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Water Scarcity Assessment in Arid Haryana: A Case Study of Mahendragarh, District

Swati Thakur

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Abstract Water and sustainable development are inextricably linked at various social, economic and environmental perspectives. As competition for water grows among population demand and freshwater supply it poses factor of challenges to the government so as to develop water strategies that take in account of limitation of availability, accessibility, affordability and rights to water in the domain of existing water scarcity. The present study evaluates Resource, Access, Use, Capacity and Environment component to form the composite Index of Water Scarcity. The overall value of WSI as 37.85 for the district is an alarming number. It was found that Mahendragarh (29.77) and Narnaul (34.03) were in the worst condition. Leaving out Resource and Environment all the other component 'Access, Capacity and Use' had very high correlation with WSI. This revealed that any policy making for water management should first improve access and capacity in an already constrained resource base..

Keywords Water resource; drylands; sustainable development; scarcity index; water management

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Swati Thakur (✉)
**Department of Geography, Dyal Singh College, University of Delhi, Delhi*
✉ *swatithakur.dsc@gmail.com*

Introduction

Water is a basic human need and limited natural resource. Moreover, the supply of fresh water available to humanity is shrinking. There are increasing numbers of rivers which are drying before reaching sea, groundwater has been extracted to the rates beyond its recharging capacity and aquifers have depleted increasing the water to depth globally. The imbalance of availability and demand have nuanced the water problem to its pressing concern for every smallest administrative units, hence nation and world.

According to the European Environment Agency, "water scarcity occurs where there are insufficient water resources to satisfy long term average requirements. It refers to long term water imbalances, combining low water availability with a level of water demand exceeding the supply capacity of the natural system". The last 20 years have witnessed development of methods to characterize, map and monitor the water scarcity globally.

Definitions of water scarcity are still being refined. The measurement of water scarcity initially started with the assessment of total useable water available to the ratio of its population. 'Falkenmark Index' is a widely known index as a pioneer to define water scarcity taking physical water shortage as its theme. This straight forward indicator was well with the available data on varied spatial scale but had limitation regarding the same. The utilization of water in its various sectors and related issue of water scarcity was an added dimension by Gleick (1996). The availability of water in late nineteen's was perceived in terms of supply (Raskin,1997) and demand (Secker et al.,1998). A further improvement in terms of capacity to avail water resources and its relation with social, economic and environmental aspects was a new perspective in water scarcity assessment. A comprehensive indicator of combination of waters scarcity and human development were summed to attain 'Social Water Stress Indicator' by Ohlson and Turtle (1999)

The path further to Water scarcity Index (WSI) as was summed by Sullivan (2002) as a holistic tool which measures the whole range of issues related to availability and its relationship to human and ecological need. The design of the scale is as such it can operate at all spatial level and enable comparison of water scarcity over time and space. By assigning indicators for the composite score regional performances can be evaluated helping the decision makers to prioritize need. Thus extensive use of WSI is seen at international (Lawrence et al 2002.); national (Sullivan and Meigh 2003, Komnenic et al. 2009); district/basin (Ty et al 2010, Manandhar et al 2012, Jemmali 2013, Huang et al.2017, Foguet et al. 2010) and community scale (Guppy 2014; Vyver 2013) to name few.

More recently the water scarcity indicators apart having been prompting the imbalances between water availability and water demand also underpins global assessment of food poverty, human development, economic and ecological health. The assessment indicator to represent water scarcity index is location specific and has to be chosen carefully. In this research an attempt has been made to evaluate the intensity of water scarcity and make priority for water poor in the region. The objective of this research is to design a set of indicators suitable to evaluate the status of water scarcity in an economically and ecologically marginalized district of Haryana. Mahendragarh district has been chosen for this study as surface water sources have already dried in this region and underground water sources are shrinking rapidly. The access to existing water has to be evaluated on socio economic basis. It is the first comprehensive application of WSI in arid region of Haryana.

Objectives

The main objectives of the study are to derive Water Scarcity Index (WSI) in study area and to determine the magnitude of water scarcity and its spatial variation.

