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Estimation of Water Scarcity in Bundelkhand Region of Madhya Pradesh: An Inter-District Analysis

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ABSTRACT

This study deals with the estimation of water scarcity in Bundelkhand region of Madhya Pradesh. Water Poverty Index (WPI) has been developed for the estimation of water scarcity. The objective of the study is 'to estimate the water scarcity in the Bundelkhand region of Madhya Pradesh' and 'to find out the factors responsible for the water problem in the region'. The study includes six districts of Bundelkhand region of Madhya Pradesh namely Chhatarpur, Damoh, Datia, Sagar, Panna, Tikamgarh. Twelve indicators under five components *i.e.*, Resource, Capacity, Access, Use and Environment has been selected for the development of WPI. Secondary data has been used for the development of Index. The result of WPI shows Damoh district with lowest WPI score while Sagar district with highest WPI score followed by Chhatarpur, Datia, Panna, Tikamgarh.

Key Words : Water Scarcity, Water poverty, Water crisis, Water resource management, Water Poverty Index, Water scarcity assessment, Bundelkhand water crisis

INTRODUCTION

Water is one of the important resources available on earth. It is an essential resource for the survival of all forms of life. It is also one of the most important basic requirements of humans. It is used for domestic (drinking, cooking, bathing, sanitation etc.) as well as productive purposes (agriculture, industries etc.). Apart from this it is also an important part of our ecological system. Only three per cent of water present on earth is fresh water rest ninety-seven per cent is saline. Of these three per cent, only twelve per cent is accessible (eleven per cent in the form of extractable ground water and one per cent as surface water in rivers and lakes), rest eleven per cent is unextractable ground water below eight hundred metre and seventy seven per cent is locked up in glaciers and permanent snow (Jha, 2018).

Water problem has been an emerging issue globally. The problem is increasing due to natural as well as anthropogenic causes. The factors like population growth, climate change, mismanagement of water resources, pollution etc. are putting heavy pressure on available water resource.

Since the beginning of twentieth century, about 64-71% of the natural wetland area has been declined due to anthropogenic causes, which led to have had a huge negative impact on hydrology, from local to regional and global level. At present, there is approximately 25% deficit of safe drinking water globally and with rapid increase in population the deficit is expected to increase by around 40% by 2050 (UN WWDR, 2018).

The trend in quality and availability of water also gets affected by changes in flood and drought risks. Around the world, billions of people get affected by drought and desertification. This has significant socio-economic impact as income per capita goes down. Also, water related disease spread, which is caused due to poor water quality and accessibility, is one of the major problems in such regions. There are numerous episodes of sickness and millions of deaths each year because of

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water related diseases. Globally around 748 million people lack access to safe drinking water. Around 2.5 billion people lacked access to improved sanitation facility in the year 2012 (WHO and UNICEF, 2014). Access to water is very important for family's health and social dignity. Water is also an essential input in agricultural and manufacturing sector. This productive use of water helps inrealizing the livelihood opportunities, income generation, etc. The lack of water for agriculture and allied sector as well as on manufacturing sector results into numerous problems like food and nutritional security, livelihood threat, migration, conflicts etc. This lack of access to adequate and safe water leads to poverty. Water and poverty are interrelated. While better water management can help in building capacity, livelihood opportunities, improving social and economic condition, empowerment, water-related disaster prevention and management, and ecosystem management, which leads to the reduction of poverty, on the other side poverty itself can have negative impacts on the management of water resources and services, as sustainability of water resources needs proper maintenance. Water is also crucial for proper functioning of ecosystem.

Water is closely related to the well-being of human. The access to safe water is essential for the human development as it is important for improved life, health, sanitation and livelihood. *Human development is about enhancing human capabilities which makes the ability to live a standard quality of life, and be educated and healthy*. Provision of safe drinking water and sanitation plays an important role in the growth and development of economy. Women and children's often bear the responsibility of collecting water from distant sources in water problematic regions, which compromises their time which can be used productively. Provision of safe water also help in decreasing child and maternal mortality. Therefore, water not only helps in fighting hunger and malnutrition, but also plays an important role in generation of healthy and educated workforce. Human development and water are interrelated. While provision of safe water helps in human development, human development also helps in better management of water problems (Lawrence *et al.*, 2002).

"Semi-arid Bundelkhand, the home of over 15.62 million humans and 8.36 million livestock suffers from water scarcity, natural resource degradation, low crop productivity (1–1.5 Mg/ha), low rainwater use efficiency (35–45%), high erosion, poor soil fertility, frequent droughts, poor irrigation facilities, heavy biotic pressure on forests, inadequate vegetation cover and frequent crop failure resulting in scarcity of food, fodder and fuel" (Palsaniya *et al.*, 2008).

Bundelkhand region has been in the news for past two decades due to persistent water crisis and its severity of drought. Drought used to occur in the past also but the frequency and intensity was relatively less. The intensity and frequency of drought have increased with time. There has been a consecutive drought year also. The Bundela and Chandela rulers in the past have managed water resources by constructing water reservoirs popularly known as Bundela tank, Chandela tank to tackle water crisis situation. However, at present the Bundelkhand region is well known for water resource problem. The region is facing severe water problem due to various natural as well as anthropogenic causes. The failure of monsoon leads to failure of crops as the agriculture in Bundelkhand region is mainly dependent on monsoon. The people in the region have been facing various socio-economic problems due water scarcity. The problem in the region has been increased due to climatic causes, inadequate water management practices, mis-management of traditional water reservoirs, unequal distribution of resources due to caste based social structure, absence of proper water management and drought proofing measures, changing cropping pattern to water-intensive crops and absence of proper coping mechanism. (Ravandale *et al.*, 2020)

So, in order to estimate the water scarcity and to find out the factors responsible for water problem in the region Water Poverty Index (WPI) is developed for the Bundelkhand region of Madhya Pradesh. It will help in identifying the sectors which needs to be improved in order to mitigate the water problem. It will also help in prioritizing the water needs of people in the region. The development of this index will further help in monitoring the improvement in various sectors over the regular intervals.

