Identifying water poverty hotspots in the state of Maharashtra, India

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ABSTRACT
The emerging global consensus that water shortage is attributed to lack of means rather than merely resource availability highlights the unequal access and distribution of water. India faces a similar situation with visible, ongoing water scarcity, affecting millions of people every year. Since the last decade, the condition has worsened unprecedentedly in various States, including Maharashtra, the wealthiest Indian state. Almost half of the state has to endure water crisis, particularly during the summers. Estimating comprehensive Water Poverty appears a critical policy tool for efficient water management. Considering the above, this work proposes the application of the Water Poverty Index (WPI) to estimate the degree of water scarcity in the state of Maharashtra, India. Different components of WPI can be aggregated into a composite index using principal component analysis and combining this information with Geographic Information System (GIS) to illustrate water poverty across the districts of the state. Using secondary data for the five components of WPI, namely, resources, access, use, capacity and environment, the generated index would substantially reflect the link among the hydro-climatic, environmental, and socio-economic aspects affecting accessibility to safe water and poverty alleviation. Such assessment would provide critical information on how some regions are considerably more affected.

1. INTRODUCTION

Water plays a very prominent role in our lives, which helps maintain hygiene and healthy surroundings and promotes various productive processes. Nevertheless, water has become one of the most stressed natural resources over the years, and United Nations has proclaimed water as an increasingly stressed resource. The fundamental in discussing water scarcity is its availability i.e., the scarcity of readily available water. This issue arises due to spatial and temporal fluctuations in water supply and demand. Different regions have a relative abundance or shortage of freshwater at varying time periods. Hence, water scarcity is essentially a local or regional problem. Inadequate water availability induces loss of human capital (through adverse impact on human health and morbidities) and natural capital (through pollution). Preventing effective utilization of available livelihood resources can lead to poverty. Like other natural resources, water acts as a factor of production, and poverty can be reduced by the efficient allocation of water (Sullivan & Meigh, 2003). Thus, improved water resource management and access to safe water and sanitation are essential for eradicating poverty and building peaceful and prosperous societies (UN World Water Development Report, 2019). India faces an ongoing water scarcity situation, affecting millions of people every year. Since the last decade, the condition has worsened unprecedentedly in various states, including Maharashtra, the wealthiest Indian state. Almost half of the state endures water crisis, particularly during the summers. The looming water crisis along with emphasis on the role of water in fighting poverty has put water issues as the central agenda at various national and international platforms. Thus, estimating comprehensive water poverty appears a critical policy tool for efficient water management. Water poverty, an evolving concept examines the link between socioeconomic aspects affecting accessibility to safe water and its physical availability. Water Poverty Index (WPI) generates result in a single number for better management of water management and poverty alleviation.

The objective of this paper is to estimate the degree of water scarcity in the state of Maharashtra, India using WPI. Different components of WPI can be aggregated into a composite index using principal component analysis and combining this information with Geographic Information System (GIS) to illustrate water poverty across the districts of the state. Using secondary data for the five components of WPI, namely, resources, access, use, capacity and environment, the generated index would substantially reflect the link among the hydro-climatic, environmental, and socio-economic aspects affecting accessibility to safe water and poverty alleviation Further, addressing the water poverty-related policy concerns, proper scale implications in available studies are not comprehensive and conclusive. For example, it is important to ask how multitier governments would address the district level water poverty given water is a state subject. In an attempt to fill this research void, this study proposes assessing the district level water poverty of Maharashtra, India, and mapping the spatial heterogeneity.

2. STUDY AREA

Maharashtra is a state located in the western part of India, occupying a significant portion of the Deccan plateau. The third-largest state with an area of 3,08,000 km^2 and a coastal stretch of 720 km along the Arabian sea to its west. Thirty-six districts of the state are placed in six revenue divisions; Konkan, Nashik, Pune, Aurangabad, Amravati and Nagpur (Economic Survey of Maharashtra, 2020-21). Bounded by the Western Ghats Mountain range, there is a major climatic divide, and the state has varying climates from tropical wet to semi-arid. The coastal districts across the western slopes in the Konkan region receive maximum monsoon rainfall, whereas the districts to the east of the Ghats get scanty rainfall with some parts of the central state and the Marathwada region receiving the lowest rainfall. A few major rivers of the country- Godavari, Krishna, Tapi and Narmada flow through the drier parts of the state. But these rivers are non-perennial and largely rainfed, which wither away seasonally. Maharashtra is the wealthiest state of the country with the largest gross state domestic product (GSDP) and contributes around 15% in All-India nominal gross domestic product (GDP) with the base year 2011-12 with more than 55% sectoral share from Services followed by Industry and Agriculture & allied activities. Nevertheless, the intrastate disparities are contrasting. In this primarily urbanized state, water supply has improved over the years, yet only 50% of the households have access to tap water where only 32% of this water is treated, and less than 42% rural population gets access to drinking water within their premises. However, access does not, by any means, ensure a safe and continuous water supply (Khamebte,2020). Despite substantial rainfall and major rivers flowing through the state, rising population, shrinking surface water bodies due to pollution, declining water quality, and poor water management has accentuated severe water scarcity.