Study Area

The Mahendragarh district is located in the semi arid region of the state. The district has about 1899 sq.km of geographical area. It lies in the south Haryana between 27° 47′ North to 28° 26′ North Latitude and 75° 56′ East to 76°51′ East Longitude. Landscape of the district comprises of undulating plains, sand dunes and baring rocky surface. Topography of the district is peculiar. The residuals of the Aravali are spreading in the district giving the rocky outlook. Climate of the district is hot and semi arid in nature. The region lies in the rainfall regime of below 400 mm average annual rainfall which denotes the condition of water scarcity in the region. The higher variation between amount of received rainfall and amount of evapo-transpiration causes the decline in soil moisture and more extensive and intensive exploitation of ground water resources. Due to scarcity of monsoon rainfall and continuously declining water resources the region has faced several times the drought conditions. The population density is 487 people per square kilometers and the total population is 922088 persons.

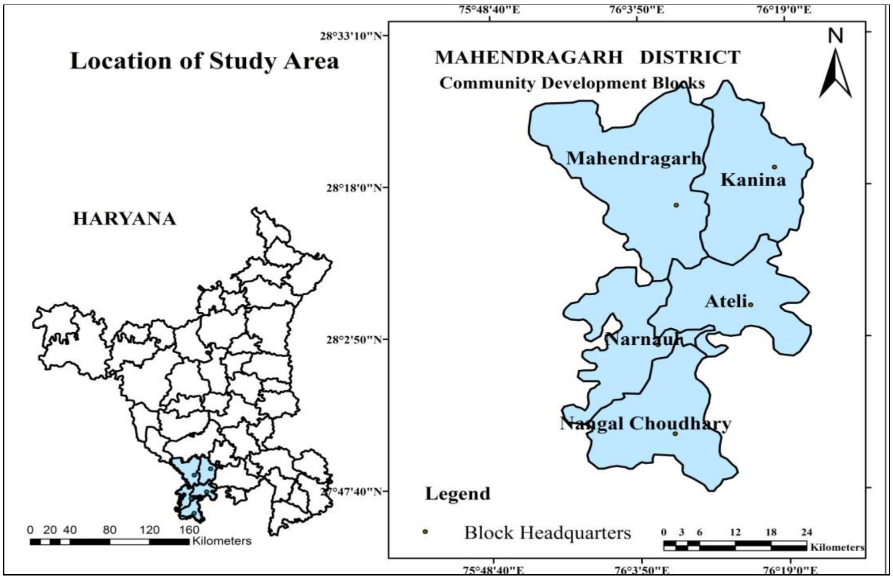

Figure 1 Location of the study area

Although highly unreliable and variable monsoon the rainy days last for average 26 days and maximum rainfall are between month of June end to end of September (84 per cent rainfall). Mean maximum temperature is 41°C promoting high rate of evaporation and aridity.

Among the various land uses Mahendergarh has 78.6 percentage net sown area of the total cultivable land making agriculture the base economic activity in the district. The work participation rate is 36.71 per cent which has decreased 6.6 percent from the year 2001 (43.3), of which agricultural cultivator and laborers are reported 55.3 per cent of the total population.

The major forms of water resources used in the district are tube wells and canal, including lift irrigation projects. The reverse slope of the region makes the conditions unfavorable here for the development of canal systems. Canal are mostly laid down according to slope so as no additional force is required to easily flow of water. But the slope in entire south and south west Haryana including district Mahendergarh is towards north and north east. Apart from general slope the local surface feature are also proved as barriers in the district. Mostly land is undulating and having sand dunes so poses problem for canal development. These topographic conditions of the region forced to depend on ground water resources and particularly deep tube wells for irrigation and other purposes. This sole dependency on tube wells lead to over exploitation and depletion of ground water.

Methods and Data Sources

The composite index for WSI is expressed as following:-

$$WSI = \frac{\beta r \times R + \beta a \times A + \beta u \times U + \beta e \times C + \beta e \times E}{r + a + u + c + e}$$

Where, WSI is water scarcity index for a particular location. Where, *β r, βa, βu, βc, βe* are the weights assigned to the respective component. The indicator and variable are normalized using min-max approach such that each score falls between 0 (worst situating) to 100 (best situation). The specific threshold is minimum & maximum value of that indicator. The calculation of weight is done based on statistically determined loads using multivariate technique. Certain aspects of this research are derived quantitatively where as the reflexive process and response of people centric focus implies qualitative assessment.