Water Poverty Index (WPI) is a multidisciplinary holistic tool, which was introduced by Sullivan *et al.* (2002) for estimating water scarcity. It captures physical, socio-economic and ecological factors of water poverty. It is one of the effective tools for estimating water scarcity. *It includes the indicators of physical availability of water as well as of socio-economic drivers of poverty along with environmental water needs.*

"The conventional methods to assess water management were purely deterministic, relying on the availability of large-scale data. A method that is easy to calculate, cost effective to implement, based mostly on existing data, and that uses a transparent process (i.e., easy to understand) was needed by policy makers and funding agencies. This motivated Sullivan et al. (2002) to design the WPI as an alternative water situation assessment tool" (Charles Van Der Vyver, 2013)

"Water Poverty Index is a new, holistic tool designed to contribute to more effective water management. The index has evolved out of an extensive period of consultation with people and agencies from many parts of the world and it has come to be regarded as the useful contribution to the suite of tools available to improve the effectiveness of Water management" (Sullivan *et al.*, 2003)

The application of WPI has been done on various region around the world including in India at various scales. At community level in South Africa, Tanzania and Sri Lanka (Sullivan *et al.*, 2002), at town level in Vaal triangle region in South Africa (Vyver, 2013), at district level in Golestan province of Iran (Shalamzari and Zhang, 2018), at national scale consisting of 140 countries (Lawrence *et al.*, 2002) and 30 countries of Meena region (Jemmali and Sullivan, 2014), at basin level in Peru (Garriga *et al.*, 2008). In India at block level in Palakkad district of Kerala (Antony *et al.*, 2012), in Vellore Taluk of Vellore district of Tamil Nadu (Maheswari *et al.*, 2017), at community level in Vidisha district of Madhya Pradesh (Wilk and Jonsson, 2013), at village level in Mon district of Nagaland (Sharma *et al.*, 2010). Basin level study in India, Nepal and Pakistan (Merz *et al.*, 2004).

Objectives:

The main objectives of the study are:

– To estimate water scarcity in the Bundelkhand region of Madhya Pradesh.

– To understand the factors responsible for water problem in the above study region.

Study Area:

Bundelkhand regionlies between Indo-Gangetic plain in north and undulating Vindhyan mountain range spread across the northwest to the south. It is situated at the central part of India. The Bundelkhand region covers an area of 7.08 million hectares. The region is administratively divided between two states *i.e.*, Uttar Pradesh and Madhya Pradesh. Bundelkhand region includes thirteen districts in which seven districts namely Banda, Chitrakoot, Mahoba, Lalitpur, Hamirpur, Jhansi, Jalaun are from U.P. and six districts namely Chhatarpur, Damoh, Datia, Sagar, Panna, Tikamgarh from Madhya

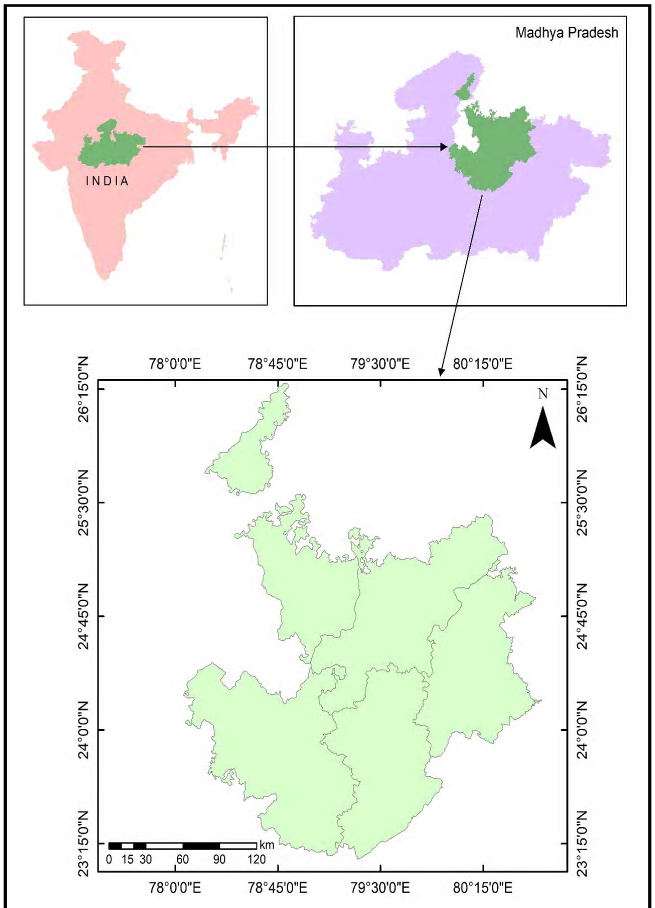

Fig. 1 : Location Map of Study Area

Table 1: Locational extent of districts of Bundelkhand region of Madhya Pradesh

District	Locational Extent
Chhatarpur	24°6´ to 25°20´ N latitude and 78°59´ to 80°26´ E longitude
Damoh	23°9´ to 24°27´ N latitude and 79°3´to 79°57´ E longitude.
Datia	25°28´to 26°20´ N latitude and 78°10´to 78°45´ E longitude
Panna	23°45´ to 25°10´ N latitude and 79°45' to 80°40´ E longitude
Sagar	23°10´ to 24°27´ N latitude and 78°04´to 79°21´ E longitude.
Tikamgarh	24°26´ to 25°34´ N latitude and 78°26´ to79°21´ E Longitude.