3. METHODS AND MATERIAL

3.1 Water poverty index construction and mapping

WPI fits the concept of an index that measures something indirectly and comprises defined components (Sullivan, 2002). WPI construction has several steps. Figure 1 briefly illustrates the research strategy adopted for the construction of WPI. The paper constructs WPI by aggregating several relevant individual indicators, upon selection of indicators, the linear relationship among indicators in each component has been established. For those indicators which are correlated, a Principal Component Analysis (PCA) has been performed to extract principal components and use them as new variables. Among various methods of normalization, we have used Z-score standardization for individual indictors and a rescaling (min-max) approach to normalize the final composite WPI. Component wise data sources are mentioned in table 1.

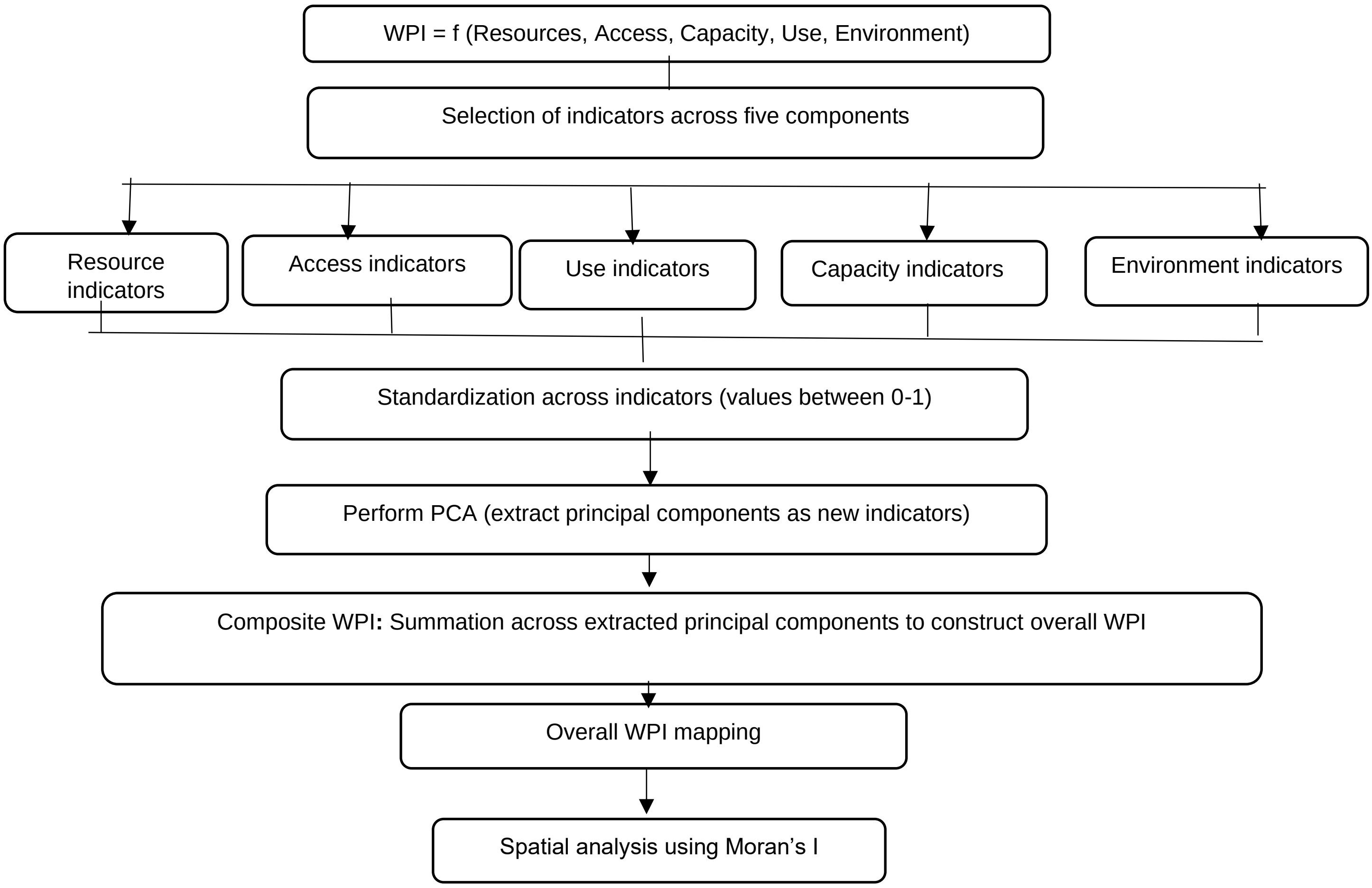

Figure 1: Research Design for WPI

Table 1: Data sources and time period adopted for the study area

COMPONENTS	INDICATOR DEFINITION	INDICATORS	DATA SOURCES	TIME PERIOD
USE	Water consumption by different sectors	Domestic(ha-m) & Industrial(ha-m); U1	Department of Water Resources, R.D. & G.R., Ministry of Jal Shakti, GOI	2017
		Irrigation(ha-m); U2		
ACCESS	Access to safe drinking water	HH with improved drinking water sources (%); A1	National Family Health Survey- 4	2015-16
	Access to in house sanitation	HH with improved sanitation facilities (%); A2		
	Access to Irrigation	Ratio of net irrigated area to net sown area; A3	Department of Agriculture, Maharashtra & Input survey, Agriculture Census, Ministry of Agriculture and Farmers Welfare, India	2016-17
	Time to obtain water (round trip)	Within premises, Less than thirty mins & Thirty mins or longer; A4	National Family Health Survey- 4	2015-16
CAPACITY	Economic	Per Capita Gross District Value Added (GDVA) at constant prices-2011-12; C1	Economic Survey of Maharashtra	2019
		HH with electricity (%); C2		
	Social	Infant Mortality Rate (IMR) (%); C3	District Socio-Economic Review, Directorate of Economics & Statistics, GoM	2020
		Literacy Rate (Age 15-49); C4	National Family Health Survey- 4	2015-16
RESOURCES	Water availability	Variance of Groundwater level(sq.mm); R1	Department of Water Resources, R.D. & G.R., Ministry of Jal Shakti, GOI	2018
		Variance of Surface water (BCM); R2		2000-2020
	Seasonal Variation	Coefficient of variation of Rainfall (30 years); R3		1990-2019
		Evapotranspiration (mm); R4		2018
ENVIRONMENT	Vegetation	Forest Cover (% of Geographical Area); E1	India State of Forest Report, Forest Survey of India, Ministry of Environment, Forest and Climate Change, GoI	2019
	Pollution	Fertilizers used per hectare of cultivable land; E2	District Socio-Economic Review, Directorate of Economics & Statistics, GoM & Department of Agriculture, Maharashtra	2020

