Assessment of the Domestic Water Scarcity Using Supply-Demand Balance Index

Dr. Bapu D. Deokar

Associate Professor, Department of Geography, Maharaja Jivajirao Shinde Mahavidyalaya, Shrigonda,413701 MS, India.
Email: *bapudeokar[at]gmail.com*

Abstract: ***Semi-arid regions undergoing rapid urbanization are increasingly vulnerable to domestic water scarcity due to population growth, changing living conditions and limited water resources. Shrigonda, a small town in Maharashtra, is typical in that it experiences seasonal domestic water scarcity due to growing demand and a limited, uneven water supply. Adapting the Supply-Demand Balance Index (SDBI), this research evaluates the domestic water scarcity in Shrigonda wards in 2019 by combining population projections, domestic water demand estimates and monthly water supply data. This study shows that during the water-stressed summer months (March-May), all nine wards experience moderate to acute domestic water scarcity (SDBI values are typically below 0.9 and, in some cases, below 0.6, indicating acute scarcity). By contrast, during the monsoon and post-monsoon seasons, most wards achieve SDBI values of 1 or greater, indicating no water scarcity. Such findings establish significant intra-annual and spatial variations in domestic water supply within the town and the need for measures such as water demand management, augmentation of source supply, and decentralized measures, such as rooftop rainwater harvesting, to enhance domestic water security.***

Keywords: Water scarcity, Water demand, Water supply, Supply–Demand Balance Index

1. Introduction

Water scarcity is a well-known environmental and development issue, caused by a gap between freshwater availability and human water use. International studies indicate that both physical scarcity (limited renewable water resources) and economic scarcity (lack of infrastructure and institutions) restrict sustainable access to good quality water, particularly in water-scarce, semi-arid regions and fast-growing urban areas. Domestic water scarcity, a type of overall water scarcity, relates specifically to the capacity of water supply infrastructure to provide adequate water for domestic use (drinking, cooking, cleaning and sanitation) at an acceptable level of quality and quantity. In India, a rising population, urbanization, and changing consumption patterns have driven an uninterrupted increase in per capita domestic water demand and a decline in per capita water availability over the past few decades. Smaller and medium-sized towns, like those in semi-arid parts of Maharashtra, are especially vulnerable, as they rely on a mix of scarce surface and groundwater, intermittent water supply and limited financial and institutional resources to develop water supply infrastructure. In such towns, domestic water scarcity is not always consistent across seasons and spatial units (wards) due to differences in supply arrangements, distribution issues and settlement structure. Shrigonda town in Ahilyanagar district, Maharashtra, is located in a semi-arid, drought-prone area where variability in the monsoon, over-pumping of groundwater, and growing water demands have collectively heightened the threat of domestic water scarcity. The town's municipal water supply must cater to the increasing population and shifts in domestic water demand, which together place strong demands during the summer water-stress months. It is important to understand the spatial-temporal variation in domestic water scarcity at the ward level to design appropriate interventions and prioritize investments in water supply and demand management. This paper uses the Supply-Demand Balance Index (SDBI) to quantify the balance between domestic water supply and demand at the ward level in Shrigonda. This article seeks to assess the extent and variation in levels of domestic water scarcity and to draw out the implications for water management.

2. Study area

In the present study, Shrigonda town is the study area, located between 18° 36' 48" North latitude and 74° 42' 00" East Longitude, with an average altitude of 552 meters. It comprises nine wards covering 79 square kilometers. It consists of Gavthan (old town), a suburban area (yellow zone), and a green zone. It has a population of 32000 (Census, 2001), a projected population of 40653 in 2019, and 7553 constructions (residential and commercial) as per Google Images of 2019. It is a drought-prone area of Maharashtra located south of Ahilyanagar City. The average rainfall is only 536 mm, most of which is received from June to September. Meanwhile, the mean maximum temperature is nearly 30°C in May, and the maximum is 12°C in December.