Table 2: Demographic profile of Bundelkhand region of Madhya Pradesh[1]

District	Population		Sex Ratio	Population Density per Sq Km		Percentage of Rural Population		Percentage of growth Rate
	2001	2011	2011	2001	2011	2001	2011	2001-11
Datia	6,28,240	7,86,375	875	224	292	79.3	76.8	18.4
Chhatarpur	14,74,723	17,62,857	884	171	203	78	77.4	19.5
Tikamgarh	12,02,998	14,44,920	901	238	286	82.3	82.7	20.1
Panna	8,56,558	10,16,028	907	122	142	87.4	87.7	18.6
Damoh	10,83,949	12,63,703	896	148	173	81.1	80.2	16.6
Sagar	20,21,987	23,78,295	913	197	232	70.8	70.2	17.6
MP Average			930	196	236	73.5	72.4	20.3
India Average			940	324	382	72.2	68.8	17.6

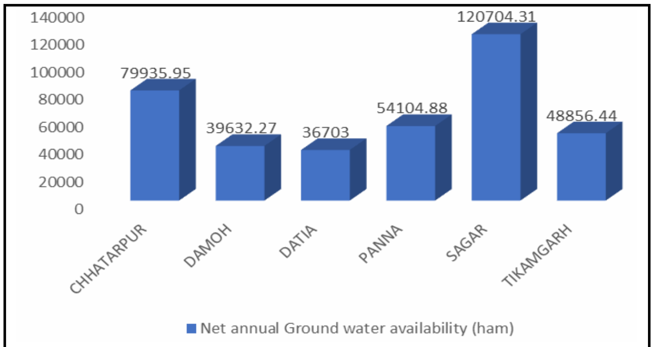

Fig. 2 : Bar diagram of Net Ground water availability in hectare-metre (ham)[2]

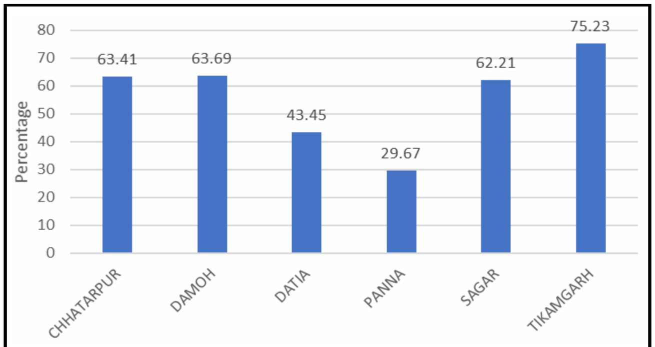

Fig. 3 : Bar diagram of stage of ground water development[3]

Pradesh. Bundelkhand region lies between 23020' and 26012'N latitude and 78020' and 81040'E longitude (NGSI, 1989; Gupta *et al.*, 2014).

The study area includes the six districts of Bundelkhand region of Madhya Pradesh.

METHODOLOGY

"The term 'Water Poverty' captures these deprivations which is people centred and has its links with general poverty. While the term water scarcity is based on the situation of the water resources" (Lawrence *et al.,* 2002).

Key Components of Water Poverty Index:

The basic structure of Water Poverty Index is made up of five major components Resource, Capacity, Access, Use and Environment; each component is made up of various sub-components identified to capture a wide range of water problems (Sullivan *et al.*, 2002)

For the development of Water Poverty Index for 6

Component	Definition
Resource	Estimates of physical availability of surface and ground water, taking account of the variability and quality of the resource as well as the total amount of water.
Capacity	Focuses on the effectiveness of people's ability to manage water. Capacity is interpreted in the sense of income to allow purchase of improved water, and education and health which interact with income and indicate a capacity to lobby for and manage a water supply.
Access	The extent of access to water for human use, accounting for not only the distance to a safe source, but the time needed for domestic water collection, and other significant factors. Access means not simply safe water for drinking, domestic use and hygiene but also water for irrigating crops or for industrial use.
Use	Water used for different purposes like domestic, agricultural and industrial use.
Environment	Evaluation of environmental integrity related to water and of ecosystem goods and services from aquatic habitats in the area. It includes sub-components such as biodiversity, environmental degradation, soil erosion, water quality etc. in order to capture the degree of maintenance of ecological integrity

[1]Source: Census, 2011
[2]MPWRD, 2015
[3]MPWRD, 2015

Table 3 : List of Indicators

Component	Variables	Definition	Value	Data Sources
Resource	R1	Per Capita Ground water availability	Number	MPWRD, 2015.
	R2	Variability of Average rainfall to normal rainfall	Per cent	IMD; Indiawaterportal.com; Indiarainfall.com.
Access	A1	% HH with access to safe drinking water	Per cent	NFHS-4 (2015-16)
	A2	% HH with access to Toilet	Per cent	NFHS-4 (2015-16)
Capacity	C1	Educational attainment (C1.1 Literacy rate and C1.2 Net Enrolment rate at primary level)	Per cent	Census, 2011
	C2	% of BPL HH to Total HH	Per cent	State BPL families Registration and Management System by Samagra Portal, 2018
	C3	U-5 Mortality rate	Number	Annual Health Survey, 2012-13
Use	U1	% of gross area irrigated to gross area sown/ cropped	Per cent	Directorate of Economics and Statistics, 2016-17.
	U2	Per capita ground water use for domestic and Industrial purpose	Number	MPWRD, 2015.
Environment	E1	% Forest area to total Geographical Area	Per cent	Forest Survey of India, 2017
	E2	% Wetland area to total Geographical Area	Per cent	Wetland Atlas, 2011.

districts of MP Bundelkhand 12 Indicators have been selected under 5 Components *i.e.*, *Resource, Capacity, Access, Use* and *Environment*. The list of indicators are illustrated in Table 3.