4. RESULTS

The water poverty index for thirty-three districts is estimated, and, in this section, we exhibit our findings. WPI score has been generated by aggregating the values of extracted principal components. After applying PCA, our indicators converged into five principal components (PCs). Also, it is necessary to understand the correlation of each variable with all five principal components and can be explained through an unrotated component (factor) matrix. This matrix demonstrates the component loading, which is simply the correlation, for each variable on each component. But unrotated component solution serves only the purpose of data reduction and fails to adequately interpret the variables (Hair et al., 2009). Hence, the components are rotated to enhance their interpretability (OECD,2005). There is no specific rule developed to guide the selection of any rotation technique. Still, with the objective of data reduction and generating a new set of uncorrelated variables, the most widely used technique is the orthogonal varimax rotation method, which is used in this study. The first principal component explains 28.29% of the total variance and has prominent loading from the indicators HH with improved sanitation, average literacy rate, HH with electricity and real GDP per capita. Hence, those districts which have performed poorly require intervention to improve these determinants of water poverty. Likewise, the second principal component explains the subsequent 21.7% of the total variance and receives loadings primarily from the domestic and industrial draft, the coefficient of variance of rainfall, variance of the surface water and consumption of fertilizers. The third principal component describes the next 13.09% of the total variance and has dominant loadings from time to collect water (less than thirty minutes), forest cover and evapotranspiration. The fourth principal component contributes to 8.20% of the total variance and receives major loadings from the variance of groundwater level and access to irrigation. Finally, the fifth principal component explains 8.05% of the total variance and has loadings primarily from HH with improved water sources, time to collect water (thirty minutes or longer) and infant mortality rate. We get the final index reflecting water poverty after aggregating these principal component values and normalizing the final score. The empirical result of this study is presented in table 2. Districts with high WPI scores have a higher degree of water-related poverty and vice versa. Using ArcMap 10.3 version, we illustrate the spatial distribution of water poverty across the state. Figure 2 illustrates the spatial variation in overall water poverty across the districts of Maharashtra.

