,27,65,288	1,18,12,91,655
% increase		25%	16%	16%

Data on water demand by district reveals significant variances that are impacted by industrial presence, cropping patterns, and population density. The water demand estimates in cubic meters (M3) for each Marathwada district from 2020 to 2050 are shown in this table. Significant variation can be seen in the data across districts, which reflects variations in industrial development, agricultural intensity, and population growth. Highest anticipated increases are seen in districts like Nanded and Aurangabad. On the other hand, districts with comparatively moderate growth include Hingoli and Parbhani. These district - by - district water demand projections are helpful for resource allocation and local planning.

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Table 8: Cultivated command area (ha) per season and district – 2017

District	Kharif	Rabi	Summer	Grand Total
Aurangabad	7,54,041	2,00,237	28,961	9,64,331
BEED	7,09,370	3,10,364	4,180	10,23,914
HINGOLI	3,11,838	82,863	1,154	3,95,855
JALNA	5,83,830	1,04,481	9,723	6,98,034
LATUR	5,80,080	2,72,355	1,201	8,53,636
Nanded	7,27,559	1,60,004	3,519	8,91,082
Osmanabad	4,14,509	2,74,336	1,829	6,90,674
Parbhani	5,20,713	2,51,816	5,328	7,77,857
Total	**46,01,940**	**16,56,456**	**55,895**	**63,14,291**
(% from total)	73%	26%	1%	

The largest user of water in Marathwada is the agricultural sector. The cultivated command area (in hectares) by district and season (2017) is shown in Table 9, which accounts for irrigation dependencies and cropping intensities

