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Assessment of Water Poverty Index (WPI) Under Changing Land Use/Land Cover in a Riverine Ecosystem of Central India

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ABSTRACT

Watershed Development is a very common phenomenon in the river basins in India due to its dynamic and continuously changing nature, which are interconnected via. Land use/ land cover (LULC) change and water poverty scenario over time. In the present study, the samples were chosen from seven sampled villages for the Water Poverty Index (WPI) in the upper Tons River Basin. Among them, Ghunwara and Maihar Village exhibit the highest and lowest WPI, i.e., 98.1 and 62.91 out of 100, respectively. This indicates that villages with a high WPI face challenges in their water requirements, regardless of the seasonal river serving the basin area. Conversely, villages with a low WPI can satisfy their water needs solely from the basin. The present analysis of the Upper Tons River Basin suggests that Land Use and Land Cover (LULC) will undergo influences or adjustments at various stages, ultimately affecting agricultural land in the impact region. It also becomes evident that areas with limited land use and land cover (LULC) extensions exhibit lower Water Productivity Index (WPI), primarily due to their reliance on agricultural land. It is observed that alterations, reductions, or modifications in LULC lead to changes in multiple aspects of agricultural land, resulting in noticeable variations in various metrics. The present paper not only evaluates the land use in the Upper Tons River Basin spanning from 2001 to 2021 but also highlights the changing patterns that impact water resources and their utilization capacity. Furthermore, the study estimates the influence of reducing specific features on the distribution of WPI and other LULC parameters. The Upper Tons River Basin faces challenges such as unfavorable rainfall patterns and inadequate planning for irrigation at the fundamental and local levels. Additionally, its geographical location in a rainfed area negatively affects the WPI.

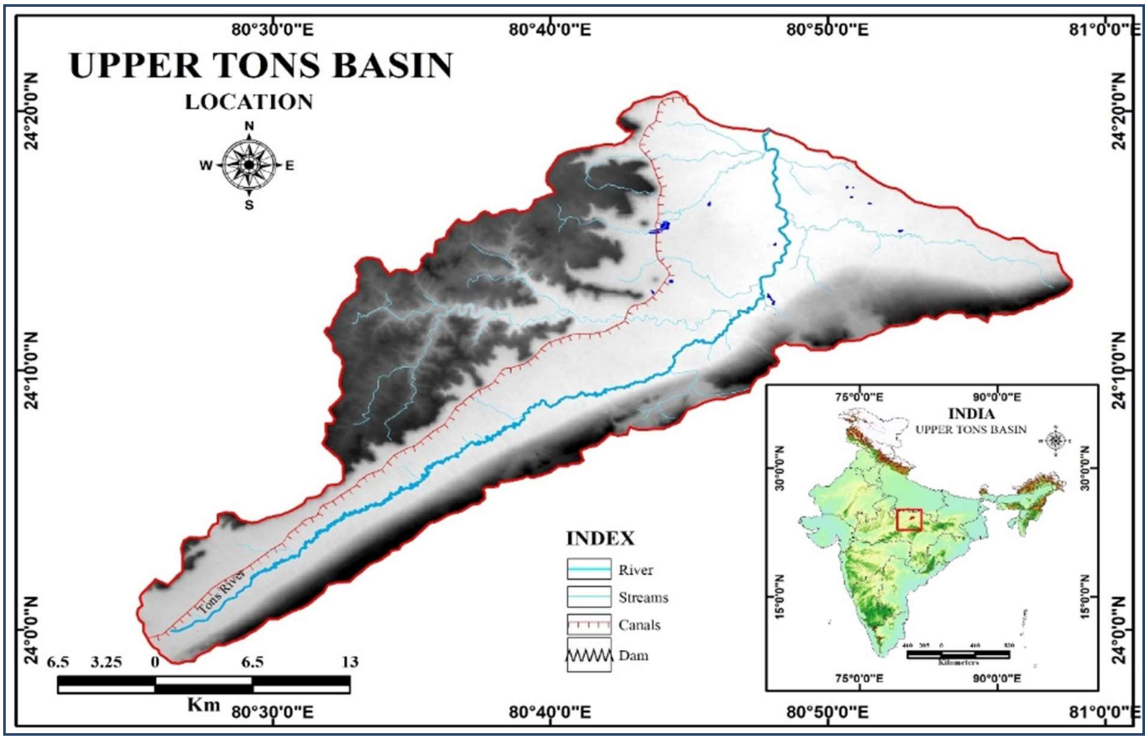
INTRODUCTION

The term "land cover" refers to the different types of natural and man-made features that can be found on the surface of the earth. This can include both natural and man-made buildings. Land usage refers to how humans use the land and its resources for a variety of reasons. Land usage and land cover have always been subject to change wherever there has been population growth, technical advancement, or economic expansion. This has always been the case (Biswas et al. 1999). Human actions have had a direct or indirect impact on the natural environment. Human production demands cannot be satisfied without modifying or converting land cover. It is anticipated that the most significant problems that the world will face in the coming century will be caused by significant shifts in the usage and coverage of land (Cox 1994). Forest, woodland, and grassland on a global scale have been converted to varied purposes in one way or another over the last three centuries to suit society's and economy's expanding demands (Bhatt & Ahmed 2014). The most significant aspects of world change at the moment are the intensification of agriculture, the urbanization of previously rural areas, and the clearing of land, all of which are the result of human activity (Grohmann 2004). Thematic layers for morphometric analysis are created via Remote Sensing (Patel et al. 2022, Barman et al. 2021, Bhatt et al. 2021, 2023). Land use maps, on the other hand, are renowned for better and more specific analysis within basins and changes, allowing for a better understanding of the basin's present Land use (Ganas et al. 2005). This project's main objectives were to conduct a LULC investigation of the Upper Tons River Basin and determine various parameters using various parameters such as The study of land use in the present context is the distribution of Northern Jharkhand's surface area with all of its natural environment and human circumstances to evaluate its socio-economic development (Stamp 1960).