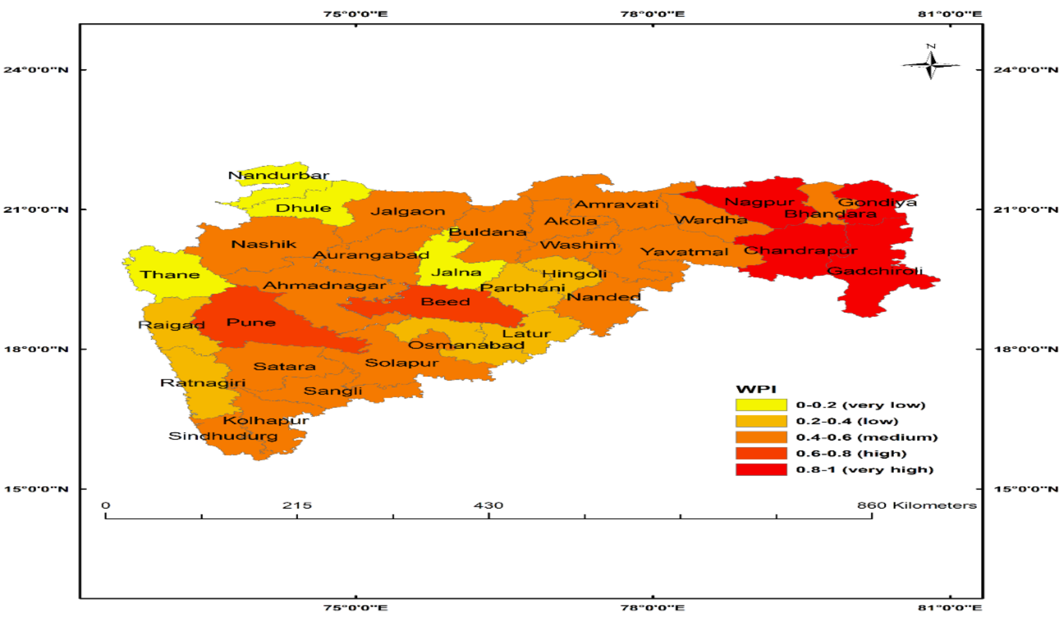

Figure 2: District wise spatial variation of water poverty index across Maharashtra

Table 2: WPI scores for thirty-three districts

Overall WPI (rank)	Very low	Low	Medium	High	Very high
	Thane (30), Dhule (31), Nandurbar (32), Jalna (33)	Nanded (23), Ratnagiri (24), Raigad (25), Latur (26), Hingoli (27), Parbhani(28) ,Osmanabad (29)	Wardha (7), Amravati (8), Yavatmal (9), Satara (10), Kolhapur (11), Sindhudurg (12), Ahmednagar (13), Solapur (14), Jalgaon (15), Buldhana (16), Aurangabad (17), Washim (18), Akola (19), Sangli (20), Nashik (21), Bhandara (22)	Gondia (4), Pune (5), Beed (6)	Chandrapur (1), Nagpur (2), Gadchiroli (3)

Clearly there is a great disparity regarding water poverty across the districts. Overall WPI score for the state of Maharashtra is 0.47, which signifies that the state has performed poorly across all five components of the composite index. Districts are divided into five categories according to their WPI score i.e., very low (0-0.2), low (0.2-0.4), medium (0.4-0.6), high (0.6-0.8) and very high (0.8-1). Out of thirty-three districts selected for our analysis, twenty-one falls into medium to very high categories. This reveals the severity of the water poverty situation in this state.

