Development of Improved Method to Calculate Water Scarcity Index and it's Application in Delhi

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Abstract

Since the late 1980s, there has been a significant increase in political and public interest in research on water shortage. The management of water resources and the reduction of poverty can both be benefited from combining the socio-economic capability to access it with the measure of water availability. This strategy enables researchers to consider fresh multidimensional water scarcity indices that have helped define the water scarcity index (WSI). The indicators which were developed to capture different elements of water shortage were investigated in this research. The article describes the development and evaluation of water scarcity index in selected villages of Delhi. WSI was calculated using objective weighting scheme of its four components (availability of resource, capacity, accessibility and environment). The index was developed as a comprehensive tool to evaluate the water problem at the household and community levels. It was created to assist decision-makers in identifying the most urgent needs for water sector interventions.

Key words:- Water Scarcity, Indicator, Index, Capacity, Access, Resource, Environment

1. Introduction:

Lack of clean water is one of the biggest problems that several communities and the entire world is facing in the twenty-first century. Due to its periodic replenishment during the course of the seasons, water was long considered a non-limited natural resource. This resource was gradually taken by man, who exploited it freely. Without enough consideration for conservation, developments in surface water control and diversion, groundwater exploration, and the use of the water resources for the different purposes have been attempted avoiding wastes and improper usage while maintaining the resource's quality. As a result, water has now become increasingly limited today—not only in dry and drought prone areas, but even in places with generally abundant rainfall. Nowadays, scarcity is understood in regard to the amounts that are available for social and economic requirements, and additionally in relation to the requirements of water for both natural and manmade ecosystems. Because deteriorated water resources are inaccessible or, at best, just minimally available to be utilized by both human and natural systems, the idea of scarcity also encompasses water quality. The United Nations (2003) defined water scarcity as "The point at which the accumulated impact of all users impacts the quality or supply of water within existing institutional frameworks to such a level that its demand by all sectors of the economy including the environment, cannot be adequately met." Most of the time, this ostensibly physical occurrence is due to the interaction of highly complex socio- economic and environmental systems. In reality, the main causes of water shortage are t he type of demand and the inefficient distribution of water, rather than the overall quantity of the natural resource. Water shortage is a "governance issue, not a crisis of water resource "(Brown,2005). In this study, water scarcity is regarded as a gap between the availability of water and the indicated demand for it in a specific domain within the current institutional framework and infrastructure.

Water Scarcity = an excess of demand compared to supply.

2. Aims and Objective:

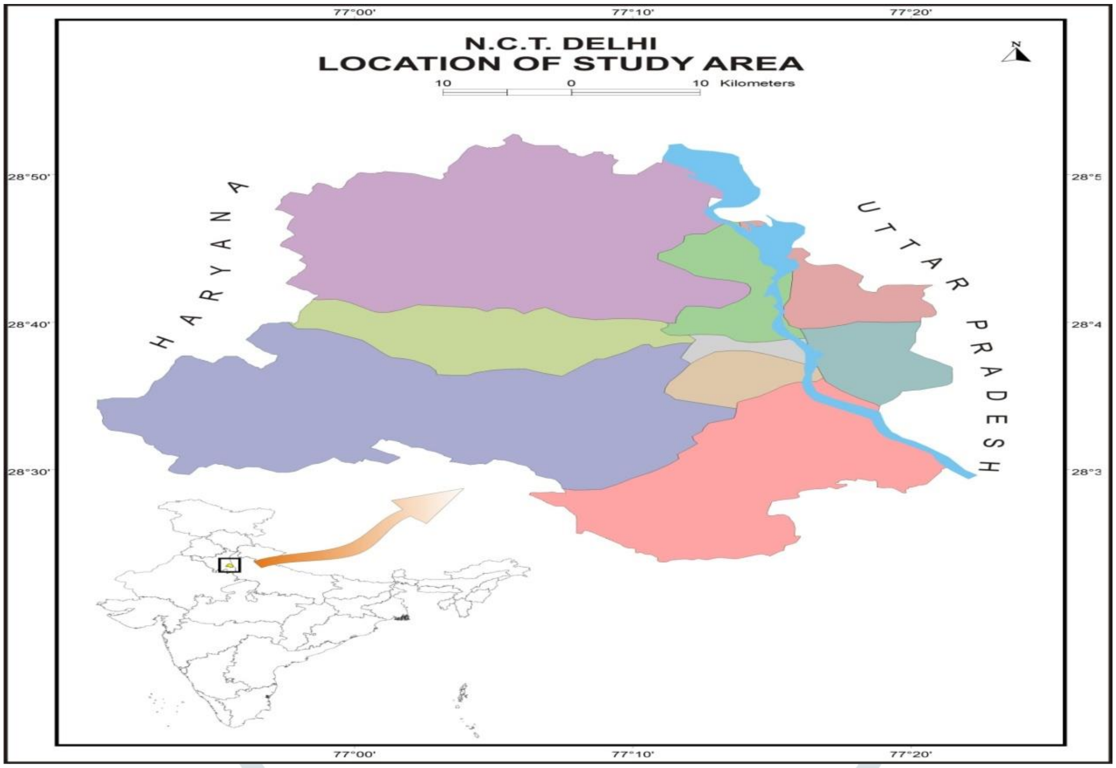
The current study's attempt has been done with the following objectives:

1) To create a useful integrated index to measure water scarcity;

2) To use the Water Scarcity Index to pinpoint places where water scarcity is a problem.

3. Study Area:

The Himalayas and Aravalis range, in the centre of the Indian Subcontinent, are separated by the NCT of Delhi, which consists of nine districts and covers an area of 1483 sq. km. Its coordinates are 76°50'24" to 77°20'37" East longitude and 28°24'17" to 28°5'00" North latitude. There are nine districts in the NCT. Rural regions fall under the administrative control of all districts, with the exception of New Delhi and central Delhi. Districts have also been further split into subdivisions. There are currently 27 sub-divisions and exactly equal numbers of Tehsils. In Delhi, three statutory towns have been operating continuously since 1961. -a) Delhi Municipal Corporation(Urban), (b) Delhi Cantonment Board, and (c) New Delhi Municipal Council . The region has 99 mm3 of rainfall on average every year, 80 percent of which falls from the end of June to September and contribute to the flow of Yamuna river. The river doesn't always have ample water to satisfy the needs of the area; as a result, Delhi primarily relies on its neighboring states for its primary water supply in order to meet its yearly water demand. Surface and underground water are the sources of water in Delhi. There is an ever-increasing demand on the water resource as Delhi's population grows from 0.4 million in 1911 to 16.7 million in 2011. Delhi is experiencing a severe water crisis. The government of Delhi's water delivery network has continuously fallen short of meeting the needs of the city's residents. (Figure 1).



Source: Census of India, 2011.

4. Data Source and Research Methodology:

The data generated by the field survey was used to conduct the present study. The study's data was gathered from 5 studied sites in Delhi. Bajidpur Thakran, Ochandi, Karala, Kharkhari Jatmal and Mundela Khurd were the five villages chosen for the survey. A total of 250 houses were surveyed, 50 of which were randomly chosen from each chosen site. Field observations and a structured questionnaire were used to obtain the primary data. The information gathered covers a wide variety of topics, such as water sources, institutional problems, demographic information, and additional time spent collecting water. Collected data was then analyzed and represented through suitable statistical techniques.

5. Result and Discussion:

5.1 Water Scarcity Index (WSI)

The Water Scarcity Index will be used to identify the factors that contribute to water shortage in a given area. Such an index would serve as a comprehensive policy tool that considers both socio-economic and physical elements. No matter of the region or size of the community, the index provides a comparative measurement of poverty in reference to water. A more equal distribution of water may be accomplished by extending the creation of the Water Scarcity Index to assist in the process of pinpointing the locations and people that need water the most.

Theoretical Background of WSI:

An index is a tool used by policy makers to assess the success of complicated issues. Its goal is to give concise and focused information for the management and policy development. The main benefits are that they mix quantitative and qualitative features and encompass several measures of success in a single figure. As a result, elements that could not otherwise be measured can be demonstrated. Such indices aid in concentrating efforts and streamlining the issue. They have a strong political appeal. They make a bigger impression on people's minds and grab the public's attention more effectively than a qualitative debate and a long list of numerous indicators. They capture the attention(Streeten,1994)." Falkenmark put forward his initial water scarcity indices in 1989, which he described as the proportion of the total yearly runoff that is usable by humans. As shown in the following table, the water situations in every area may be divided into three categories based on three thresholds: not stressed, stressed, shortage or scarcity of water and absolute water scarcity.

Table 1: Indictor of Water Stress by Falkenmark

Index (per capita/ year/ m^3)	**Category**
More than 1700	Not Stressed
Between 1000 to 1700	Stressed
Between 500 to 1000	Water Scarcity
Less than 500	Absolute Water Scarcity

Source: Falkenmark, M. and Widstrand, C. (1989), Population and Water Resources: A Delicate Balance.