Due to increased urbanization and commercialization of land in both urban and rural areas, the changing forest area and diminishing agricultural land have been offset by an increase in non-agricultural land. Changing rural morphology and rising concretization have been the formal process in recent years, where individuals have become much more competent and awarded to earning chances and modifying the various locations in which they are. Land use change may be seen over 20 years when it will be considerably more obvious. Land use is an essential component of geographical studies, and the way a region's land is utilized and maintained may be used to gauge its progress to some extent (Choudhary 2002). The practice of investigating the land use for a certain goal is known as land utilization. Land use affects the natural and human environment, which is inextricably linked to physical, climatic, and educational factors, as well as human activities that alter those variables to achieve certain aims (Al Saud 2009). The geographical distribution of sunlight, rainfall, the topography of the land, drainage quality, mineral availability, and the position of human settlement in relation to market centers and transportation lines all influence Land use. The aim and nature of land use are influenced by the geographical differentiation of these aspects. Although the area suitable for anyone's use is frequently relatively limited, the land on the earth's surface has potential value for some use or combination of purposes. Land use is a notion that has been devised to suit practical reasons and refers to the interplay of land and the environment. The primary goal of a Land-use Survey is to document the distribution of land under diverse uses in varied socioeconomic and environmental situations and to allocate resources to enhance those uses using scientific principles while avoiding environmental deterioration. As a result, LULC planning is required to meet the changing demands of the population.

LULC planning's purpose is to guide LULC decisions in such a manner that all available environmental resources are put to the best possible use while also being conserved for the future. LULC planners have the primary responsibility of analyzing diverse land features in terms of various natural aspects and recommending the optimal use under prescribed management techniques for long-term utilization. Any alternate land use should be recommended without disrupting the area's natural equilibrium. The purpose of this study is to investigate the alterations that took place in Northern Ethiopia's land use and land cover as a direct result of the implementation of integrated watershed management. Alterations to land use and plant cover are among the alternatives for watershed management. These alterations are made to rehabilitate degraded areas and protect soil and water systems. Integrated watershed management seeks to enhance people's living conditions by reducing population pressure, increasing land productivity, and ensuring sustainable livelihoods and land use practices. These goals can be accomplished through enhancing land production and lowering population pressure. If the intervention strategy and its results are carefully analyzed and researched, it may be possible to foster the replicability of land resource management. As a consequence of this, the primary concerns of the research are the implications of integrated watershed management and the shifts in the dynamics of land use and land cover.

The idea of poverty used in the WPI's framework is based on research by Townsend (1979) and Sen (1983, 1985, 1995, 1999), and it has been expanded by Desai (1995). It is recognized that poverty is a state brought on by a lack of capabilities. Building on the fundamental needs method that was initially proposed by Pigou (1920), Sen has shown that poverty is the result of a lack of at least one of the fundamental conditions (or talents) that are necessary for a productive living. In this sense, we are linking an absence of water with a shortage of one of these essential necessities; nevertheless, an absence of water will also have a variety of additional repercussions. For instance, it can be demonstrated that a lack of water has a direct impact on health since personal and food cleanliness would be compromised. Additionally, bad water quality or polluted water can cause a variety of diseases. As a consequence of this, having limited access to it will affect the functioning of the economy, and the obvious but occasionally neglected time that will be spent harvesting water will be time that cannot be used for other purposes. It is expected that a lack of water will have a severe impact on the ecology of the area by either hastening the process of desertification and wind-driven soil erosion or reducing the rate at which biomass may develop. To better understand the many ways in which this impacts people's lives, we can look to the Sustainable Livelihoods Framework (Scoones 1998, Carney 1998), which donor organizations frequently use to measure the success of development efforts. The framework examines the impacts of development in terms of a number of qualities, which are referred to as capitals or assets for maintaining lifestyles and are described as natural, physical, financial, social, and human assets. The framework also evaluates the effects of development in terms of a number of other characteristics. We use a mix of some or all of these to maintain our lifestyles. Poor communities, by definition, lack some or all of the resources needed for a living. The objectives of this paper are (i) to assess the LULC changes from 2001 to 2020. (ii) To Estimate the Impact of LULC



(Source: SRTM-DEM 30m resolution)

Fig. 1: Location map of the study area.

change during the Watershed Development of the Upper Tons River Basin and (iii) to evaluate the Water Poverty Index (WPI) in the rain fade Tons River basin due to rapid urbanization and agricultural demands.

MATERIALS AND METHODS

Study Area

The Tons River Basin is located in the north-eastern part of Madhya Pradesh. The area of this basin falls in the districts of Satna, Panna, and Katni between the latitudes of 23°58'36.14"N and 24°20'41.38" N and the longitudes of 80°25'7.32"E and 80°58'47.07" E. (Fig. 1). The total area of Upper Tons River Basin is 797.93 km^2. The Upper Tons River Basin is divided into five sub-basins. The perimeter of the River Basin is 171 kilometers, and the total number of streams found in the basin is 59, having a total length of 303.97 kilometers (Yadav 2018).

Data and Methodology

The study has been conducted using secondary data from sources. Toposheets and various satellite imageries have been used in the research. The Toposheets were downloaded from the Survey of India Portal, while the Landsat 4-5 (TM) and Landsat 8 (OLI/TIRS) satellite images were downloaded from the USGS Earth Explorer Portal. The Land use-Landcover Map for the years 2001 and 2021 was created utilizing topographical maps that were georeferenced spatially and masked, along with Supervised Classification of satellite pictures using ArcGIS software.