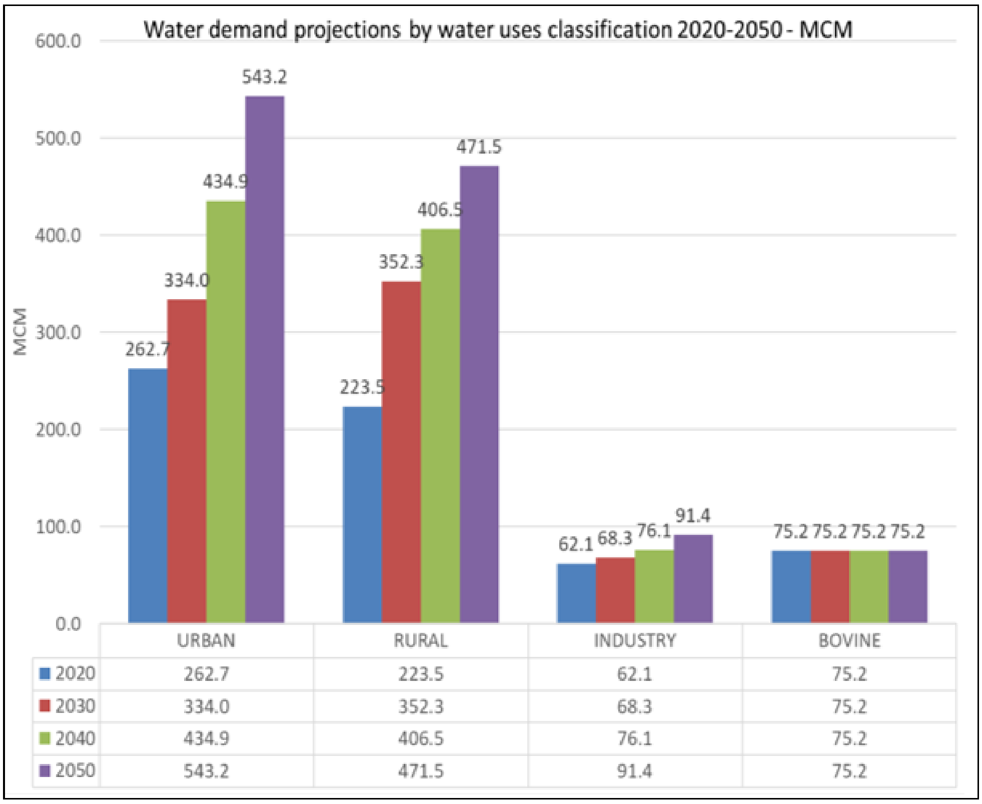

Figure 5: Water demand projection by sector 2020 - 2050

Figure 5 shows the total water demand projection by sector (agriculture, domestic, and industrial) for the same time period, graphically representing sectoral demand forecasts. Because of the region's agrarian economy and reliance on irrigation, agriculture continues to be the largest consumer during this time, holding a dominant share. Although overall demand is still dominated by agriculture, the graph shows that by 2050, domestic and industrial water requirements will have significantly increased. Industrial water demand is growing at the fastest rate, which is indicative of continued industrialization, particularly in urban and peri - urban areas like Latur and Aurangabad. This sectoral shift emphasizes the necessity of diverse water management policies, including encouraging agricultural water efficiency, growing municipal supply networks, and enforcing environmentally friendly industrial water practices.

Table 9: Percentage of water demand projections by sector 2020 – 2050

	2020	2030	2040	2050
Urban	42%	40%	44%	46%
Rural	36%	42%	41%	40%
Industry	10%	8%	8%	8%
Bovine	12%	9%	8%	6%
Sum	100%	100%	100%	100%

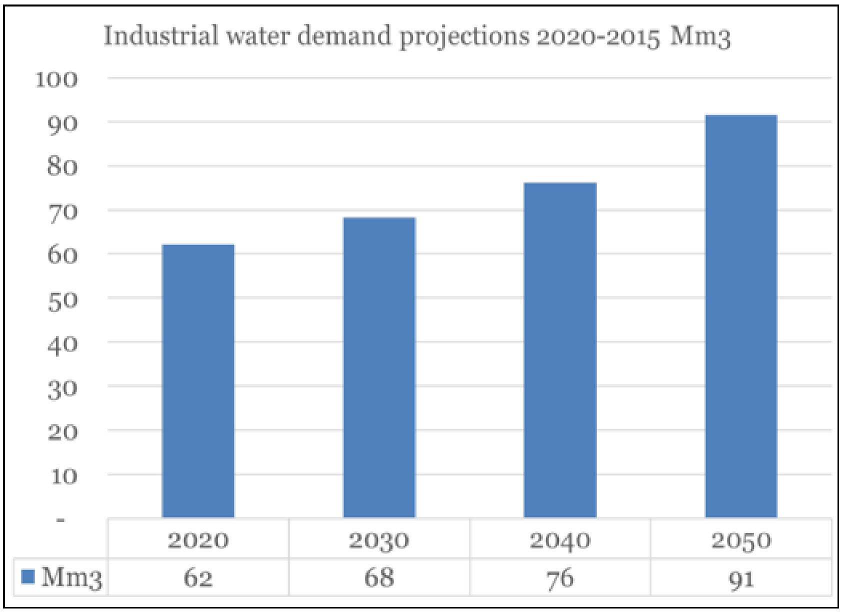

Figure 6: Projected industrial water demand 2020 – 2050

Table 9 displays the percentage distribution of water demand by sector to help visualize proportional pressures in the future. Figure 6 further illustrates the sharp rise in industrial water demand between 2020 and 2050, with reference to analysis of Figure 5.