HDI method has been used for the normalization of data.

$$\mathrm{HDI} = \frac{X_t - X_{min}}{X_{max} - X_{min}}$$

Where X_i is the actual value of X for observation i, X_{min} is minimum value of X and X_{max} is maximum value of X.

Aggregation of data has been done based on equal weight method.

$$\mathrm{WPI} = \frac{w_r R + w_a A + w_c C + w_u U + w_e E}{w_r + w_a + w_c + w_u + w_e}$$

where $w_r = w_a = w_c = w_u = w_e = 1$ (for equal weights) and R is Resource component, C is Capacity component, A is Access component, U is Use component and E is Environment.

The score of WPI is between 0-100. 0 indicates the poor condition while 100 indicates best condition.

RESULTS AND DISCUSSION

Index of each components of Water Poverty Index has been calculated and the aggregation has been done based on equal weight method for the construction of Water Poverty Index.

The result of Water Poverty Index shows district Sagar (61) with highest WPI score followed by Datia (53), Chhatarpur (53), Panna (42), Tikamgarh (42), and Damoh (41) district. The result of WPI score shows that district Tikamgarh having very poor condition in Resource (9) and Access (9) component. While Panna having very poor condition in Access (14), Use (16) and Capacity (20) component. District Chhatarpur having poorest condition in Access (6) component. While Datia having poorest condition in Environment component (0). The

Table 4 : Result of water poverty index and its components

District	Resource	Capacity	Access	Use	Environment	WPI
Chhatarpur	69	86	6	60	46	53
Damoh	40	45	39	25	56	41
Datia	35	82	100	50	0	53
Panna	100	20	14	16	61	42
Sagar	87	64	57	55	41	61
Tikamgarh	9	67	9	72	52	42

result of WPI and its component is illustrated in Fig. 4 and Water Poverty Map for the region has been prepared based on result of Water Poverty Index *i.e.*, Fig. 10.

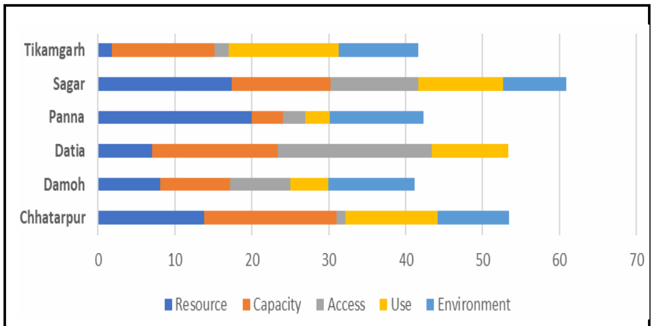

Fig. 4 : District values of Water Poverty Index

Table 5 : Resource index

Sr. No.	District	R1	R2	Resource Index
1.	Chhatarpur	74	64	69
2.	Damoh	81	0	40
3.	Datia	0	70	35
4.	Panna	100	100	100
5.	Sagar	85	89	87
6.	Tikamgarh	7	11	9

The Resource Index shows district Panna (100) with highest score followed by Sagar (87), Chhatarpur (69). While Tikamgarh (9) district with the lowest score followed by Datia (35) and Damoh (40). Datia district is having highest variability in rainfall followed by Tikamgarh, Chhatarpur. The per capita ground water availability is lowest in district Damoh followed by Tikamgarh, Chhatarpur, Datia. District Tikamgarh is in worst condition due to high variability in rainfall and low per capita availability of ground water. The result of Resource component is illustrated in Fig. 5 and resource map for the region has been prepared based on result of Resource Index *i.e.*, Fig. 11.

Table 6 : Capacity Index

Sr. No.	District	C1	C2	C3	Capacity Index
1.	Chhatarpur	58	100	100	86
2.	Damoh	78	13	46	45
3.	Datia	87	79	79	82
4.	Panna	61	0	0	20
5.	Sagar	50	59	83	64
6.	Tikamgarh	50	56	94	67

The Capacity Index shows district Chhatarpur (86) with highest score followed by Datia (82), Tikamgarh (67), Sagar (64). While district Panna (20) with lowest score followed by Damoh (45). The Educational attainment is lowest in Sagar and Tikamgarh district followed by Chhatarpur and Panna district. The Economic capacity is lowest in Panna district followed by Damoh, Tikamgarh, Sagar and Datia. The economic capacity is low due to high no. of BPL households. While health attainment is lowest in Panna district due to high U-5 Mortality rate followed by Damoh, Datia and Sagar district. District Panna is in worst condition incapacity component due to lowest health attainment, low economic