The five essential components of the water poverty index are combined to form the broad statement shown below in Equation (1):

$$WPI = \frac{\sum_{i=1}^{N} w_i X_i}{\sum_{i=1}^{N} w_i} \quad \text{...(1)}$$

'Xi' denotes the structure for the WPI component, whereas 'wi' denotes the weight given to that component, and WPI is the water poverty index value for that site. Each component is composed of several subcomponents, which are then merged using the same method to produce the components. Equation (1) may be rewritten to account for the parts mentioned above.

$$WPI = \frac{w_r R + w_a A + w_c C + w_u U + w_e E}{w_r + w_a + w_c + w_u U + w_e} \quad \text{...(2)}$$

Equation (ii) represents the five components' weighted average (R, A, C, U, and E): resources (R), access (A),

Table 1: Comparison of water poverty index and sustainable livelihood capitals.

WPI Components	Livelihood Capitals
Resources	Natural capital, as well as physical and financial capital, represents infrastructure.
Access	Social capital, financial capital
Capacity	Human and social capital, including institutional issues and financial capital for investment
Use	Physical capital, financial capital
Environment	Natural capital

capacity (C), use (U), and environment (E). Each component is first standardized to have a value between 0 and 100. As a result, the final WPI value likewise falls within this range. The best scenario (or the lowest level of water poverty) is considered to be 100, while the worst situation (or 0) is considered to be. Other methods of integrating the data to get the WPI were taken into consideration, but it was determined that this method produced the desired results while maintaining the benefits of simplicity and clarity (Sullivan et al. 2003).

Water Poverty Index

Complex and adaptable, the Water Poverty Index (WPI) measures how severely people are affected by water scarcity. Several measures of water and human well-being are linked to reach this conclusion. This index's primary purpose is to draw attention to people who are poor and lack access to clean water. The Water Poverty Index (WPI) collaborates with other groups to study the environmental, social, and economic factors that contribute to water scarcity and the inability to put this resource to good use. Consultation with many stakeholders, politicians, and scientists establishes the five most important criteria in calculating WPI: resource (R), access (A), capacity (C), use (U), and environment (E). The WPI components and how they support themselves are listed in Table 1.

The Resource (R) factor considers the variability, quality, and quantity of available water while making an assessment (Table 2). The Access (A) factor, on the other hand, assesses how easy it is to get water by considering criteria like how far it is from homes and how long it takes for each individual to gather it. Similarly, the Capacity (C) component assesses people's abilities to manage water, which includes the amount of money individuals have available to spend on improving their water quality, education, and health. Use (U), the fourth component assesses the many uses of water, including those in the home, agricultural, and industrial settings, among others. Last but not least, the Environment (E) component analyzes the environmental quality of the water as well as an evaluation of the ecological benefits and services offered by the aquatic ecosystems in the region.

WPI Structure

The Water Poverty Index for a certain site can be determined using the method proposed by Sullivan et al. (2003), which is shown below.

$$WPI = \frac{W1 \times R + W2 \times A + W3 \times U + W4 \times C + W5 \times E}{W1 + W2 + W3 + W4 + W5}$$

Where,

Wi = is the Weight applied to each of the five components

R – Resource, A – Access, U – Use, C – Capacity, E – Environment.

These weights (Wi) cannot have a negative value, and their sum must equal one. To ensure that the WPI value falls somewhere between 0 and 100, each component has been standardized. The maximum possible score of 100 indicates

Table 2: WPI component variables for study sites.

WPI Components	Variables/Sub-components
Resources (R)	• Runoff potential • Ran potential • Variability of rainfall
Access (A)	• Time required to carry water • Reliability of pipe water supply • Percentage of agricultural land with access to the river for irrigation
Capacity (C)	• Percentage of households with economic activities
Use (U)	• Total percentage of households owning only agricultural land • Total percentage of households with agricultural land and livestock • Water required per household (domestic water demand including cattle demand)
Environment (E)	• Quality index of water sources with percentage of people dependent on similar water quality. • Percentage of area with natural vegetation.

Source: Thakur et al. (2017)

Table 3: Calculation for Resource (R) Component.

S. No.	Sample Villages	Rain Index (Ir)	Perennial river benefit factor (B)	Runoff Index (R)	Corrected Runoff Index (Ik) = (R*(1-B)+B)	Resources (R)= (Ir+Ik)/2*20
1.	Maihar	1	0.35	0.22	0.493	14.93
2.	Sarlanagar	1	0.32	0.29	0.5172	15.17
3.	Bharauli	1	0.28	0.32	0.5104	15.10
4.	Mohania	1	0.31	0.26	0.4894	14.89
5.	Ghunwara	1	0.14	0.37	0.4582	14.58
6.	Gagdi	1	0.16	0.41	0.5044	15.04
7.	Nainiya	1	0.21	0.31	0.4549	14.55

the best possible circumstance, while the lowest possible score of 0 indicates the worst possible circumstance.

Calculation of Components

Tables 4–8 describe how to calculate five components according to Coppin (1990):

Resource (R)

The Resource component is computed as follows:

$$R = \frac{Ir + Ik}{2} \times 20$$

Where,

The rain index is Ir, while the runoff index is Ik. Table 3 depicts the computation of the Resource component. The main source is excess if yearly rainfall exceeds water requirements for annual crop rotation in the area, i.e., Rain index (IR) = 1.

If annual precipitation falls 'p' percent short of what is required for agricultural production, the Rain sub-index (IR) is given a rating of 1 (p/100). The fluctuation of the climate contributes to the unpredictability of rainfall. To calculate adjusted rainfall, rainfall is multiplied by the variability of rainfall. The runoff index, denoted by the letter 'k,' is arrived at by deducting the present runoff from the sufficient perennial runoff, with the number '1' serving as the highest possible benchmark. The surface water rating is, if there is plenty of water available for domestic use, livestock, and crop irrigation, or if the water supply from a nearby source or tap reliably and indefinitely satisfies all needs. These rivers will be of assistance to many communities located along the larger rivers that are fed by snow. Using the perennial river benefit factor 'B' (benefit for all settlements = 1), one may determine what percentage of Sample Villages are comprised of such settlements. For the purpose of calculating the corrected runoff index, the factor is multiplied by the value '1' of the perennial runoff index, and the non-beneficial value (1 B) is multiplied by the runoff index that is produced by rainfall.