The component used to calculate WSI are:

- Resource (R): the amount of physical availability of water resources, its inter annual and seasonal variation and service reliability related to its sufficiency for the population
- Access (A): how well the population is benefited in terms of efficiency in its uses, less efforts put in to access and to its affordability
- Uses (U): different water use efficiency pertaining to domestic and agriculture.
- Capacity (C): the ability to cope water resources associated problem in terms of population equipped with knowledge, social and financial capacity
- Environment (E): to sustain environmental integrity through land and water quality and proportion of vegetation cover.

To evaluate each of the components a set of variables were chosen to elicit the water poverty situation in the study area. Table 1 gives detail of the structure and framework of WSI, indicator used, calculation method and scale of enumeration. The sub-indicator (X) is normalized using the following equation:

$$X = \frac{Xi - \min(Xi)}{\max(Xi) - \min(Xi)} \times 100 \qquad (2)$$

Where, min (X_i) and max (X_i) are respective threshold value of the indicator. It was multiplied by 100 to assess the value in range of 0 to 100. The index comprises of five components and 12 variables. Both primary and secondary data sources were used. The data related to water availability were collected from the Irrigation and Agriculture Department (Narnaul and Chandigarh) and CGWB (Central Ground Water Board), Chandigarh from its annual report on Assessment of Dynamic Groundwater Resources of Mahendragarh District (2015-16), Annexure II-D1 and Annexure III Climate data was obtained from Indian Meteorological Department (IMD) on request and open source digital data for 18 point station in the study area was derived from FAO, AQUASTAT data (2016) available for climatic parameters on 1km sq.grid for the globe. The socio economic data was obtained from District Census Handbook and Primary Census Abstract, 2011.

Table1 Framework for Water Scarcity Index (WSI) in Study Area

Component/Indicatiors	Calculation	Scale	Relation with WSI
Resources (R)	(R1)Per capita ground water availability (m^3/yr)	Block	High R1 – Less water poverty
	(R2) Co-efficient of variation of annual rain-fall(%)	District (2000-2016)	High R2 – High water poverty
Access (A)	(A1) Percentage household to treated piped water supply.	Block	High R1 – Less water poverty
	(A2) Percentage household access to safe sanitation	Block	High R1 – Less water poverty
	(A3) Proximity location of point water source to household (%)	Block	High R1 – Less water poverty
Use	(U1) Domestic water use (lpcd)	Block	High R1 – Less water poverty
	(U2) Percentage irrigated to total cultivated land	Block	High R1 – Less water poverty
Capacity	(C1) Literacy Rate (%)	Block	High R1 – Less water poverty
	(C2) Per capita income	Block	High R1 – Less water poverty
	(C3) Economically active population (%)	Block	High R1 – Less water poverty
Environment	(E1) Water Quality Index	Block	High R1 – Less water poverty
	(E2) Vegetation cover (%)		High R1 – Less water poverty

Result and Discussion

The accurate focus on the five components is a prerequisite. All the components are average of the variable assessed. R1was assessed by taking groundwater availability in the block. Surface water is practically absent in this area apart the canal network set up under JLN lift irrigation scheme. Canal is merely 0.3 percent of the total uses for domestic purpose and around 9.41 percent for irrigation purposes. The distributaries are supplying water in the adjoining region as per availability of water in the canal after every 15 days interval. The blocks which correspond to average groundwater depth more than 60 meters are zone of scarce region in the study area. Figure 2 gives the groundwater depth to elaborate the fact. The coefficient of rainfall is high (42.67 per cent) depicting variable rainfall. The access component reflects the human dimension of water scarcity issues relating to sufficiency, accessibility, health and hygiene.