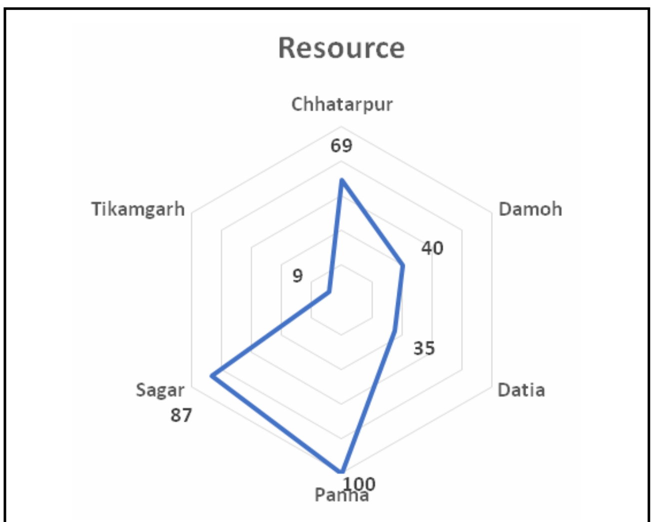

Fig. 5 : Pentagram of Resource Index

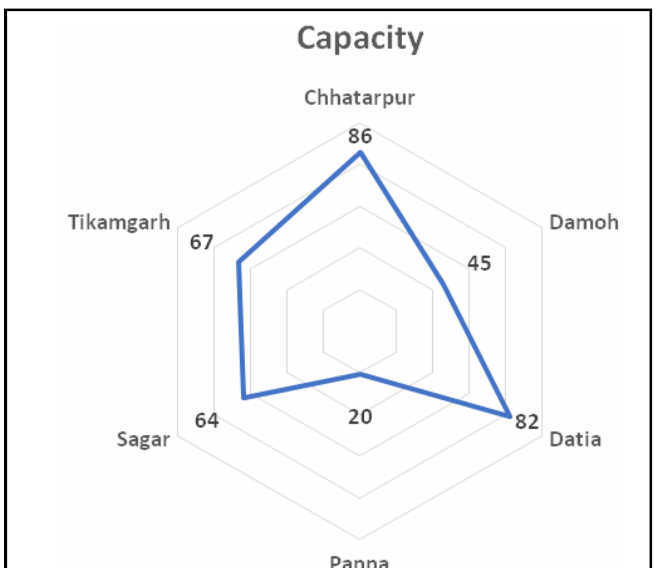

Fig. 6 : Pentagram of Capacity Index

capacity and poor educational attainment. The result of Capacity component is illustrated in Fig. 6 and Capacity map for the region has been prepared based on result of Capacity Index *i.e.*, Fig. 12.

Table 7: Access Index

Sr. No.	District	A1	A2	Access Index
1.	Chhatarpur	12	0	6
2.	Damoh	49	29	39
3.	Datia	100	100	100
4.	Panna	0	28	14
5.	Sagar	69	45	57
6.	Tikamgarh	12	7	9

The Access Index shows district Datia (100) with highest score followed by Sagar (57) and Damoh (39) district. While district Chhatarpur (6) with lowest score followed by Tikamgarh (9), Panna (14) and Damoh (39). The access to toilet is very poor in Panna district followed by Chhatarpur, Panna and Damoh. The access to drinking water is very poor in Chhatarpur district followed by Tikamgarh, Panna, Damoh and Sagar district. Chhatarpur district is having poor score in Access component due to poor condition in access to Toilet and drinking water. The result of Access component is illustrated in Fig. 7 and Access map for the region has been prepared based on result of Access Index *i.e.*, Fig. 13.

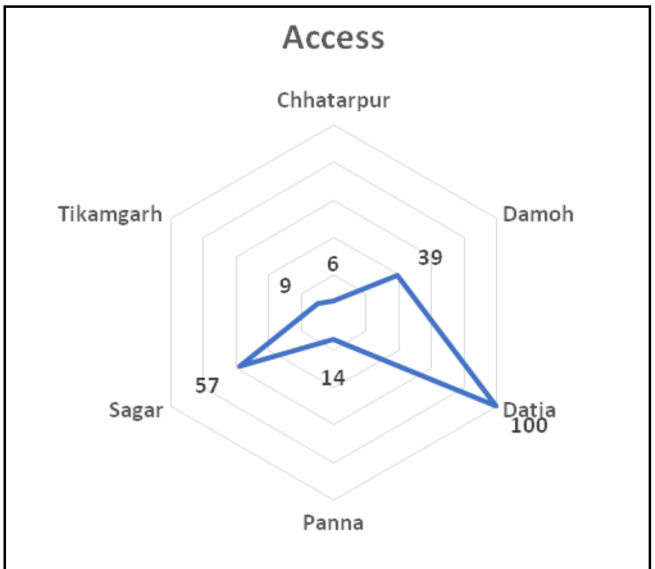

Fig. 7 : Pentagram of Access Index

The Use Index shows district Tikamgarh (72) with highest score followed by Chhatarpur (60), Sagar (55), Datia (50). While Panna (16) with lowest score followed Damoh (25). Gross irrigated area to gross area sown is lowest in Panna and Damoh district followed by Sagar, Chhatarpur and Tikamgarh. Water use for domestic and industrial sector is lowest in Datia followed by Panna and Damoh district. District Panna is having lowest score in Use component due to poor irrigation and low water use for domestic and Industrial purpose. The result of Use component is illustrated in Fig. 8 and Use map for the region has been prepared based on result of Use Index i.e., Fig. 14.