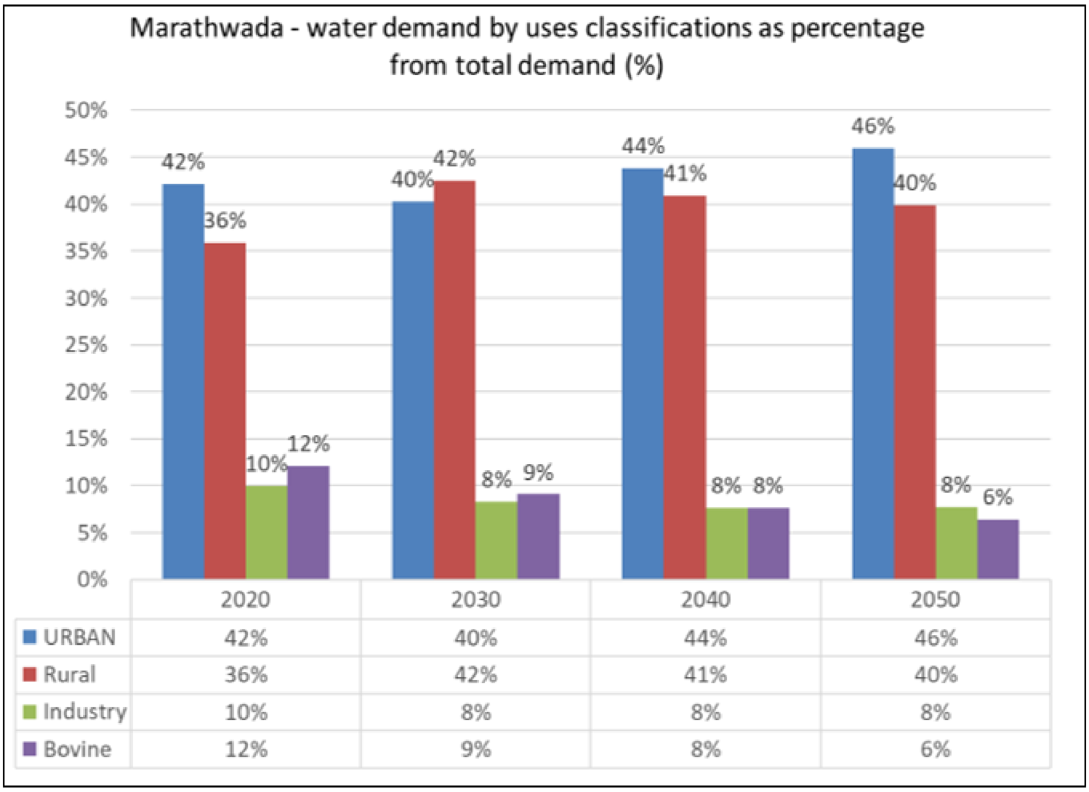

Figure 7: Marathwada - water demand by sector as percentage of total demand (%)

A sectoral breakdown of overall water demand is provided in Figure 7, which supports the idea that agricultural priorities should be balanced with new urban and industrial demands.

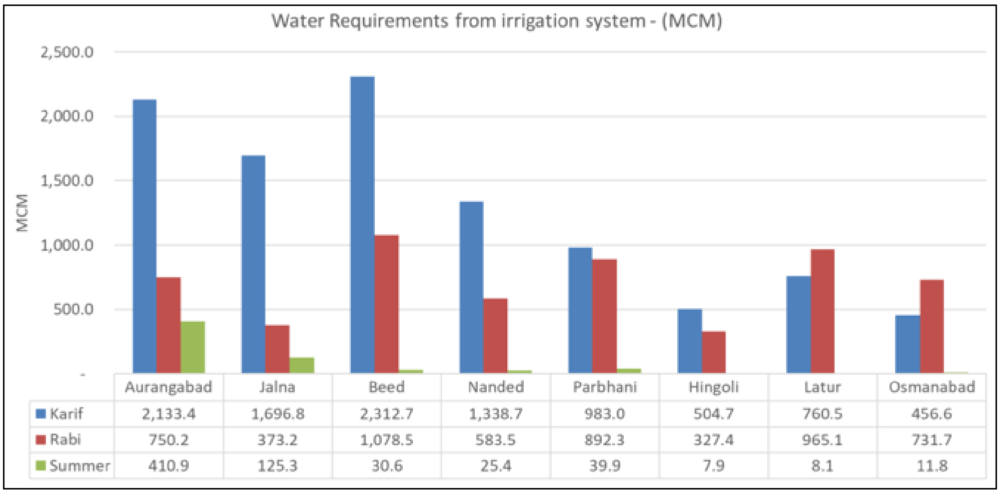

Figure 8: Seasonal Water Requirements from irrigation system - (MM3) per District

Figure 8 reinforces the magnitude of demand during the Rabi and Kharif seasons by displaying the seasonal water requirements from irrigation systems (in MM3) for each district.

Table 10. Projected Irrigation efficiency factor

	Year	2000	2020	2030	2040	2050
Irrigation Efficiency	%	40	43	46	48	51
Increase from Baseline	%	0	3%	6%	8%	11%

A forecast of the anticipated irrigation efficiency factors for the entire region is given in Table 10. According to the data, current efficiency levels are still below ideal, particularly in surface irrigation systems, even though some improvements are anticipated as a result of technological advancements and policy initiatives.