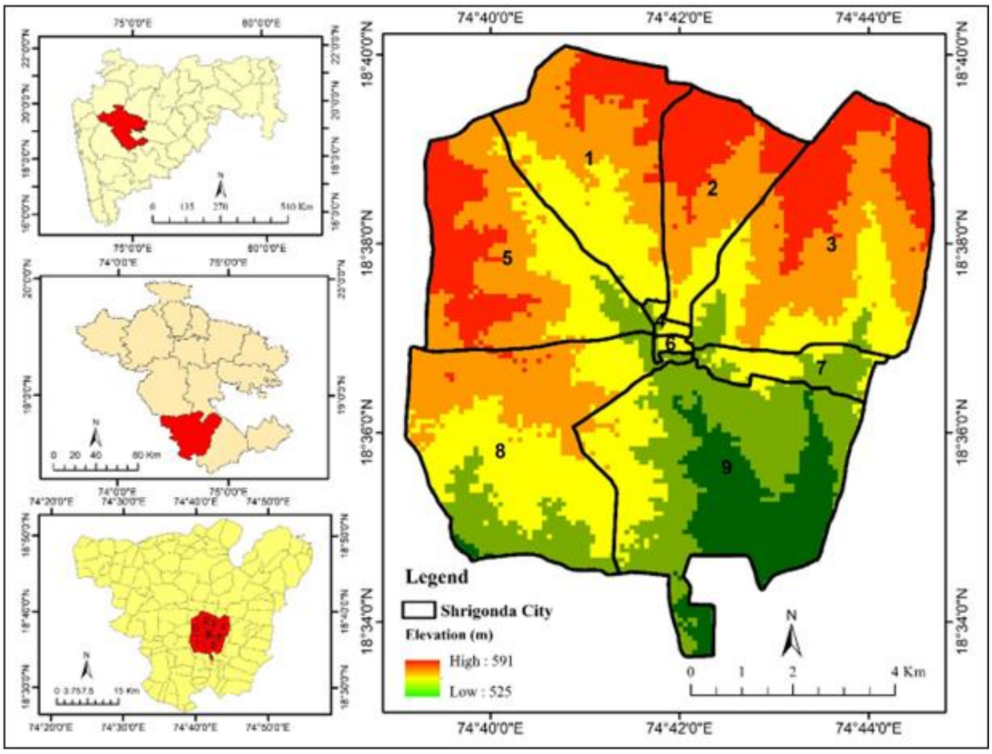

Figure 1: Location of Study Area

3. Database and Methodology

3.1 Database

The assessment of domestic water scarcity in Shrigonda Town combines primary and secondary data. Ward-wise water supply and demand statistics for 2019 are drawn from field surveys and municipal records, which provide monthly estimates of total water supply (TWS) and total water demand (TWD) in cubic meters for each of the nine wards. Projected ward-wise population for 2019 is derived from demographic data and growth rates, allowing Estimation of domestic water consumption and demand at the household level.

3.2 Methodology

To contextualize the analysis and define SDBI categories, the study draws conceptually on the SDBI framework used by Huang and Yin to characterize water scarcity levels, as well as on the domestic water scarcity assessment work of Tariq and Shahrour. Additional scholarly and institutional sources on water scarcity definitions, drivers, and assessment methods inform the broader conceptual framing.

Estimation of domestic water demand

Domestic water demand in each ward is estimated by multiplying the domestic water consumption rate (DWCR) in liters per capita per day (lpcd) by the ward population, then converting the result to monthly volumes. The general expression for monthly total water demand is:

$$TWD_i = \frac{DWCR \times POP_i \times 30}{1000}$$

Where
TWDi = TWD for the ith month in (cubic meters/month)
DWCR = Domestic Water Consumption Rate
POPi = population for the i^{th} year in (per capita)

The DWCR value is derived from household survey data on self-reported water use and is cross-checked against relevant Bureau of Indian Standards recommendations for urban domestic water supply norms.

Calculation and classification of SDBI

The SDBI for each ward and month is calculated using the ratio of TWS to TWD:

$$SDBI_i = \frac{TWS_i}{TWD_i}$$

SDBIi = Supply–Demand Balance Index for the ith year
TWSi = Total Water Supply for the ith year in (cubic meters/year)
TWDi = Total Water Demand for the ith year in (cubic meters/year)

Based on the categorization adapted from Huang and Yin, domestic water scarcity levels are classified according to SDBI ranges: 0–0.3 (extreme water scarcity), 0.3–0.6 (acute water scarcity), 0.6–0.9 (moderate water scarcity), 0.9–1 (slight water scarcity), and ≥1 (no water scarcity). Ward-wise SDBI values and corresponding scarcity levels are then tabulated for all months, with particular emphasis on the water-stress period of March to May. This allows identification of wards facing the most severe domestic water scarcity and facilitates temporal comparison between dry-season and wet-season conditions.