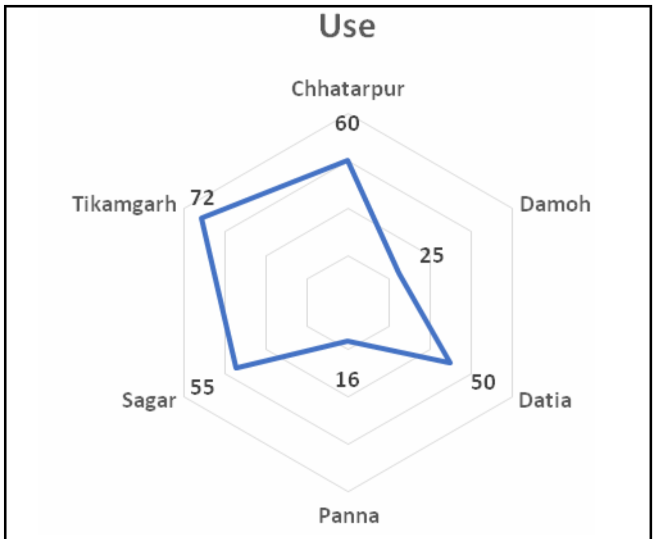

Fig. 8 : Pentagram of Use Index

Table 8: Use Index

Sr. No.	District	U1	U2	Use Index
1.	Chhatarpur	20	100	60
2.	Damoh	0	50	25
3.	Datia	100	0	50
4.	Panna	0	32	16
5.	Sagar	10	99	55
6.	Tikamgarh	56	87	72

Table 9: Environment Index

Sr. No.	District	E1	E2	Environment Index
1.	Chhatarpur	46	46	46
2.	Damoh	94	18	56
3.	Datia	0	0	0
4.	Panna	100	22	61
5.	Sagar	67	15	41
6.	Tikamgarh	4	100	52

The Environment Index shows district Panna (61) with highest score followed by Damoh (56), Tikamgarh

(52). While district Datia (0) with lowest score followed by Sagar (41) and Chhatarpur (46). Percentage of forest area to total area is lowest Datia followed by Tikamgarh, Chhatarpur and Sagar. While Wetland area is lowest in Datia followed by Sagar, Damoh and Panna. District Datia is having lowest score in Environment component due lowest percentage of forest area and wetland. The result of Environment component is illustrated in Fig. 9 and Environment map for the region has been prepared based on result of Environment Index *i.e.*, Fig. 15.

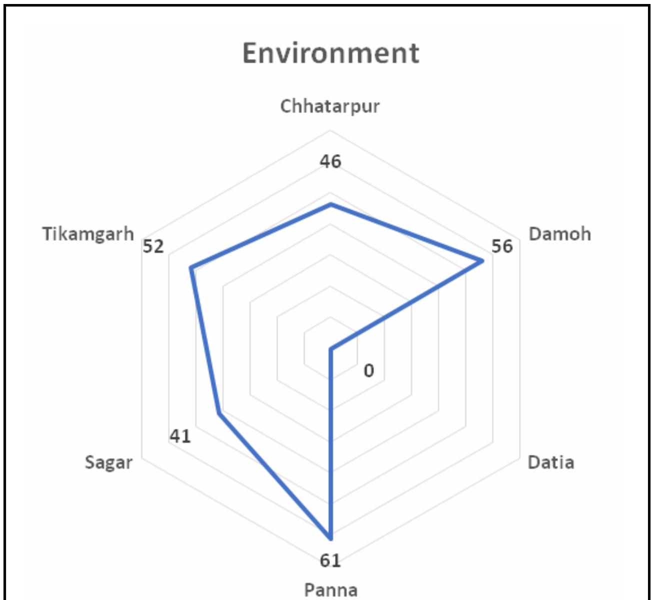

Fig. 9 : Pentagram of Environment Index

The result of correlation shows the high association between Use and Capacity component. There is a positive correlation between Capacity and WPI. Resource component has a negative correlation with Use (-0.49), Capacity (-0.43) and Access component (-0.13). WPI has a positive correlation with all four components except Environment. Access component has a positive correlation with Capacity component (0.30). There is a negative correlation between Use and Environment

Table10: Correlation between components and WPI

	Resource	Capacity	Access	Use	Environment	WPI
Resource	1.00					
Capacity	-0.43	1.00				
Access	-0.13	0.30	1.00			
Use	-0.49	0.83	-0.02	1.00		
Environment	0.28	-0.63	-0.86	-0.31	1.00	
WPI	0.36	0.59	0.48	0.41	-0.53	1.00