5.3 Agriculture

The largest consumer of water in Marathwada is agriculture, and modern farming methods have made the area's water shortage considerably worse. Water - intensive crops like sugarcane, which need 2, 000 to 3, 000 mm of water per crop cycle—an unsustainable demand given the limited water availability—dominate large areas despite their propensity for drought. Sugarcane cultivation has been further promoted by political incentives, putting tremendous strain on groundwater and surface water supplies. The issue is exacerbated by irrigation inefficiencies, as micro - irrigation methods like sprinkler and drip systems, which can save 30–40% of water when used, are not widely adopted. Ineffective irrigation techniques result in significant water waste and the depletion of already limited resources. Furthermore, the use of bagasse as biofuel for the production of liquor and jaggery releases gases that interfere with monsoon systems, and agricultural practices like shifting cultivation, which involves burning vegetation, have a negative impact on the local climate and rainfall patterns. Marathwada farmers deal with a number of socioeconomic issues, such as declining landholdings, water scarcity, high input costs, a lack of crop diversification, and insufficient support systems like minimum support prices. Since more than 100 farmer suicides were recorded in Beed district alone in early 2024 as a result of these factors, Marathwada has tragically come to represent the economic vulnerability and distress caused by drought in Indian agriculture.

5.4 Drought

As rainfall has decreased and the climate has changed, Marathwada has seen an increase in the frequency and intensity of droughts. More than half of the area has seen moderate to severe drought conditions in the last ten years, with Beed and Osmanabad districts continuously reporting the worst. Rabi crops and overall agricultural productivity are seriously threatened by negative rainfall trends and an increase in the frequency of droughts. From 2001 to 2016, the Vegetation Health Index (VHI), which combines the Vegetation Condition Index (VCI) and Temperature Condition Index (TCI), was used to track the effects of drought on vegetation. The results showed that Marathwada's vegetation health was consistently stressed, particularly after 2000. The years 2002, 2009, and 2015 are critical drought years; in the latter, more than 70% of the region experienced severe drought, one of the worst in decades. Local livelihoods have been severely damaged by these frequent droughts, which have led to crop failures, livestock losses, poverty, and worsening agrarian crises. As a result, socioeconomic vulnerabilities have grown throughout the region.

5.5 Water Crisis

In Marathwada, water scarcity has long been a problem, but during the last four decades, its scope and intensity have significantly expanded. Marathwada was formerly a region with a relatively balanced hydrology, but due to human activities like careless borewell drilling, ineffective irrigation techniques, and disregard for watershed management, the area is currently experiencing severe water stress. The region's inherent climate vulnerabilities have been aggravated by systemic and anthropogenic factors. Compared to other regions of Maharashtra, the region receives substantially less annual rainfall—less than 800 mm—and this rainfall is irregularly distributed, leading to protracted dry spells and inadequate groundwater recharge. The monsoon patterns have become even more unstable due to climate change, causing erratic extremes like prolonged droughts or cloudbursts that don't adequately replenish aquifers. A hazardous water deficit spiral has been produced by the combination of low recharge and highwater withdrawal. Environmental factors also contribute to the crisis: shifting cultivation, which involves burning vegetation, and illegal forest encroachment weaken rainfall and monsoon drafts by lowering the temperature differential between the land and the Indian Ocean. Burning biofuels like bagasse also releases greenhouse gases and sulphur dioxide, which alter the local climate and monsoon intensity. The problems with water availability in Marathwada are made worse by the Indian Ocean's warming, which also lessens temperature contrasts and weakens monsoons and increases extreme weather events.

6. Case Study of Vidharbha

Similar to Marathwada, Vidarbha, a drought - prone area of Maharashtra, has experienced ongoing problems with water scarcity. However, the Jal Shakti Abhiyan, a nationwide initiative to address India's water crisis through sustainable water management techniques, has made Vidarbha its focal point since 2019. This case study examines the main initiatives, achievements, and continuing difficulties of the Jal Shakti Abhiyan in Vidarbha, offering information applicable to water - stressed areas of India.