The Use component displays the variables in which water resources are used for various purposes i.e domestic, livestock and agriculture. It is crucial to know the water requirement for end use such as bathing, washing utensils, cooking, drinking, cloth washing, hygine and cleanliness requirements for effective water management. Following the minimum quantity of water requirement recommended by WHO to fulfill rural house hold need the supply and access to water in four categories are (i) no access with >5 lpcd, (ii) scarce averaged upto 20 lpcd (iii) basic averaged upto 50 lpcd (iv) optimal range 100-200 lpcd. Percentage share of maximum household in respective categories are taken for individual villages. Agricultural water use was evaluated as irrigation water use percentage irrigated areas to total cultivated areas was taken as proxy indicator to the agricultural water requirement. As used by Sullivan (2003), higher the value more is the water usage in agriculture.

The importance community capacity as a component is understood within the context of managing water resources effectively considering knowledge, financial, infrastructural abilities of a community. Regarding knowledge education is often used as an indicator to understand links between health and environment, ability to suggest improvement and determine household well being.

C_1 was evaluated by measuring literacy rate at administrative level. Financial capital C_2 plays an important role in households' capacity to manage and develop water resources. C_3 evaluates population engaged in non-agricultural activities. It gives more resilience to the vulgarities of water shortage and economic alternative to deal with poverty.

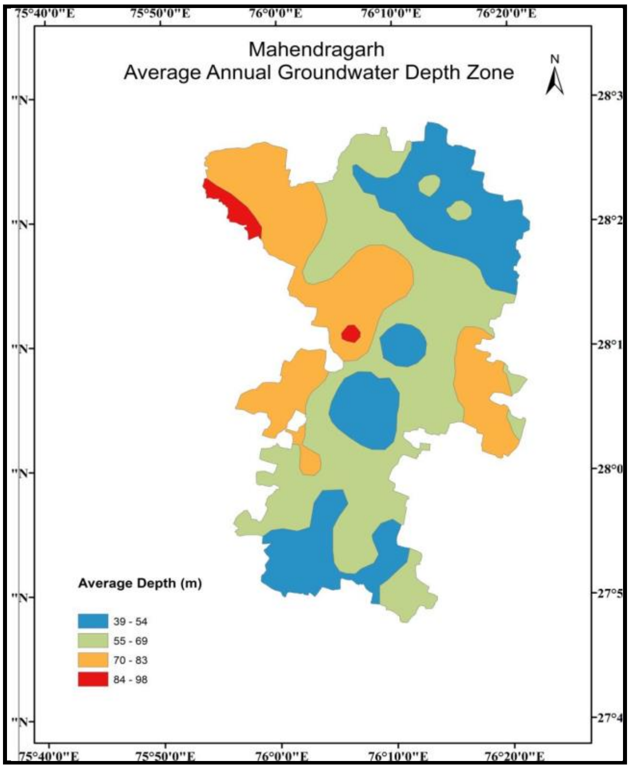

Figure 2 Average annual ground water depth zone (1999-2016)

E1 identifies the degree of environmental integrity through the level of water quality. The study has been supplemented by the report on Water Quality in Mahendragarh district by Department of Soil Sciences, Haryana Agricultural University. The study incorporated 10 different parameters of bio chemical, thermal conductivity, SAR, RSC and pH value. The index incorporated was percent of good quality groundwater available in each block. Higher the score lesser is the poverty as suitability of groundwater to various uses are not restricted. The terrestrial characteristic of the environment plays significant it in water availability and sustainability. Measured by vegetation coverage it is an index to ecosystem functions. Decreased vegetation cover indicates disturbances in natural state of ecosystem and increased possibility of soil erosion, sedimentation and desertification. It was calculated as vegetation percentage to total area (E2).

The index varies from 29.97 to 46.85 with mean value for the district to be 37.84. This falls under very severe water scarcity scale as identified by Lawrence (2003). It is worst condition to deal in terms of scarcity. If compared block wise the district has an alarming scores. Table 2 illustrates component wise description of the structuring of WSI. As seen Mahendragarh (29.77) and Narnual (34.03) have value lesser than 35, whereas Nagal Choudhary has WSI value 37.35. The better performing districts are Ateli (46.86) and Kanina (39.98).

Across spatial scale the problem of non- availability of water was more in Mahendragarh blocks. When correlated with underground water depth and rainfall zone one can easily infer the physical scarcity. Narnual and Nagal Choudhary block also conferred insufficient water. Though climatic estimate cannot be interpreted in such small scale but the high Aridity Index (88.44 per cent) and CV of rainfall (38.19 in Ateli to 42 in Mahendragarh) make rainfall less reliable posing constraints to its natural availability.