Access (A)

The access (A) component is computed as follows:

$$A = \frac{Id + Ii}{2} \times 20$$

Where,

The index of the amount of time that households are able to carry water is denoted by Id, and the indicator of irrigation access is denoted by Ii. The Access componentize computation is illustrated in Table 4. As a direct consequence of this, the water carrying time index is as follows:

$$R = 1 - \frac{T}{480}$$

Where,

T represents the amount of time that must be spent collecting and storing the water. According to the results of the field tests, the longest amount of time necessary to transport water is 480 minutes, while the least amount of time necessary with a direct pipe supply in the house is zero minutes. It is possible to determine it at the scale of the sample village as

$$Id = \frac{w1X\ Id1 + w2X\ Id2}{w1 + w2}$$

Where,

homes W1 and W2 are the ones who get their water from a well out in the country, whereas homes W3 and W4 get their water from a municipal pipe system. The time indexes for remote water collection are Id1 and Id2, while the time index for pipe water collection is Id2. The following is included in the irrigation accessibility index:

$$Ii = \frac{Ti}{Ta}$$

Where,

Table 4: Calculation for Access (A) Component.

S. No.	Sample Villages	Households that depend upon distant water resources (w1)	Households that depend on pipe water resources (w2	Water carrying time index for distant water source (Id1) = 1 – T/maximum time required	Water carrying time index for a pipe water source (Id2)	Water carrying Index (Id) = (w1 × Id1 + w2 × Id2)/(w1 + w2)	Irrigation access index (Ii)	Access Index (A) = (Id + Ii)/2*20
1.	Maihar	5022	8047	0.69	1	0.89	0.37	12.67
2.	Sarlanagar	153	191	0.65	1	0.86	0.38	12.45
3.	Bharauli	641	852	0.69	1	0.88	0.66	15.43
4.	Mohania	52	77	0.66	1	0.88	1.32	22.00
5.	Ghunwara	762	952	0.64	1	0.85	1.05	19.04
6.	Gaddi	137	157	0.56	1	0.81	0.95	17.69
7.	Nainiya	214	257	0.55	1	0.82	1.43	22.50

Ti is the total area in km^2 with access to irrigation, while Ta is the total arable land in km^2.

Capacity (C)

As the education component of capacity, the literacy rate is employed, while the percentage of households with economic activity is used as the economic component. Consequently, the following formula is used to compute the capacity component:

$$C = \frac{Ic + Iic}{2} \times 20S$$

Where,

Ic stands for education capacity index, while Iic stands for income capacity index.

Education capacity index

$$Ic = \frac{L}{100}$$

Income capacity index

$$Iic = \frac{Tc}{Th}$$

Where,

The letter L stands for the literacy rate, the letter Te represents the number of households in the sample villages that are involved in economic activities, and the letter N stands for the total number of households in the sample villages. The computation of the Capacity component is shown in Table 5.

Use (U)

The value of the Use component is determined by a household's average daily water use measured in liters per person. It is generally agreed that one liter per person per day constitutes the bare minimum water usage. The value of the Use component is determined by a household's average daily water use measured in liters per person. It is generally agreed that one liter per person per day constitutes the bare minimum water usage.

$$U = \frac{S + Smin}{Sr - Smin} \times 20$$

Where,

S is the quantity of water that a home uses (measured in liters per cubic meter per day), Smin is the predicted minimal

Table 5: Calculation for Capacity (C) Component.

S. No.	Sample Villages	Literacy rate (%) (L)	Education capacity Index (Ic) = (L/100)	Number of households which has economic activities (Te)	Total number of households (Th)	Income capacity index (Iic) = (Te/Th)	Capacity (C) = ((Ic + lic)/2)*20
1.	Maihar	59.14	0.59	4328	8047	0.54	11.29
2.	Sarlanagar	64.17	0.64	121	191	0.63	12.75
3.	Bharauli	61.49	0.61	581	852	0.68	12.97
4.	Mohania	80.80	0.81	43	77	0.56	13.66
5.	Ghunwara	64.16	0.64	685	952	0.72	13.61
6.	Gaddi	74.90	0.75	102	157	0.65	13.99
7.	Nainiya	69.83	0.70	193	257	0.75	14.49

water demand (measured in liters per cubic meter per day), and SR is the amount of water that is required in a home (measured in liters per cubic meter per day). The calculation of the Use component is shown in Table 6.

Again,

$$S = \frac{K}{Hs}$$

Where,

Hs is household size and

$$K = \frac{La \times Ha \times Lb \times Hb}{Ht}$$

Where,

A household (Ha) with exclusively agricultural land collects La liters of water per day, while a family (Hb) with both agricultural land and animals collects L liters per day. Ht is the total number of homes. Ht is the total number of homes in a certain area.

$$WQI = \sum_{i=1}^{7} Wi \times$$

Environment (E)

The Environment component is a weighted average of the water quality index (WQI) and the natural vegetation coverage index. WQI computation entails collecting water from the field, analyzing it in the laboratory, and ultimately calculating it as described below. The evaluation of natural vegetation is carried out by using Google Earth pictures. The Environment (E) component is computed as follows:

$$E = \frac{Iw + Iv}{2} \times 2$$

Where,

Both the Water Quality Index (WQI) and the Natural Vegetation Coverage Index (NVCI) are denoted by the letters Iw and Iv,, respectively. The results of the computation for the Environment component are presented in Table 8. According to the Natural Sanitation Foundation (NSF), the Water Quality Index (WQI) is the weighted linear sum of the sub-indices (I) that are as follows:

$$WQI = \sum_{i=1}^{7} Wi \times I$$

The weights of the nine constituents are shown as follows:

$$Iv = \frac{V}{A}$$

Where,

The natural vegetation index is denoted by Iv. V represents the natural vegetation-covered area, while A represents the Village's entire area.