6.1 Key Features

a) A focus on collecting and storing rainwater on rooftops in both urban and rural areas.
b) Government encouraged installation among homeowners, public institutions, and schools by offering incentives and requiring rainwater harvesting for large buildings.
c) Partnerships between the public and private sectors enabling broad adoption.
d) Restoration of tanks, ponds, and other conventional water features to improve groundwater recharge and water storage.
e) Creation of percolation tanks, check dams, and recharge pits to raise groundwater levels
f) Watershed development initiatives led by the community to enhance soil moisture retention and lower runoff.
g) Tree - planting campaigns to enhance soil health and local climate regulation.

6.2 Nagpur Municipal Corporation (NMC):

a) Out of approximately 705, 000 properties in Nagpur city, only a few thousand have installed functional rainwater harvesting systems.
b) The NMC offers a 5% property tax rebate to incentivize adoption of rainwater harvesting systems and this has led to almost 1, 363 properties, benefited by 2024.
c) In collaboration with international partners, the Nagpur Smart City Project has implemented IoT - enabled rainwater harvesting systems in municipal schools. These systems provide real - time groundwater level monitoring, making Nagpur a pioneer in integrating

Internet of Things (IoT) technology for water conservation.

6.3 Amravati Municipal Corporation (AMC):

a) The AMC has actively promoted awareness campaigns, workshops, and public discussions to encourage RWH adoption.
b) Simplified permitting processes have made it easier for residents to install rooftop systems.
c) Many schools are reducing pressure on municipal water supplies by collecting rainwater for non - potable uses like toilet flushing and gardening.
d) A success story is that of the Jarida Village Ashram School in Amravati, which installed rooftop rainwater harvesting systems in 2022, significantly improving water security during dry periods.

6.4 Challenges

a) Due to lack of awareness, funds and technical knowledge, widespread adoption of rainwater harvesting still remains limited.
b) Expenses of integration of advanced technology like IoT are high, also requiring capacity building at the local level.
c) Limited coordination between government bodies, private partners, and communities proves to be a hindrance to sustenance and expansion of water conservation efforts.

Vidarbha's participation in the Jal Shakti Abhiyan offers important insights on how to tackle water scarcity through the application of comprehensive water management strategies. Combining rainwater harvesting, watershed development, afforestation, technological innovation, and public engagement creates a robust framework that other drought - prone regions can implement to improve their agricultural resilience and water security.

7. Recommendations for Similar Areas

1) Run comprehensive community education initiatives to inform locals about the value of watershed management and rainwater harvesting (RWH).
2) To avoid inefficiency, establish routine inspection and maintenance procedures for the current RWH and recharge systems.
3) Provide sufficient staff and resources to municipal authorities so they can carry out compliance inspections efficiently.
4) Use scientific aquifer mapping to gain a precise understanding of groundwater resources.
5) To stop overuse and depletion, implement licensed, regulated groundwater extraction.
6) Increase agricultural water use efficiency by expanding technical training and subsidies for micro - irrigation techniques like sprinkler and drip systems.
7) To increase drought resilience, encourage farmers to switch from water intensive crops, like sugarcane, to crops that require less water, like oilseeds, pulses, and millets.
8) Include village - level committees and local gram sabhas in water budgeting, conservation planning, and monitoring.
9) Encourage public - private collaborations to increase the development of infrastructure.
10) Install real - time groundwater monitoring systems that provide data to the general public, promoting openness and well - informed decision - making.
11) Promote the use of technologies like the IoT - enabled water management systems that Vidarbha has seen.
12) Create regional climate adaptation plans to increase resistance to extreme weather and rainfall fluctuations.

8. Conclusion

The current water crisis in Marathwada is the result of the complex relationship between anthropogenic pressures, unsustainable farming practices, and climate variability, resulting in worsened drought and agricultural distress. The case of Vidarbha, Maharashtra, demonstrates how the Jal Shakti Abhiyan's efficacious interventions which intertwined rainwater harvesting, watershed development, community engagement, and technological innovation, have successfully mitigate water scarcity issues. Similar multifaceted strategies that emphasise climate resilience, efficient water use, awareness, and enforcement can aid Marathwada in achieving sustainable water security and agricultural stability. Extensive water resource management based on scientific understanding, equipped with community engagement, is essential to resolving the region's water crisis and improving livelihoods in the concerned drought - affected area.

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