Table 2 Water Scarcity Component Values and Water Scarcity Index in the Study Area

	Mahendragarh	Kanina	Ateli	Narnaul	Nagal Choudhary	District
R1	26.52	85.96	68.66	29.5	47.68	51.67
R2	42.43	40.14	38.91	40.9	35.13	39.5
R	34.48	63.05	53.78	35.2	41.41	45.58
A1	22.13	12.13	64.8	21.81	16.84	27.54
A2	36.24	46.48	54.55	47.63	26.82	42.35
A3	43.75	54.17	60	39.29	35	46.44
A	34.04	37.59	59.78	36.24	26.22	38.78
U1	24.94	25.83	30	18.57	29	25.67
U3	5.295	2.456	18.07	56.83	55.39	27.61
U	15.12	14.14	24.03	37.7	42.19	26.64
C1	66.96	68.64	69.16	65.96	42.46	62.64
C2	29.17	33.33	40	28.57	30	32.21
C3	34.21	37.87	57.62	42.81	33.52	41.2
C	43.45	46.61	55.59	45.78	35.33	45.35
E1	41.67	66.67	80	50	80	63.67
E3	1.883	0.333	2.1	0.469	3.24	1.605
E	21.78	33.5	41.05	25.23	41.62	32.64
WPI	29.77	38.98	46.85	34.03	37.35	37.8

Source: Calculated by the author

The score for both agriculture and domestic water use is very low. Inadequate availability and constraints to use was evaluated through access component. The access score with 38.78 for the district also comes under severe scarce level. On an average only 28 per cent household is supplied with treated water and a very low score of operational water point sources (46.4) in study area reflects the grim reality. The dependency on outer sources of water and hence frequent investment for domestic and agriculture use has sought additional burden to Narnaul and Nagal block. 28 out of 36 villages consumers less than 20 lpcd (minimum standard by WHO) by its 60 percent habitants. Figure 4 presents component wise performance of individual blocks in the study area. Greater agricultural water use is seen in Narnaul and Nagal block with larger area under irrigated agriculture. But the respondents revealed the problem of low yield and crop loss over recent 10 years due to decline in water availability. As perceived by respondent 78 per cent shows high level of distress and are forced to shift their job presently or in near future.