The Falkenmark's index can be utilized to evaluate the water status on a smaller scale if data are available. However, this indicator has serious flaws, just as other one-dimensional indices. Only physical water scarcity is taken into account in Falkenmark water stress index and the average amount of water available per person is evaluated without taking into account both spatial and temporal variability in specific areas within a nation. According to Lawrence et al(2003) definition of "water poverty, people can be "water poor" for one of two reasons: either they do not have enough water to meet their basic requirement because it is not available, or They are "income poor," which means that despite having water available to them, they may not be able to afford to pay for it.

The WSI is a comprehensive tool created to identify the connections between problems with the availability of water resources and ecological and human demands. Its theoretical framework includes physical availability of water resources (R), the level of access to water resources and sanitation (A), capacity and ability of people to sustain access (C), the use of water for different purposes (U), and the environmental variables that impact the water supply to eco-systems (E). Managers of water resources and decision-makers can use this composite index to look at the linkages between social deprivation, poverty, access to water, environmental integrity and health (Sullivan, 2003).

Sullivan's work served as the basis for the present study's suggested Water Scarcity Index. The WSI proposed in the current study has a fundamentally comparable structure and aims to achieve an integrated analysis of socio-economic features, resource availability, and environmental component of Water Scarcity/poverty. The main goal of the WSI is to give water managers a tool for holistically assessing the water condition in various regions.

5.2 Components of the WSI:

The following have been recognized as key elements of the proposed index:

1) **Resource:-** Surface and ground water's physical accessibility is covered by the resource component. As it refers to the water that people can actually utilize, it is most pertinent when assessing the WSI. An ample water supply with little unpredictability is shown by a greater value for this component, which indicates better water conditions. The resource's dependability or variability is a significant additional factor that influences availability; it should be taken into account because the lesser the portion of the entire resource that can be used, the more variable the resource is. Hours of water availability are used as a measure of resource availability in the current study. It contains the water's temporal and spatial variability in the study area. That is a crucial WSI indicator.

2) Access :- Another aspect of the WSI is people's access to water. The ability of people to acquire water to meet their needs considering variables like distance and time to fetch water, right of access to water and costs, is what separates access from availability of water resources which is related to water resource infrastructure and the natural environment. Regular and sufficient accessibility to improved drinkable water inspires necessarily for improved sanitation and hygiene conditions. Whereas, a lack of access to clean water will gradually result in wasted time spent fetching it, time that could have been spent doing something useful. Ownership of a source of water whether it's a hand pump, a tap or a tube well is used in the proposed Index to symbolize access to resources, whereas non-ownership or usage of a common source of water indicates difficulties or less access to resources.

3) Capacity:- The capacity component consists of a group of socio-economic indicators that can demonstrate how well people can provide and manage water. The average per capita spending serves as the initial indicator of this component's economic potential and is connected to human wellbeing and quality living conditions. A greater score of this indicator indicates a greater ability to afford enough clean water, to have access to water resources, and to have the technology to deal with water-related problems. The word "capacity" is used to refer to the amount of money needed to buy better water. As a result, the price of the water is employed as a measure for the capacity component.

4) Environment:- The environment component covered a number of environmental factors that affect the distribution and management of water. These indicators incorporate not just the stress levels and water quality, but also how strongly water and environment are valued across a country's legislative and policy framework. Water quality (the suitability of the water to be drunk) has been used as an indicator in the suggested index.

5.3 Applying Weight to the WSI Structure:

In an index, weights are employed to alter the relative significance of various components. This is typically done for drawing attention to the issue that is thought to be most essential. The resource component of the proposed study measures the accessibility of water, and it was evaluated by averaging three distinct variables: (a) Water quantity adequacy, which considers whether availability of water is sufficient to meet demands of human or livestock, (b) supply regularity and reliability, and (c) variability of resource in different seasons. In the research, there are four categories for resource availability: almost always (excellent water availability), 6 to 8 hours (acceptable availability), 6 hours (poor availability of water), and fewer than 4 hours (very poor water availability). More hours means more water availability, so a weight of four is given to the category of continuous supply of water, a weight of three to that of water availability between 6 and 8 hours, a weight of two to that of water availability between 4 and 6 hours, and a weight of one to that having supply of water for less than 4 hours.

The accessibility component consider whether or not individuals can get clean water. Water resource ownership serves as a representation of it. Those who owned their own sources of water had easy access to it, while others who utilized shared sources of water had difficulty getting it since it required more time to gather or was farther away. Private ownership of water sources is therefore given a weight of 2, whereas common sources are given a weight of 1.