Based on Karl Pearson's Correlation method

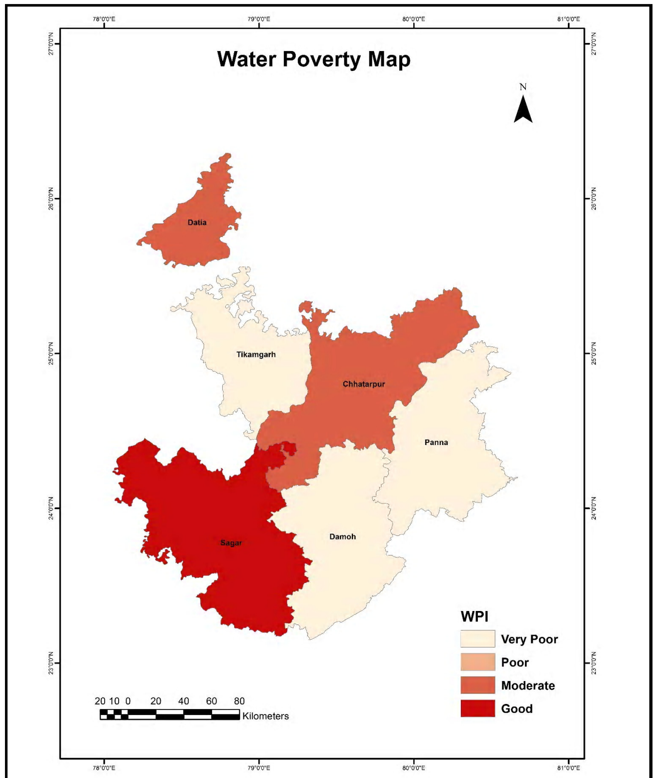

Fig. 10 : Water Poverty Map

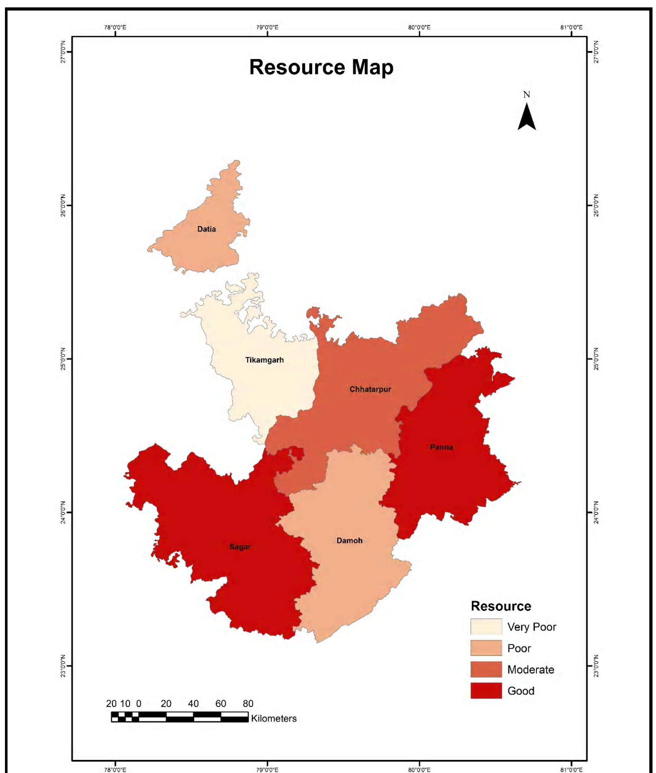

Fig. 11 : Resource Map

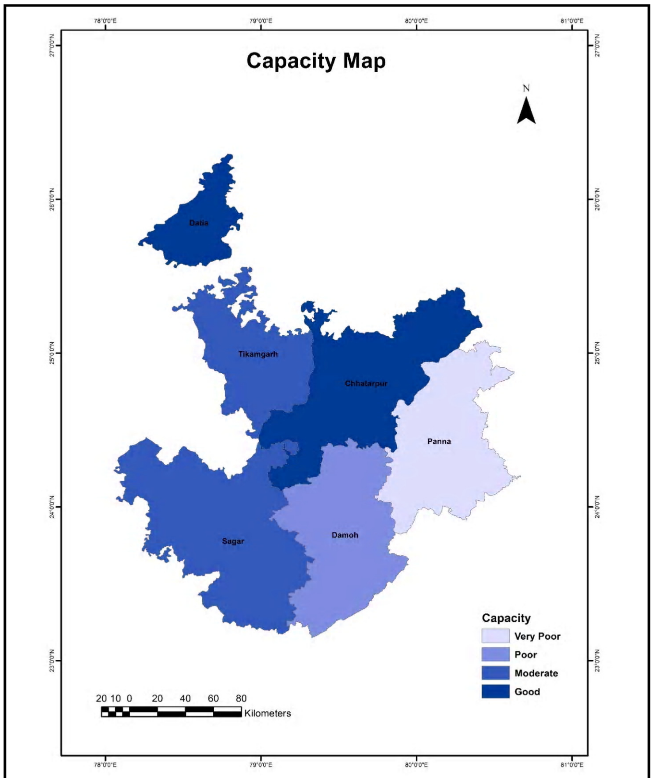

Fig. 12 : Capacity Map

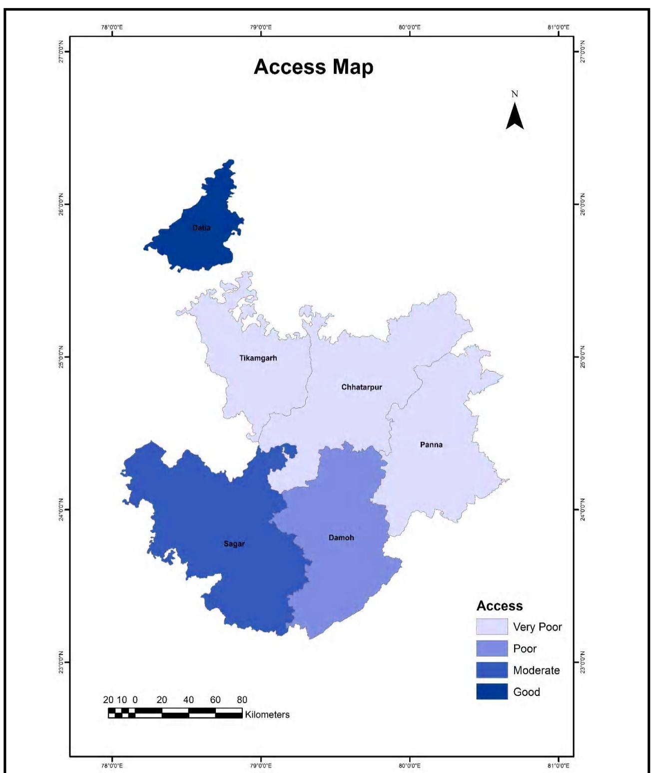

Fig. 13 : Access Map

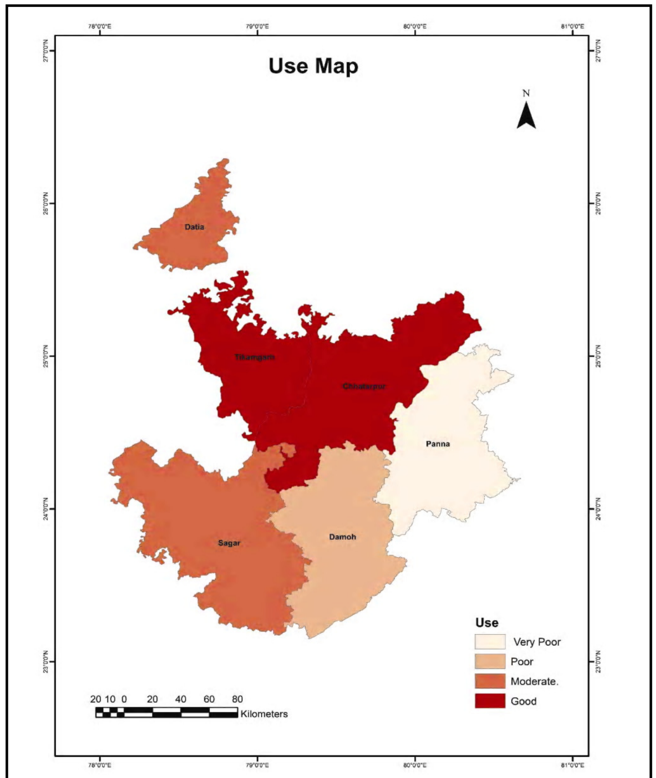

Fig. 14 : Use Map

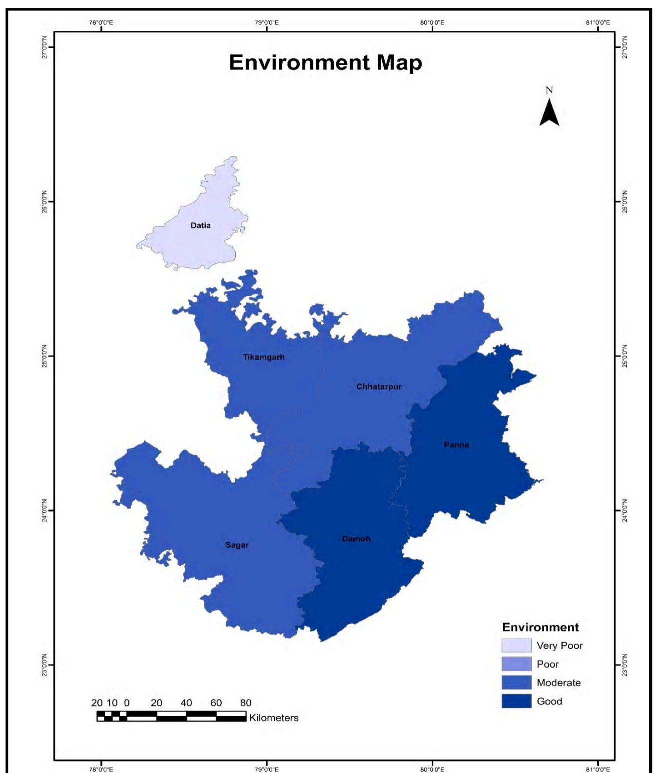

Fig. 15 : Environment Map

component (-0.31).

Conclusion:

The Resource component shows the district Tikamgarh in very critical condition followed by Datia and Damoh. The districts with high rainfall variability are Datia and Tikamgarh. While per capita ground water availability is very low in Damoh followed by Tikamgarh, Chhatarapur and Datia district. Construction of water reservoirs and water management practices are very necessary in these districts in order to address the water resource problem.

In the Capacity component district Panna and Damoh are in worst condition. The condition of educational attainment is very poor in Tikamgarh, Sagar and Chhatarpur district. While Panna, Damoh and Tikamgarh district have the low economic capacity as these districts have high no. of households, which are in the category of Below Poverty Line (BPL). While the health attainment is very poor in Panna district followed by Damoh and Datia having high U-5 Mortality rate. The improvement in health and educational sector is important along with efforts for improving economic condition.

Improvement in access to drinking water and access to toilet is very important in districts with poor access. Access to drinking water is very poor in Chhatarpur district followed by Tikamgarh, Panna and Damoh. While the access to toilet facility is very poor in Panna followed by Tikamgarh, Chhatarpur and Damoh district.

In the Use component district Panna and Damoh is in worst condition. District Panna Damoh and Sagar have very poor condition of irrigation as the gross irrigated area to gross area sown was low. The irrigation facilities must be developed by providing water and promoting efficient irrigation techniques. While the ground water use for domestic and industrial purpose is low in Datia followed by Panna and Damoh district.

