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"Climate Change Vulnerability Assessment and Adaptation Planning at the Tehsil Level: A Geospatial and Socio-Economic Analysis of Ujjain District, Madhya Pradesh"

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Abstract

Climate change poses significant challenges to sustainable development by increasing the frequency and intensity of extreme weather events, altering precipitation patterns, and affecting natural and human systems. This study, titled "Climate Change Vulnerability Assessment and Adaptation Planning at the Tehsil Level: A Geospatial and Socio-Economic Analysis of Ujjain District, Madhya Pradesh," aims to assess the spatial and socio-economic dimensions of climate vulnerability across the tehsils of Ujjain district. The research integrates geospatial techniques, remote sensing, Geographic Information Systems (GIS), and socio-economic indicators to evaluate the vulnerability of different tehsils based on three key components: exposure, sensitivity, and adaptive capacity. Climate variables such as temperature trends, rainfall variability, drought occurrence, land use/land cover changes, water resource availability, agricultural dependency, population characteristics, and infrastructure accessibility are analyzed to develop a composite Climate Vulnerability Index (CVI). The study identifies vulnerable hotspots and examines the differential impacts of climate change on agriculture, water resources, livelihoods, and human well-being. Based on the findings, a tehsil-specific adaptation planning framework is proposed, emphasizing climate-resilient agriculture, sustainable water management, ecosystem conservation, disaster risk reduction, and institutional strengthening. The outcomes of the study are expected to support evidence-based policymaking, local climate action planning, and resilient development strategies for Ujjain district and similar agro-climatic regions of central India.

Introduction

Climate change may be referred to as the long-term variation in the temperature, rainfall, and wind patterns among other elements of climate system of our planet Earth. Although natural causes of climate variation such as volcanic eruption and solar radiation have always contributed to climatic variation, the current phase of climate change can be largely attributed to man. The greenhouse effect caused by the growing concentration of greenhouse gases like carbon dioxide, methane, and nitrous oxide by industrialization, deforestation and consumption of fossil fuels has resulted in global warming. The effects of this trend towards warming are far-reaching, such as the increase of sea level, the melting of glaciers and the interference with ecological systems. The scientific community underlines climate change as something that is not off in the future but a fact that is being experienced today that affects not only the natural but also the human systems of the world. Climate change has emerged as one of the most significant environmental issues of the 21st century in the international scale. It does not evenly distribute its effects in geographical locations and so the developing countries are overburdened with it since it has low adaptive capabilities. Small island countries face an existential risk because of rising sea levels and arid and semi-arid areas are increasingly affected by droughts. Likewise, developed countries are also experiencing increased extreme weather conditions like hurricanes, wild fires and flooding.