RESULTS AND DISCUSSION

LULC Analysis

Changing LULC patterns are a global and regional phenomenon that affects people all over the world. Changes in LULC are influenced by changes in certain natural characteristics over a period of time. Since 2001, changes in LULC have been noticed, as seen in Fig. 2 and 3, created using the supervised classification approach in ArcGIS software, where we can see changes in all parameters. The main parts of landing have been created in the Landsat data evaluation and mapping methodologies, as shown in Table 7, where fluctuation in LULC over 20 years may be shown.

Table 7 and Fig. 2 show where vegetation cover has increased to 195.54 km² in 2021 as compared to 2001, where Vegetation cover was 176.32 km² which includes Shrubs, grasslands, Plantation crops, and forest regions from Bhander Plateau and Kaimur Hills. The built-up area has also increased by 574.8% in 2021, 17.41 km² which was

Table 6: Calculation for Use (U) Component.

S. No.	Sample Villages	No. of households	Total water demand (Tw)	Total population (Tp)	Water use S = (Tw/Tp)	Use component U = (S – Smin)/(SR – Smin)*20
1.	Maihar	8047	4278589.9	40235	106.34	17.22
2.	Sarlanagar	191	138299.28	1337	103.44	16.23
3.	Bharauli	852	331359.84	3408	97.23	14.12
4.	Mohania	77	204803.88	2316	88.43	11.13
5.	Ghunwara	952	540545.6	4760	113.56	19.67
6.	Gaddi	157	76890.75	785	97.95	14.13
7.	Nainiya	257	118078.65	1285	91.89	12.31

Table 7: LULC Assessment, 2001-2021.

S.No.	LULC	Area (km^2)		Change	
		2001	2021	km^2	%
1.	Built-up	2.58	17.41	14.83	574.8
2.	Vegetation	176.32	195.54	19.22	10.9
3.	Agricultural Land	425.68	434.84	9.16	2.1
4.	Fallow Land	148.62	93.32	-55.3	-37.2
5.	Barren Land	33.21	52.61	19.4	58.4
6.	Waterbodies	11.52	4.21	-7.31	-63.4
Total		797.93	797.93	0	0

(Source: Supervised Image Classification, Landsat 05 and 08, 2001-2021)

2.58 km^2 only. The area under the Agricultural land was 434.84 km² in 2021, which was 425.68 km² with an increase of 2.1%. Area under Fallow and Barren Land is 93.32 km² and 52.61 km² in 2021 which was 148.62 km² and 33.21 km² out of which fallow land has decreased by – 37.2% and barren land increased by 58.4 %, whereas waterbodies with the total area of 4.21 km² in 2021 have recorded decrease of – 63.4% with compared to 2001 where it was 11.52 km².

Table 7 also shows the land use evaluation from 2001 to 2020, showing that the vegetation cover rose by 21.41 km^2 or 22.49%, which is a very good number. 33.12% increase in grassland has also been noted. It's also worth mentioning that the district's 15.86 percent rise in the built-up area has been a key influence in the Land use shift. Map 2 depicts the shift in land use from 2001 to 2020. The changes in the LULC components, particularly in Vegetation, Agriculture, and Plantation, are vividly visible on the map.

Further from Fig. 2 itself, we can infer that the vegetation level has subsequently increased on account of the decrease in the fallow land with respect to the conversion of traditional agriculture. Area Underwater bodies have also decreased with the increase in agricultural land and built-up areas. An increase in the barren land on account of fallow land has a major impact on the river basin and the agricultural practices for the future perspectives. From Fig.3, it can be inferred clearly that subsequent changes in LULC and its components have been recorded. The agriculturally induced LULC change is the main factor of change, which has further transferred into all other land use components. We all know that land use change is influenced by economic and social activities, as well as temporal variations based on ground observations, departmental assessments, and remote sensing surveys, which may be used to detect land use change and compute the Change Matrix.

According to the study topic, the decadal Land Use Change Matrix has an influence on the landscape owing to shifts in economic activity. It is used during the transition of agricultural methods from traditional to plantation crops. The ensuing shift in land use patterns has been a widespread and natural process that has been documented and a matrix created.

The decadal shift is also subject to a behavioral and social baseline, which has developed during the district's land use change journey's several transitional phases. In terms of demographics, the transition from rural to urban