In the Environment component the percentage forest area is very low in Datia and Tikamgarh district followed by Chhatarpur and Sagar. While wetland area is lowest in Datia followed by Sagar and Damoh.

The overall score of WPI shows that district Sagar with highest WPI score followed by Datia, Chhatarpur, Panna, Tikamgarh, and Damoh district. Water resource management is very important in Tikamgarh, Datia, Damoh and Chhatarpur district as these districts have very poor condition in water resource. The result of WPI score shows that district Tikamgarh having very poor condition in Resource and Access component. While Panna having very poor condition in Access, Use and Capacity component. District Chhatarpur having very poor condition in Access component. The result of WPI shows that there is a need of improvement in all the five components in order to mitigate water scarcity problem.

Development of rainwater harvesting structures and maintenance of water bodies/structures such as tanks, ponds, wells etc. will help in addressing water resource problem in districts with poor water resource. Improvement in access to safe water and sanitation should be made to ensure equitable access to improved water and sanitation facility. Provision of better health and education facility, skill development and generation of various livelihood opportunities will help in making people more resilient to water crisis. Apart from this improvement in agricultural sector should be made along with promoting efficient use of water in agriculture sector through drip/sprinkler irrigation facility. Creating awareness among people about water conservation and the collective work of administration and local people in mitigating water related problems will help in addressing the problem.

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