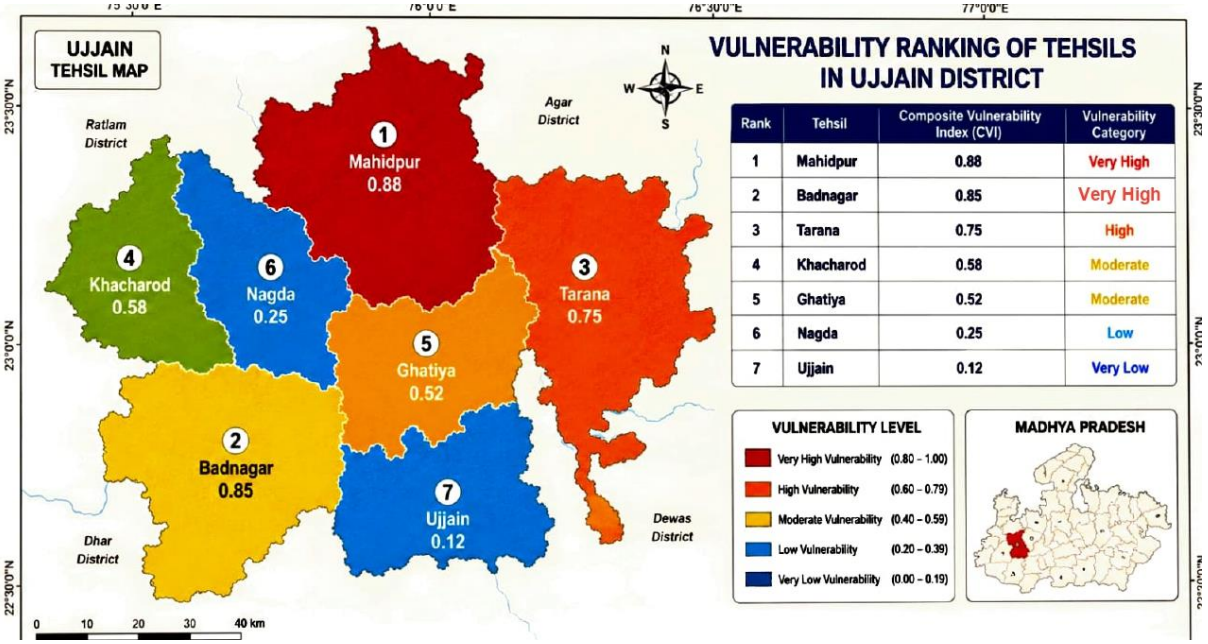
These impacts are not only disruptive on the ecosystems, but also, a big threat to economic stability, food security and human health. Global systems are interconnected, so the effects of climate change in one area may have ripple effects throughout the world. International conventions and partnerships to reduce and adapt climate change have also evolved into a worldwide reaction to climate change. Other treaties such as the Paris Agreement are concerned with cutting down the global rise in temperature to significantly lower than 2 o C of the levels before the industrialization age. The pledges to countries to reduce emissions and go more resilient are the nationally determined contributions (NDCs). Nonetheless, even with these efforts, the rate at which climate change occurs is still exceeding mitigation efforts. The disconnect between the policy promises and practice is a major issue, especially in the developing world where resources are limited to adequately act on climate .

Besides mitigation, adaptation has become a popular concept as a requisite measure to address inevitable effects of climate. The process of adjusting both natural and manmade systems in order to minimize the damage and exploit the opportunities available is known as adaptation. This incorporates coming up with climate resilient infrastructure, enhancing water management systems

and incorporating sustainable agriculture. The international community is beginning to give attention to localized adaptation plans because it is realized that the impacts of climate are context-specific. Therefore, the local and regional vulnerability has gained significance towards effective planning and policy making

Ujjain is a geographically and culturally very important district of the west of Madhya Pradesh. The area falls under the Malwa Plateau that has fertile black soil that can be utilized to carry out agriculture. Climate is semi-arid seasonal i.e. hot summers, monsoon season and cold winters. Kshipra is an important water body in the district that has agricultural uses and livelihoods of the locals. Ujjain also is agriculturally productive and vulnerable to the weather change because of geographical peculiarities of the region. Ujjain is an agrarian based district and the majority are engaged in agriculture and other related practices. Other crops grown in the region like soybean, wheat and pulses are some of the major crops, highly dependent on monsoon rainfall. The district is also experiencing an increasing urban area especially in the Ujjain city, which is synonymous with religious importance and tourism. Nonetheless, rural locations are still struggling with the issues of infrastructure, irrigation systems, and availability of new technologies in the agricultural sector.

The district has both urban and rural inequities in socio-economic development indicators. Compared to urban centres, which are a better choice in terms of access to education, medical facilities, and employment opportunities, rural areas are poor and lack resources. The rural households are more susceptible to the impacts of climate change because of the dependence of their livelihood on climatic-sensitive sectors such as agriculture. In addition, population growth and land degradation are other factors that have put further strain on the natural resources. Geographic and socio-economic characteristics of Ujjain district should be known in order to measure climate vulnerability and to deal with adaptation planning. The environmental conditions and socio-economic factors interact to define overall resilience of the region. The tehsil level analysis helpful in identifying some of the areas that are more vulnerable and require special interventions. Local strategy like this is critical in the development of effective climate change adaptation.



The vulnerability ranking of the seven tehsils of Ujjain District, Madhya Pradesh, based on a composite vulnerability index. The thematic map classifies each tehsil into different vulnerability categories using a color-coded scheme ranging from Very Low Vulnerability to Very High Vulnerable. The map also includes a ranking table, district boundaries, neighboring districts, a north arrow, scale bar, and a location inset showing the position of Ujjain District within Madhya Pradesh. Among all the tehsils, Mahidpur records the highest vulnerability score of 0.88, ranking first and falling under the Very High Vulnerable category. It is represented in dark red, indicating the highest level of vulnerability.