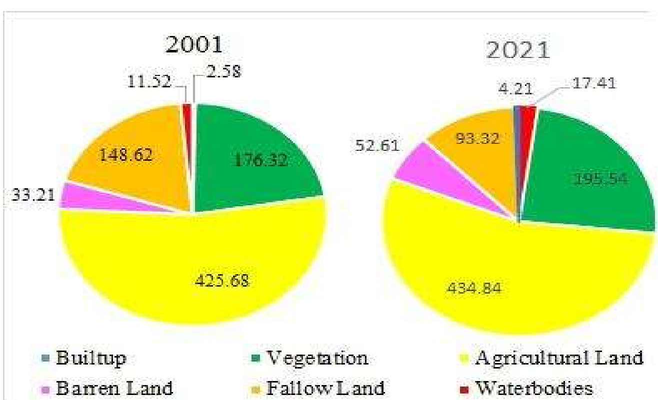
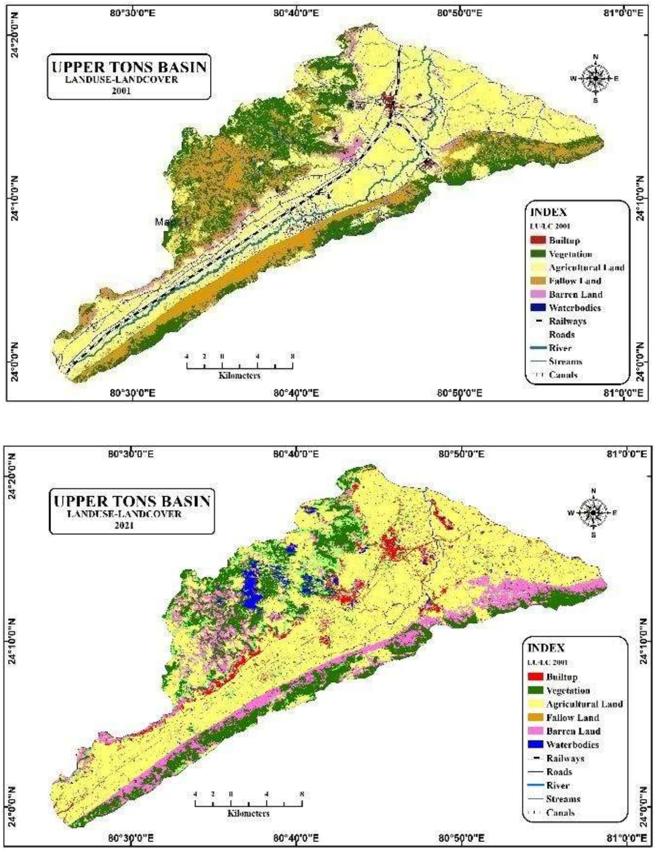


Fig. 2: LULC Assessment, 2001-2021 and Change.



(Source: Landsat 05, USGS Earth Explorer, Path-143, Row-043, taken on 08.06.2001)

Fig. 3: LULC Map of Upper Tons River Basin, 2001 and 2021.

causes a shift in economic activity behavior to improve their living standards. As a result, the fundamentals of land use have changed, both on the ground and through mapping and statistical methods. It's also worth noting that between 2001 and 2010, the biggest shift in the temporal land use pattern was evident based on vegetation, cash crop planting, and shrinking Barren land limitations.

The change in Land use has also been the pull factor around the urban centers and induced rural-to-urban migration in the purview of the district boundary and away from it to neighboring urban centers. The demographic increase has created new settlements around and nearby to an urban and leaner extent along the Roads and other types of transportation.

Any number that is larger than 75 will be considered extremely low, and any number that is less than 25 will be considered extremely high. Any Figure that is greater than 100 or less than zero will be adjusted to 100 or zero. It was

Table 8: Calculation for Environment (E) Component.

S. No.	Sample Villages	Vegetation area (Iv)	WQI for various sections			eWQI (Iw)	Environment (E) = (Iw + Iv)/2*20
			Western	Central	Eastern		
1.	Maihar	0.17	-	-	100	0.51	6.8
2.	Sarlanagar	0.31	-	-	50	0.93	12.8
3.	Bharauli	0.44	-	50	-	1.32	17.6
4.	Mohania	0.21	-	50	-	0.63	8.4
5.	Ghunwara	0.78	50	-	-	2.34	31.2
6.	Gaddi	0.16	50	-	-	0.48	6.4
7.	Nainiya	0.28	50	-	-	0.84	11.2

Table 9: WPI for upper tons river basin.

S. No.	Sample Villages	Resource (R)	Access (A)	Capacity (C)	Use (U)	Environment (E)	WPI
1.	Maihar	14.93	12.67	11.29	17.22	6.8	62.91
2.	Sarlanagar	15.17	12.45	12.75	16.23	12.8	69.4
3.	Bharauli	15.10	15.43	12.97	14.12	17.6	75.22
4.	Mohania	14.89	22.00	13.66	11.13	8.4	70.08
5.	Ghunwara	14.58	19.04	13.61	19.67	31.2	98.1
6.	Gaddi	15.04	17.69	13.99	14.13	6.4	67.25
7.	Nainiya	14.55	22.50	14.49	12.31	11.2	75.05

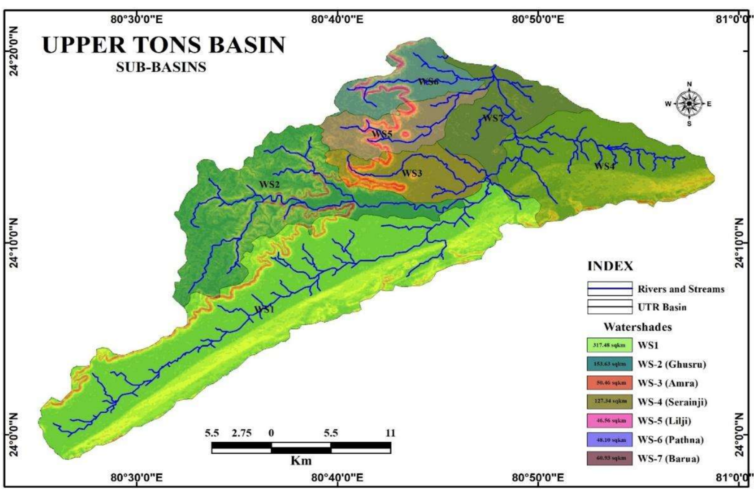
decided to give each component of the WPI framework the same amount of weight. Hence, W = 1 was entered into equation 1. After multiplying each factor by 20, the resulting score, which ranges from 0 to 100, is then tallied. The average WPI for the upper Tons River basin is shown in Fig. 4, with the Environment Component having the lowest score and the Access Component having the highest score. The final WPI score for each of the 7 Sample Villages in the research region, as well as the scores for each component, can be found in Table 9 which can be found below.