4. Results and Discussion

Water scarcity, defined as an imbalance between water supply and demand, is closely linked to water security. This situation worsens during the dry season, when available surface water and groundwater decline, while demand increases. Domestic water scarcity is a function of the total water supply (TWS) made by Shrigonda Municipality and the domestic water consumption rate (DWCR) in the area. The levels of water scarcity are calculated as follows;

Table 2.1: Domestic water scarcity levels

SDBI Value	SDBI Level
0 to 0.3	Extreme water scarcity
0.3 to 0.6	Acute water scarcity
0.6 to 0.9	Moderate water scarcity
0.9 to 1	Slight water scarcity
≥1	No water scarcity

(Source: Huang & Yin, 2017)

The findings show seasonal and intra-ward differences. The SDBI, which indicates the level of supply relative to demand (where values close to 1 or higher reflect a balance or surplus), is a good indicator of water trends. In the early months (January to May), a clear deficit is seen across most wards. In January, while some wards, like Ward 4 and Ward 6, have near-equilibrium conditions (SDBI ≈ 0.99), most wards experience a slight water deficit, with SDBI values between 0.85 and 0.93. This shortage gradually worsens from February to May. In March and April, the SDBI drops dramatically across all wards, with values ranging from 0.61 to 0.76, reflecting a high level of stress on the water supply. In May, the SDBI is at its lowest (0.54-0.57 in several wards), the time of year when water scarcity is greatest due to high demand and dwindling water sources.

Table 1: Total Water Demand (TWD) and Total Water Supply (TWS) in the Shrigonda Town

Ward No	Projected Population (2019)	January			February			March			April			May			June		
		TWD	TWS	SDBI	TWD	TWS	SDBI	TWD	TWS	SDBI	TWD	TWS	SDBI	TWD	TWS	SDBI	TWD	TWS	SDBI
1	**4191**	13201.65	12342.05	**0.93**	12321.54	10561.32	**0.86**	14291.31	9744.75	**0.68**	14081.76	8801.10	**0.63**	14940.92	8444.865	**0.57**	13830.30	13201.65	**0.95**
2	**4445**	14668.50	13090.53	**0.89**	13690.6	11201.40	**0.82**	15846.43	10334.63	**0.65**	15335.25	9334.50	**0.61**	16535.40	8956.675	**0.54**	14668.50	13335	**0.91**
3	**4034**	13312.20	11254.86	**0.85**	12424.72	10165.68	**0.82**	14381.21	9379.05	**0.65**	13917.30	8471.40	**0.61**	15006.48	8128.51	**0.54**	13917.30	12707.10	**0.91**
4	**4553**	15707.85	15525.73	**0.99**	14660.66	14023.24	**0.96**	16937.16	13408.59	**0.79**	17073.75	12976.05	**0.76**	19054.31	10585.73	**0.56**	16390.80	16390.80	**1.00**
5	**4307**	13567.05	12016.53	**0.89**	13265.56	10853.64	**0.82**	14686.87	10013.78	**0.68**	14859.15	9044.70	**0.61**	15354.46	8678.605	**0.57**	14213.10	13567.05	**0.95**
6	**4444**	15331.80	15154.04	**0.99**	14309.68	13687.52	**0.96**	17220.5	13087.58	**0.76**	16665	12665.40	**0.76**	18598.14	10332.30	**0.56**	16665	15998.40	**0.96**
7	**4728**	15602.40	13923.96	**0.89**	14562.24	11914.56	**0.82**	16855.32	10992.60	**0.65**	16311.60	10638	**0.65**	16855.32	9526.92	**0.57**	15602.40	14184	**0.91**
8	**3963**	13077.90	11056.77	**0.85**	12206.04	9986.76	**0.82**	13513.83	8599.71	**0.64**	13672.35	8322.30	**0.61**	14742.36	7985.445	**0.54**	13077.90	12483.45	**0.95**
9	**5988**	17964	16706.52	**0.93**	17604.72	15089.76	**0.86**	20419.08	12993.96	**0.64**	20119.68	12574.80	**0.63**	20419.08	12065.82	**0.59**	19760.4	18862.20	**0.95**
Ward No	Projected Population (2019)	July			August			September			October			November			December		
		TWD	TWS	SDBI	TWD	TWS	SDBI	TWD	TWS	SDBI	TWD	TWS	SDBI	TWD	TWS	SDBI	TWD	TWS	SDBI
1	4191	13641.71	15590.52	1.14	13641.71	14291.31	1.05	13201.65	13830.30	1.05	13251.94	13641.71	1.03	12573	12573	1.00	12992.10	12992.10	1.00
2	4445	14468.48	15846.43	1.10	15157.45	15157.45	1.00	14001.75	14668.50	1.05	14468.48	14468.48	1.00	14001.75	13335	0.95	14055.09	13779.50	0.98
3	4034	13755.94	13755.94	1.00	13755.94	13130.67	0.95	12707.10	12707.10	1.00	13130.67	11880.13	0.90	12102	10891.80	0.90	11880.13	11254.86	0.95
4	4553	16937.16	16937.16	1.00	16937.16	16937.16	1.00	16390.80	16390.80	1.00	16231.45	15525.73	0.96	14341.95	13659	0.95	14114.30	13408.59	0.95
5	4307	14019.29	14686.87	1.05	14019.29	14019.29	1.00	13567.05	14213.10	1.05	13351.70	12684.12	0.95	12274.95	11628.90	0.95	12684.12	12016.53	0.95
6	4444	16531.68	16531.68	1.00	16531.68	16531.68	1.00	15998.40	15998.40	1.00	15842.86	15154.04	0.96	13998.60	13332	0.95	14465.22	13087.58	0.90
7	4728	15389.64	14656.8	0.95	15389.64	13923.96	0.90	14893.20	13474.80	0.90	14656.80	13191.12	0.90	13474.80	12056.40	0.89	13923.96	12458.28	0.89
8	3963	12899.57	13513.83	1.05	12899.57	12899.57	1.00	12483.45	11889	0.95	12285.30	12285.30	1.00	11294.55	11294.55	1.00	12285.30	11056.77	0.90
9	5988	19490.94	20419.08	1.05	19490.94	19490.94	1.00	18862.20	17964	0.95	18934.06	18562.80	0.98	17964	17065.80	0.95	18562.80	17634.66	0.95