The capacity indicator aims to identify those socio-economic factors that may affect people's capacity to effectively manage water resources. This indicator took into account whether or not the water they have access to costs them anything. When a single source is sufficient to meet everyone's water demands and they only have to pay for that one source, that source is given a weight of 2, however when several sources are required to meet everyone's needs, that source is given a weight of 1, which is not ideal.

The environment component comprises a variety of measures, including those for ecological integrity as well as water quality and "stress" indicators. The fourth environmental indicator is water quality. The gap between those who claimed the water was of high quality and those who said it was of poor quality determines how much weight this indication has. Hard/saline water is assigned a weight of 1, whereas water with a weight of 2 is considered poor quality water, weight age of 3 is considered acceptable, and water with a score of 4 is considered good.

The four indicators' weights fall between 4 and 12 on a scale. The sum of the maximum weights assigned to each indication, 12, is regarded to represent the ideal water condition, while the lowest possible weight assigned to all indicator, 4, represents the potential degree of water scarcity. For a specific reason, weighted average of the four components—resource (R), accessibility (A), capacity (C), and environment (E)—makes up the value of the water scarcity index. The total sum of the indicators must be divided by the total weights (of all indicators), which in this case is 12. This will normalize the data and yield a WSI value between 0 and 1. Thus, the WSI for each of the chosen villages will display degrees of water scarcity ranging from 0 to 1. A lower WSI score represents the worst water scarcity situations, whereas a higher WSI value indicates a reduced level of water shortage.

5.4 WSI Scores For the Selected Sample Villages:

Based on the results of the field survey, Table 2 illustrates the sample villages' scores on the WSI with the greatest value listed first.

Table 2: WSI Values for Villages

Rank	Village	Availability	Ownership	Cost	Quality	Total	WSI
1	Karala	3.0	2.0	2.0	3.0	10.0	0.8
2	Ochandi	3.0	2.0	1.0	2.0	8.0	0.7
3	Bajidpur Thakran	2.0	2.0	1.0	2.0	7.0	0.6
4	Mundela Khurd	2.0	2.0	1.0	1.0	6.0	0.5
5	Kharkhari Jatmal	1.0	2.0	1.0	1.0	5.0	0.4

Source: Primary Survey

Village wise description is given below-

Karala received a WSI score of 0.8, is at the top of the list. It receives the highest marks for both water supply and quality. In terms of ownership, it has a relative weights of 2, which indicates that each household has a private water source and doesn't devote much time to acquiring water from other areas. Karala reports a weighted score of 2 for the cost indication, indicating that they are receiving an acceptable supply from a single source of water and paying solely for that source on the basis of their average annual usage. Karala village is quite lucky for not having any shortage of water when considering the total values of the indicators and their resulting WSI ratings.

Ochandi is rated second in WSI hierarchy with a score of 0.7. This village's weighted availability score was 3, its ownership and quality indicator scores were 2 and 1, and its cost score was 1. The majority of those surveyed said they were paying for water filtration, and the quality of the water is much below ideal levels. This suggests that the locals would have an increased financial burden.