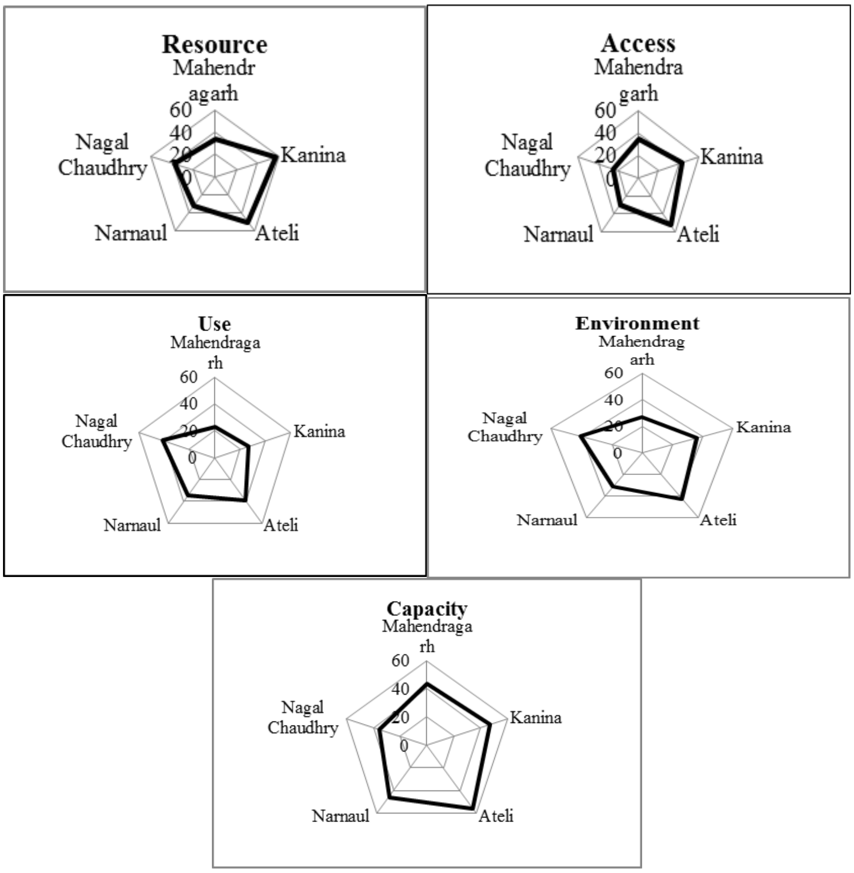

Figure 3 Component performance indifferent blocks of Mahendragarh district

Lastly, environment component shows that apparently soil fertility loss and vulnerability to climatic extreme at acceptable limits but quality of water is a major problem. Application of chemical fertilizer, depleting ground water level and lack of recharge has affected the quality standards of ground water.

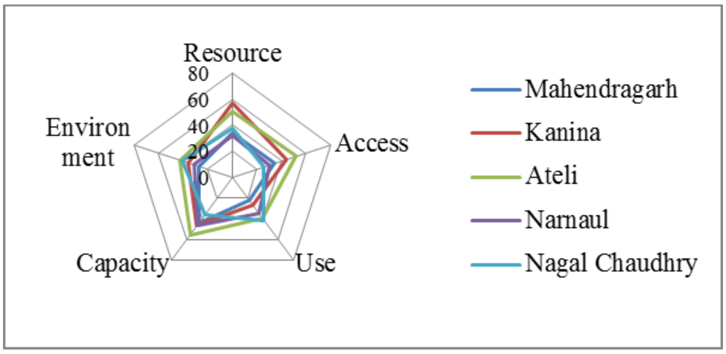

Figure 4 Illustration for WSI component value for five blocks in Mahendragarh district

The overall capacity of the population takes a better position with 45.35 as an average for the district but the value needs all effort not only to build in resilience for the current situation but also to improve the water poverty situation. Figure 4 is the pentagram illustration for component values for each block. The closer is the pentagram to the core greater is the scarcity as it depicts lesser score in 0-100 scales. Since total amount of physical water received is constant and cannot be improved the other components becomes more significant to decision making regarding water management. The results of cross correlation of the component and WSI reveal that there is relatively low correlation among component as seen in Table 3.

Table 3 Correlation Coefficient for the WSI Components (Kendall's tau-B)

	Resource	Access	Use	Capacity	Environment	WSI
Resource	1.000					
Access	.114	1.000				
Use	.335	.571**	1.000			
Capacity	.159	.448**	.476**	1.000		
Environment	-.111	-.063	.075	.059	1.000	

WSI	.286*	.579**	.457**	.525**	.101	1.000

Source: Computed by author

The components with greater correlation with WSI are access, use and capacity. Resource and environment component show very low correlation of .28 and .10 respectfully. The component access and use (.57) and capacity and use (.46) depicts positive correlation each. The intensive study on spatial scale of community (block) level reveals that all variables for component are conceivable to assess the water scarcity index and no single component owns to the result. This suggests that the impact of relatively each indicator is proportionate, which marks a well contracted composite index.

Conclusion

Within the pretext of limited data availability and contextualizing scarcity related to water resources, this paper came up with a set of indicator which could reflect the physical, social, economic and environmental dimension of water scarcity. A set of 12 indicators covering variety of subjective dimensions of water scarcity is undertaken in an already marginalized arid region of Haryana in Mahendragarh district deprived of natural resources and economic development. The study reveals that the water poverty situation is worse in its measurement scale with average score for the district as 37.8. Poor accessibility (38.78), water use in-efficiency (26.64) and poor environment integrity (32.64) reflects that water scarcity is a multidimensional phenomena. The study results suggest need of location specific efforts to deal with the grim situation of water scarcity. The water poor blocks with weakest scarcity index should be a top priority. A joint effort at community level and assistance from external sources is the need of hour.

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