(Source: Field Survey, 2019) Note: Total Water Demand and Total Water Supply in cubic meters

June is a transitional month. Although there has been some relief since May, the water supply remains insufficient in several wards. However, some wards (e.g., Ward 4) reach balance (SDBI = 1.00), possibly reflecting localized improvements driven by early monsoon rains or improved management. The situation changes from July, coinciding with the monsoon. Most wards have SDBI values of 1.00 or more in July, indicating a surplus or equilibrium. For example, Ward 1 has an SDBI of 1.14, while Ward 2 has an SDBI of 1.10, indicating a surplus. This pattern persists into August and September, when multiple wards have an equilibrium (SDBI = 1.00) or a mild surplus (≈1.05). This improvement in water supply can be attributed to rainwater recharge, higher reservoir levels, and reduced reliance on scarce water resources. Between October and December, a second period of declining SDBI values is observed, but there is no immediate return to severe water scarcity. In October, most wards remain close to balance (SDBI ≈ 0.95-1.00) as the monsoon's impacts persist. However, in November and December, SDBI values drop below 1.00 in many wards, indicating the start of a new water deficit period. However, the deficits during these months are less severe than those in the pre-monsoon months.

Comparing wards, it is found that wards with larger populations (such as Ward 9) have higher demands and greater variation in the adequacy of supply. In contrast, other wards (e.g., Ward 4 and Ward 6) are more robust, with more balanced water supply for extended durations.

In summary, the results clearly demonstrate the seasonality of water supply in Shrigonda town. Critical scarcity is observed in the months prior to the monsoon (March-May), while the monsoon months (July-September) offer some relief and surplus. Water resource management practices such as storage, conservation and balanced distribution are crucial for addressing water deficits in the summer months.

Table 2: SDBI values and water scarcity levels in the Water Stress Period (March to May)

Ward No.	March		April		May	
	SDBI Value	SDBI Level	SDBI Value	SDBI Level	SDBI Value	SDBI Level
1	0.68	Moderate water scarcity	0.63	Moderate water scarcity	0.57	Acute water scarcity
2	0.65	Moderate water scarcity	0.61	Moderate water scarcity	0.54	Acute water scarcity
3	0.65	Moderate water scarcity	0.61	Moderate water scarcity	0.54	Acute water scarcity
4	0.79	Moderate water scarcity	0.76	Moderate water scarcity	0.56	Acute water scarcity
5	0.68	Moderate water scarcity	0.61	Moderate water scarcity	0.57	Acute water scarcity
6	0.76	Moderate water scarcity	0.76	Moderate water scarcity	0.56	Acute water scarcity
7	0.65	Moderate water scarcity	0.65	Moderate water scarcity	0.57	Acute water scarcity
8	0.64	Moderate water scarcity	0.61	Moderate water scarcity	0.54	Acute water scarcity
9	0.64	Moderate water scarcity	0.63	Moderate water scarcity	0.59	Acute water scarcity

(Source: Calculated by Researcher)

The temporal evolution of SDBI values during the water stress period (March-May) clearly shows a progression of water scarcity across all wards. In March, the SDBI values ranged from 0.64 to 0.79, with all wards falling under moderate water scarcity. This suggests that at the start of the pre-summer period, water supply is already stressed but still within acceptable levels. Wards 4 and 6 have relatively higher SDBI values (0.79 and 0.76), suggesting better conditions, while slightly lower values in wards 8 and 9 indicate stress conditions.