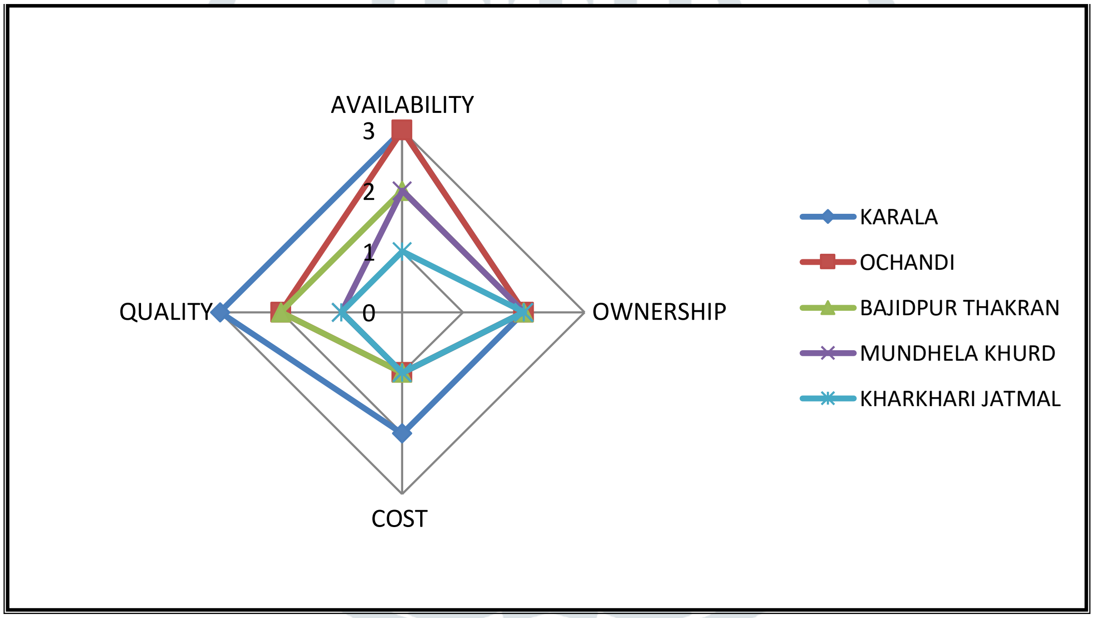
Bajidpur Thakran has a WSI score of 0.6, which puts it in the medium water scarcity category. As it receives supply of water for around 6 hours per day, it receives a rating of 2 for the availability indication. The village's whole dwellings are connected to the municipal water system. For private ownership of water resources, it receives a maximum of 2 weighted points. Those who were polled do not like the water's quality. Hence, the quality indicator's score for the water shortage index is 1. This community receives a weight of 1 for the cost indication since improving the water quality requires more expenditures. A score of 0.6 doesn't suggest happiness about supply of water.

Mundela Khurd village's WSI value of 0.5 does not suggest that its water supply is in excellent condition. The village's water distribution system is in a hopeless situation. The availability indications indicate a poor supply of water. Less than six hours a day of water are supplied to this community. consequently, the availability of water receives a weighted score of 2. The weighted score for the ownership indicator is 2, meaning that almost all families have private ownership of their water resources. As this area relies on groundwater (Tube well) for its supplies, the low ground water quality has a negative impact on its WSI score. Because of its high nitrate and calcium concentration, water from tube wells is essentially unsuitable for human consumption. It receives a 1 for the quality indicator. The cost indication also receives a weighted score of 1, as every household must pay for water filtration or find an alternative source of drinking water, increasing the expense of satisfying their water needs. This village's overall water status looks to be unsatisfactory.

Kharkhari Jatmal's WSI score is 0.40. It receives a weight of 1, indicating that the community has a limited quantity of water. Owning the water resource denotes having adequate access to water, which raises the bar for it. This village's water quality is also rather poor because it receives its water supply from tube wells, and the groundwater there is both hard and heavily polluted with nitrates. Score 1 is also true for both quality and price. This results in fewer water sources, limited access, poor quality, and high water usage costs. With a WSI value of 0.5, the water scenario is poor.

5.5 WSI Matrix:

In Figure 2, the differences between sample villages are depicted using WSI Matrix.



Source: Primary Survey

Figure 2: WSI Matrix for Villages

The component scores are displayed in a quadratic diagram along with the strengths and weaknesses for each village. For instance, the resource component score for Karala and Ochandi Village is the greatest, but the ecological impact of water usage in Kharkhari Jatmal is lowest. Due of the low scores on the environmental axis, Mundela Khurd samples appear to be fairly severe. Even if the grades for the access components are almost the same across all areas, access alone does not qualify as "no water poor". The capacity component demonstrates how to utilize revenue to fulfill the demand for water. For instance, residents of the villages of Kharkhari Jatmal and Mundela Khurd must spend extra on coping mechanisms owing to the provision of hard water. As a result, households must shoulder the responsibility. The graph demonstrates that, when looking at the WSI scores as a whole, the situation is most terrible in the villages of Kharkhari Jatmal and Mundela khurd and these villages require the most immediate intervention since they have poor ratings across the board.

6. Conclusion:

In order to identify the locations and groups that need water the most and to facilitate a more equal distribution of water, the development of the WSI is being extended. The WSI and the factors that made up its foundation accurately reflected the state of the communities. The WSI's goal is to give a efficient and transparent instrument that enables the water situation at the community or local level to be communicated in a way that is a lot more coherent than before to deliver surprising or novel outcomes. According to the WSI calculation findings in the study area, only one Karala village is not facing water scarcity, while Kharkhari Jatmal is under extremely severe water stress. other villages are experiencing modest to medium levels of water stress. The WSI calculation's outcome may be used as a foundation for policy formulation in the creation of water supply provision in Delhi.

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