The outcomes shown here are the product of the WPI's initial development and use at the local level. It is obvious that a thorough examination of the claim that the index values accurately reflect the extent of water poverty is not practicable. Instead, we used a consultative approach. Participants at workshops from a variety of national and local government agencies learned about and contributed to the index as well as compared the findings to their in-depth local knowledge. Participants in each case concurred that the WPI and its underlying elements accurately reflected the state of the communities.

Watershed Development

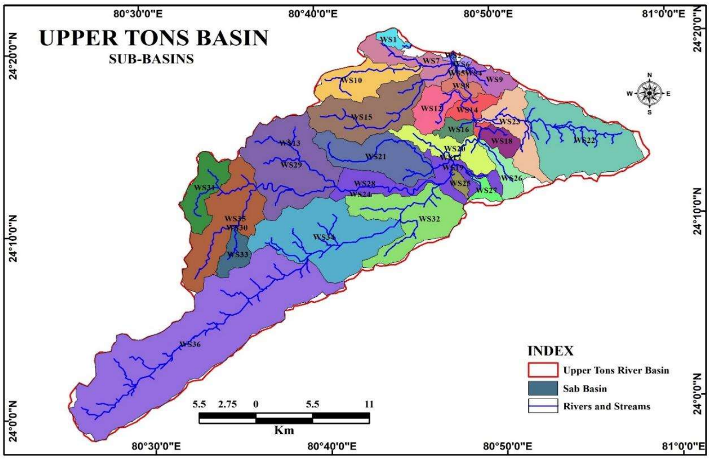
Watershed development is a gradual process that occurs as a result of several natural and regional forces that affect any river basin area over time. The growth of the Basin and the watershed are inextricably interwoven. The Tons River Basin is located at an elevation of 610 m in the Kaimur Range (Upper Vindhyan), with a linear length of 264 km and an area of 16,860 km^2. The morphometric features were utilized to build a quantitative approach to the development of the Tons River basin. The drainage network was created using SRTM, DEM, and Landsat8 data.

Upstream, the trellis pattern dominates the drainage basin, while the center and downstream are dominated by the dendritic pattern. The drainage density indicates a permeable subsurface and dense plant cover in the basin. For a smaller drainage area, greater form factor values suggest a bigger flow peak. The Tons River Basin is prone to soil erosion, as evidenced by its high roughness number and relief ratio. The Tons River Basin is less prone to flooding and soil erosion and has a great supply of surface water, according



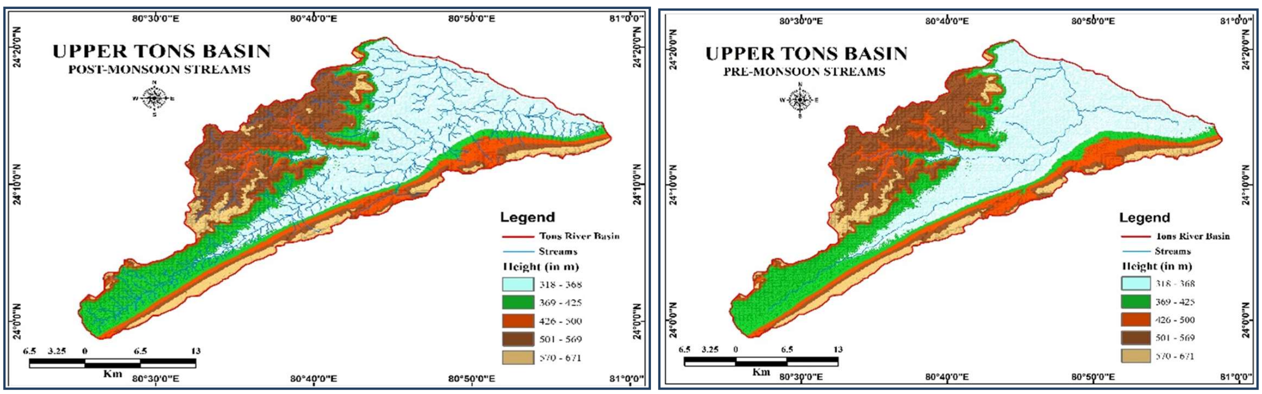
(Source: DEM and SRTM-30m, 2001-2021)

Fig. 4: Watersheds of Upper Tons River Basin.



(Source: DEM and SRTM-30m, (March) 2021)

Fig. 5: Sub-Basins in UTB.



(Source: DEM and SRTM-30m, (May and October) 2021)

Fig. 6: Pre and Post Monsoon Streams in the Upper Tons River Basin, 2021.

to the present study. This research would help with water resource utilization and would be enhanced for the long-term development of the Tons River basin area.

These studies aimed to establish a relationship between morphometric drainage parameters and basin hydrologic features using GIS. As a result, the current study's purpose is to quantify the Tons River Basin's morphometric properties (linear, areal, and relief aspects) as well as hydrologically characterize them. Fig. 4 shows an overview of watersheds in the UTB, with 7 separate watersheds retrieved using DEM and Hydrology tools in ArcGIS 10.4.1 for key rivers such as the Ghusru, Amra, Serainji, Lilji, Pathna, Barua, and Tons, as well as their lower (WS-1) and upper (WS-2) courses (WS-7). WS-1 is the largest, covering 317.48 km^2, while WS-5 is the smallest, at 46.56 km^2.

In the Upper Tons River Basin, the watershed division in Fig. 5 is further broken into 36 minor sub-basins. Sub-basin SW-36 is the biggest, whereas Sub-basin SW-25 is the smallest, as seen in Fig. 5. The pre and post-monsoon stream in the Upper Ton's river basin is shown in Fig. 6. The river basin's watershed development is influenced by spatial configurations and locational significance. The development of the watershed is governed by an accessibility index and a penetration scale, through which every project may scale and identify its core objectives, ensuring the watershed's consistency with current developmental matrixes.