In April, there is a slight decrease in SDBI values across wards (0.61-0.76), but it still falls in the moderate scarcity category. This indicates progressive drying of water sources, possibly due to rising temperatures, increased evapotranspiration, and rising water demand. Interestingly, wards 6 and 7 show less fluctuation, suggesting local adaptation or effective water resource management. A notable change is observed in May, with all wards classified as experiencing severe water scarcity and sharp reductions in SDBI values (0.54-0.59). This consistency indicates the peak-stress point, reflecting an acute water scarcity situation. The uniformity of SDBI values among wards indicates that as water scarcity increases, spatial variability decreases, impacting all wards similarly. The result highlights the need for proactive water management, especially ahead of the hot summer months, to prevent extreme water scarcity and ensure water equity.

5. Conclusion

This research paper uses the Supply-Demand Balance Index (SDBI) to measure ward-level domestic water scarcity in Shrigonda, a semi-arid town in Maharashtra. The study uses projected ward-wise population and domestic water demand estimates, along with monthly water supply data for 2019, to show that while most wards have adequate or surplus domestic water supply during the monsoon and post-monsoon periods, all wards experience moderate to severe domestic water scarcity during the summer water-stress period between March and May. The SDBI values for each ward during the water-stress period (0.54 to 0.79) indicate that water supply meets only half to three-quarters of domestic water demand, suggesting the need to either curtail domestic water demand or rely on alternative water sources.

The results highlight the need to consider intra-annual and spatial variations in domestic water scarcity analysis, and the value of SDBI as an operationalization tool for planning and monitoring domestic water scarcity in small- and medium-sized cities. In terms of policy, ensuring domestic water security in Shrigonda would require a mix of approaches: enhancing and diversifying water sources; improving the efficiency of the distribution system; promoting rooftop rainwater harvesting and other non-conventional water supply options; and promoting efficient water use through public education and suitable economic measures.

References

[1] Census of India (2021), "District Census Handbook of Ahmednagar", Published by the Director of Census Operations, Government. Printing Press Mumbai.

[2] Food and Agriculture Organization (FAO). (2012). *Coping with water scarcity: An action framework for agriculture and food security*. FAO Water Reports.

[3] Indian Meteorological Department (IMD). Annual Rainfall Data of Shrigonda Station from 1970 to 2023, National Data Center (NDC), Pune.

[4] Metcalf, Eddy, & Inc. (2012). Wastewater Engineering Treatment and Reuse. Tata McGraw-Hill Private Limited.

[5] Mohammad Karamouz & Paniz Mohammadpour & Davood Mahmoodzadeh, 2017. "Assessment of Sustainability in Water Supply-Demand Considering Uncertainties," Water Resources Management, vol. 31(12), pages 3761-3778

[6] Neelmudiyona, V. T., Preethi V., and S. Govindarajanb (2023). Performance evaluation of buried PVC pipelines for tank irrigation: a case study of Deevanur Tank, Water Supply Vol 23 No 2, 923 Doi: 10.2166/ws.2023.031

[7] NITI Aayog. (2023). *Composite Water Management Index: A tool for water management*. Government of India.

[8] NWM. (2023). National Water Mission. Ministry of Jalshakati, Department of Water Resources. Retrieved from http://nwm.gov.in/

[9] Purnima, B. C., & Jain, A. K. (2005). *Waste Water Engineering*. New Delhi: Laxmi Publications(P) Ltd.

[10] Ranade, R. (2000). *A Water Harvesting Manual for Urban Areas: Case Studies from Delhi*. New Delhi: Publication Center for Science and Environment.

[11] UN Department of Economic and Social Affairs (2019): Revision of World Urbanization Prospects, Population Division of the UN Department of Economic and Social Affairs (UN DESA), New York.

[12] Wang, Z., Huang, Y., Liu, T., Zan, C., Ling, Y., & Guo, C. (2022). Analysis of the Water Demand- Supply Gap and Scarcity Index in Lower Amu Darya River Basin,

Central Asia—*International Journal of Environmental Research and Public Health*, *19*(2), 743.

[13] Zhu, R., & Fang, Y. (2022). Application of a water supply–demand balance model to set priorities for improvements in water supply systems: A case study from the Koshi River Basin, Nepal—*International Journal of Environmental Research and Public Health, 19*(3), 1606.