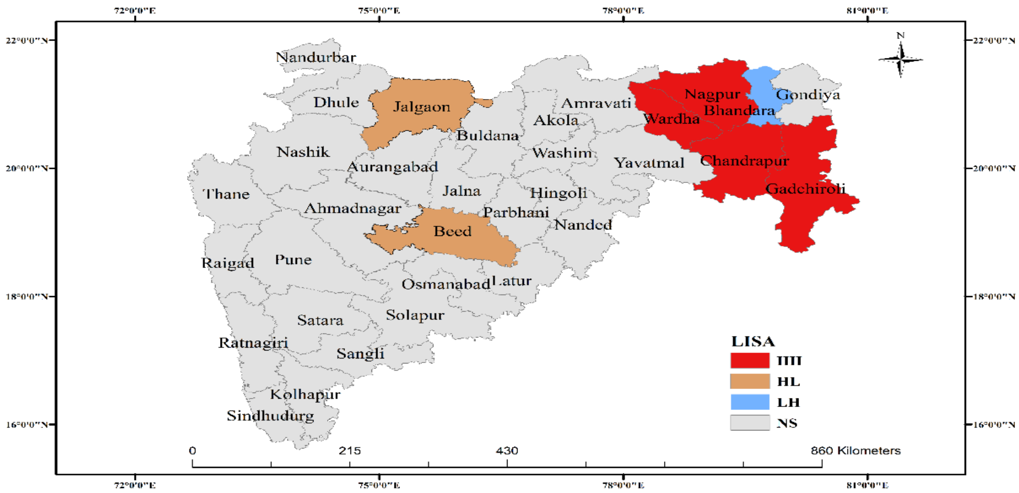

Figure 3: LISA cluster map for the overall WPI in the districts of Maharashtra

Further, we assessed the spatial pattern in the clustering of water poverty across the districts of Maharashtra. Global Moran's I value is found to be positive and statistically significant at the level of p<0.05. A spatial clustering pattern is found for the local spatial analysis with Moran's I value of 0.305. This is reflected in LISA map, figure 3, where most of the high values are clustered around districts reflecting medium to high water poverty, as shown in the overall water poverty index map (figure 2).

5. DISCUSSION

Eleven districts fall into the category of very low and low scores, indicating these districts have performed better than others in terms of water poverty across all five components of WPI.

The districts in the Konkan division, namely Thane, Ratnagiri, Raigad have performed well in the overall WPI except Sindhudurg which has medium water poverty. This division belongs to the north and south Konkan coastal plain agroclimatic zone which is the wealthiest part of the state; along with rich natural resources and abundant rainfall, the region has a share of around 40% in GSDP. These districts have performed well in overall WPI ranks. High forest cover (as % of total geographical area), literacy rate, HH with improved water services and low consumption of fertilizers per hectare of land with low variation in the groundwater level, surface water and rainfall over the years, the region has maintained environment, resource and capacity components. However, progress is required in the improved sanitation facilities and access to irrigation. Similarly, the Pune division has medium to high overall WPI scores across the districts with coverage from the Western Ghat mountain zone to Western plain transition zone II passing through Sub- Mountain transition zone I. In this region rainfall varies from very high to low. Also, the Krishna River, along with most of the west-flowing rivers passing through the area, which are mostly rainfed, the surface water variation is very high leading to inconsistent availability of water for irrigation and other purposes. Overall WPI score ranges from medium to high. The region has high per capita GDP, but the access to electricity and health facilities are below the state average.