CONCLUSIONS

The Water Poverty Index (WPI) is a phenomenon and subject to change due to components like LULC pattern and watershed area of the river basin, which are closely proportional and interlinked according to the research conducted in this paper. It is evident from the above research that WPI remains lower in the southwestern part as compared to the north-eastern part of the river basin. Results show the WPI of 7 sample villages in the River Basin, out of which Ghunwara and Maihar Village have the maximum and minimum WPI which is 98.1 and 62.91, respectively, out of 100, which shows that with high WPI, villages face challenges in fulfilling its water needs irrespective of river which serves the basin area seasonally and with low WPI village fulfill all its water need from the basin. In our analysis of the Upper Tons River Basin, LULC will be influenced or adjusted at various stages, and agricultural land is in the impact region at the end. From all the above discussions, it is clear that the WPI is lower in the areas of fewer LULC extensions due to dependency on agricultural land and that when LULC is influenced, lessened, or altered, multiple components of agricultural land will change, and various metrics will be noted. In addition, the report provides an assessment of land use in the Upper Tons River Basin from 2001 to 2021, as well as its shifting patterns which have also impacted the water resources and its access with use capacity. The impact of decreasing certain features on the distribution of WPI and other LULC parameters has also been estimated. The Upper Tons River Basin suffers from unfavorable rainfall patterns, as well as negligence in irrigation planning at the basic and local levels. Its geographical location in a rainfed area also acts negatively on the WPI.

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REFERENCES

Al Saud, M., 2009. Morphometric analysis of Wadi Aurnah drainage system, western Arabian Peninsula. *The Open Hydrology Journal*, 3(1), pp. 69-73.

Barman, B.K., Rao, C.U.B., Rao, K.S., Patel, A., Kushwaha, K. and Singh, S.K., 2021. Geomorphic analysis, morphometric-based prioritization and tectonic implications in Chite Lui river, Northeast India. *Journal of the Geological Society of India*, 97, pp. 385-395.

Bhatt, S. and Ahmed, S.A., 2014. Morphometric analysis to determine floods in the Upper Krishna basin using Cartosat DEM. *Geocarto International*, *29*(8), pp. 878-894.

Bhatt, S.C., Patel, A., Pradhan, S.R., Singh, S.K., Singh, V.K., Tripathi, G.P. and Kishor, K., 2023. Morphometric and Morphotectonic Attributes of Ken Basin, Central India: Depicting Status of Soil Erosion, and Tectonic Activities. *Total Environment Advances*, 200088.

Bhatt, S.C., Singh, R., Singh, R., Singh, V.K. and Patel, A., 2021. Morphometric and morphotectonic studies of Sindh Basin, Central India, using advanced techniques of remote sensing and GIS. In *Geological and Geo-Environmental Processes on Earth* (pp. 259-275). Springer, Singapore.

Biswas, S., Sudhakar, S. and Desai, V.R., 1999. Prioritisation of subwatersheds based on morphometric analysis of drainage basin: A remote sensing and GIS approach. *Journal of the Indian Society of Remote Sensing*, 27, pp. 155-166.

Carney, D. (ed.), 1998. *Sustainable rural livelihoods: What contribution can we make?* London: Department for International Development.

Choudhary, A., 2002. Morpho-Lithological analysis and groundwater resource management through GIS modeling and DIP: a case study of Bata River, Himachal Pradesh (Doctoral dissertation, University of Allahabad).

Coppin, N.J., 1990. Use of vegetation in civil engineering. In I.G. Richards (Ed.), *Butterworths: Ciria* (pp. 23-36).

Cox, R.T., 1994. Analysis of drainage-basin symmetry as a rapid technique to identify areas of possible Quaternary tilt-block tectonics: an example from the Mississippi Embayment. *Geological Society of America Bulletin*, 106(5), pp. 571-581.

Desai, M., 1995. *Poverty, Famine and Economic Development: The Selected Essays of Meghnad Desai, Volume II*. Edward Elgar Publishing Ltd.

Ganas, A., Pavlides, S. and Karastathis, V., 2005. DEM-based morphometry of range-front escarpments in Attica, central Greece, and its relation to fault slip rates. *Geomorphology*, 65(3-4), pp. 301-319.

Grohmann, C.H., 2004. Morphometric analysis in geographic information systems: applications of free software GRASS and R. *Computers & Geosciences*, 30(9-10), pp. 1055-1067.

Patel, A., Singh, M.M., Singh, S.K., Kushwaha, K. and Singh, R., 2022. AHP and TOPSIS-based sub-watershed prioritization and tectonic analysis of Ami River Basin, Uttar Pradesh. *Journal of the Geological Society of India*, 98(3), pp. 423-430.

Pigou, A.C., 1924. *The Economics of Welfare*. Macmillan.

Scoones, I., 1998. *Sustainable Rural Livelihoods: a Framework for Analysis*. Blackwell Publishing Ltd.

Sen, A., 1983., Poor, relatively speaking. *Oxford Economic Papers*, 35(2), pp. 153-169.

Sen, A.K., 1985. *Commodities and Capabilities*. North-Holland

Sen, A.K., 1995. *Mortality as an Indicator of Economic Success and Failure*. Discussion Paper 66. London School of Economics and Political Science, London.

Sen, A.K., 1999. *Development as Freedom*. Clarendon.

Stamp, L.D., 1960. *Applied Geography*. Pelican Books, p. 38.

Sullivan, C.A., Meigh, J.R. and Giacomello, A.M., 2003. The water poverty index: development and application at the community scale. *Natural Resources Forum,* 27(3), pp. 189-199

Thakur, J.K., Neupane, M. and Mohanan, A.A., 2017. Water poverty in upper Bagmati River basin in Nepal. *Water Science*, *31*(1), pp.93-108.

Townsend, P., 1979. *Poverty in the UK*. Penguin

Yadav, S.K., 2018. *Impact of Morpho-tectonics on drainage network of Upper Tons Basin*. Doctoral Thesis. University of Allahabad, Prayagraj.