Nashik division has primarily tribal-dominated districts, lying around the Western drought prone region with low to medium WPI scores. Major rivers of the state, namely, Godavari and Tapi, flows through this part of the state; however, the physical availability of water is similar to Pune division with high variation in rainfall and surface water. The tribal districts with low literacy have very poor access to sanitation, irrigation and electricity. Similar results are found about Nashik city, where it is in the bottom five cities of India in terms of access to improved water and sanitation facilities resulting in negative impact on overall household productivity (Prabha et al., 2020). More than half of the districts under the medium to high category WPI belongs to the Aurangabad division, which is the Marathwada region of the state and the Vidarbha region, consisting of Amravati and Nagpur divisions. These are the drought-prone and impoverished regions of the state. Seasonal ground water deviation is found to be very high. A large section of the population is engaged in agriculture, producing water-guzzling cash crops such as cotton and sugarcane. Additionally, the rainfall variance in these regions is excessive and are dependent on rainfed rivers to fulfil their water needs, escalating the severity of the water situation. Yavatmal, Buldhana and Akola are parts of the Vidarbha region located in the eastern part of the state, which has India's most backward districts. Districts of the Marathwada and Vidarbha region are known for the simultaneous existence of poverty and drought. During every summer season, these regions are staring at water emergencies with increasing dependence on water tankers to fulfil their water needs. The overall water poverty scenario is the worst in the eastern Vidarbha part of the state, particularly in districts namely Chandrapur, Nagpur, Gadchiroli and Gondiya. Pune and Nagpur are some of the prosperous and highly urbanized districts of the state. Yet, there is a considerable size of the population suffering from water poverty in these urban agglomerations. Prabha et al., (2020) also maintain along the same line that households in Pune walk greater distances to fetch water on a regular day. Nagpur presents unsatisfactory outcome across all the five components of WPI, capturing the grievous situation of water problems in the region. The district has much higher infant mortality rate than the state average along with lower access to improved water and sanitation. However, Jalna and Chandrapur appeared as outliers with extreme scores, which may be due to data constraints. Also, the decent WPI scores by districts located in different parts of the state indicates that not any one factor, such as resource availability, income level or access to resources, can determine water prosperity.

The major findings of this study contrast with the results by Goel et al. (2020), where Maharashtra appeared as a better performer displaying low to medium WPI; the present work shows that downscaled picture at the district level is significantly different. Maharashtra is facing serious water poverty. Pandey et al., (2022) concludes comparable result using national sample survey data and suggests that Maharashtra falls under the unsafe category in terms of WPI. The current work advocates that along with physical abundance and accessibility to water, improvement in the determinants of capacity and environment are important to tackle water poverty. This coincides with the arguments by Shalamzari &

Zhang (2018) and Goel et al., (2020) stating that while attempting any improvement in water poverty, policymakers must pay attention to these components. There is an extensive economic, social and climatic spatial variation across the state, which has a distinct intrastate impact. This is now an overdue task to look into new ways of water availability which must incorporate the massive spatial and temporal variations in the distribution of water resources in India considering its access as well. (Cronin et al., 2014). Water resource availability should not be treated as the only factor to reduce water stress but its management is necessary. Despite having abundant water resources, a region can be less water secure if it lacks in water management (Yadav & Ibrar, 2022).

6. SUMMARY

The present study uses the concept of water poverty index to understand water stress in the state of Maharashtra, India. The looming water stress in this region indicates substantial use of this resource, affecting resource sustainability with rising possibilities of conflicts. WPI is a systematic and integrated indicator to emphasize water stress. Effective water management requires linkage between water availability, its accessibility as well as capacity to manage safe water from improved sources to meet water demand. This study chooses a set of fifteen indicators under five components to evaluate WPI. Based on the analysis of thirty-three districts of the state, the overall WPI of Maharashtra is 0.47, which implies high water stress. Our result shows that WPI is mainly influenced by access and capacity components, as the extracted factors are primarily dominated by improved sanitation followed by groundwater use for irrigation and infant mortality rate. Since around fifty per cent of the population is dependent on agriculture, improvement in water availability for agriculture throughout the year and fair distribution might help reduce water poverty. Simultaneously, the development of access facilities through capacity building by improving literacy rate, infant mortality rate and income can substantially improve the situation. Apart from this, WPI is also sensitive to environment components. Therefore, the ecological needs of water must be addressed while targeting water poverty. Nonetheless, one of the major constraints of this study is the inability to create this composite index for any one particular year. The unavailability of data for all the five components every year produces such an outcome. Data available in the public domain for a few components are a little old. However, using the available data will be helpful in assessing the existing disparity because forecasting variables or extrapolating them based on previous data may give an ambiguous result. The presence of outliers in the final index such as Chandrapur and Jalna appeared with extreme scores, maybe resulting from data constraints. Some crucial variables like water quality from the resource component are dropped due to the inability to find data for all the districts. Likewise, the limitations of the final WPI index are the index is effective depending on its ability to minimize the loss of information retained in each indicator. Using secondary data, this is a study assessing water poverty across the districts of the state facing crucial water management issues. Thus, the index may not be very exhaustive due to data constraints or certain other limitations, but the results may be helpful to serve the decision-making purpose.

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