Badnagar ranks second with a vulnerability score of 0.85, also classified as very high Vulnerable. Tarana occupies the third position with a score of 0.75, indicating high Vulnerable conditions. The central-western tehsil of Khacharod has a vulnerability score of 0.58, placing it in the Moderately Vulnerable category and ranking fourth. Ghatiya, located in the central part of the district, records a score of 0.52, ranking fifth and classified as Moderately Vulnerable. The least vulnerable tehsils are Nagda and Ujjain. Nagda ranks sixth with a vulnerability score of 0.25, falling under the Low Vulnerability category. Ujjain Tehsil records the lowest vulnerability score of 0.12, ranking seventh and classified as Very Low Vulnerability, indicating comparatively better resilience and lower overall vulnerability. the spatial distribution demonstrates that the northern and eastern parts of Ujjain District exhibit relatively higher vulnerability, whereas the southern and central regions show lower vulnerability levels. The map effectively highlights regional disparities in vulnerability and serves as an important tool for prioritizing disaster risk reduction, resource allocation, regional planning, and policy interventions.

The ranking and classification provide valuable information for administrators and planners to identify highly vulnerable tehsils requiring immediate attention while supporting sustainable development and resilience-building strategies across the district.

Research Methodology

Research methodology refers to the theoretical and systematic examination of the methodologies used in a research project. The process encompasses all stages of the method, starting with establishing objectives for the investigation to collecting, examining, and interpreting data. The methodology section provides a detailed explanation of the design, processes, and techniques used for data collection and assessment. A research methodology elucidates the techniques used by scholars to conduct their inquiries and provide dependable, authentic data that fulfills their aims. The research methodology of a climate change vulnerability assessment of the tehsil level in Ujjain District in the proposed study is a qualitative field research coupled with quantitative data analysis. The study starts with gathering of secondary information on climatic variables (temperature, rainfall variability, extreme events) including India Meteorological Department and the district statistical records. To collect demographic and socio-economic data at the tehsil level, census reports and government databases would be used to collect demographic and socio-economic data. Indicators of three dimensions (exposure, sensitivity, and adaptive capacity) would then be used to construct a vulnerability index, usually in accordance with frameworks suggested by the Intergovernmental Panel on Climate Change. The prioritization of tehsils on the basis of their relative vulnerability would be undertaken through normalization, weighting (e.g. Principal Component Analysis or equal weighting) and composite indexing.

Research Questions

1. How can tehsils in Ujjain district be comparatively ranked based on composite climate vulnerability indicators?
2. Which factors significantly contribute to variations in climate vulnerability across Ujjain district?
3. How do location-specific adaptation interventions vary across tehsils based on their vulnerability profiles?
4. What mechanisms enable effective integration of climate adaptation into district-level development planning?

Objectives of the study

1. Identifying and prioritizing the most vulnerable Tehsil in the Ujjain district.
2. Understanding the factors causing vulnerability in the district
3. Identifying location specific adaptation interventions to reduce vulnerability arising due to climate change.
4. Devising methods to mainstreaming adaptation in development programs at district
5. level.

Hypothesis of the study

H1: Tehsils with higher exposure and sensitivity and lower adaptive capacity will exhibit higher composite vulnerability scores than other tehsils.

H2: Climate vulnerability is positively associated with exposure and sensitivity factors and negatively associated with adaptive capacity factors.

H3: The effectiveness and suitability of adaptation interventions vary significantly across tehsils depending on their specific vulnerability characteristics.

H4: Integration of climate adaptation into district development programs is more effective when supported by institutional coordination, policy alignment, and stakeholder participation.

Method Adopted

A quantitative approach is a method that is systematic and is concerned with numerical data, measurement and statistical analysis to draw objective conclusions. The quantitative methodology is applied in the study to create a climate vulnerability index based on quantifiable variables like the trends in temperature, oscillations of rainfalls and socioeconomic indicators. It is relevant in that it ensures the accuracy, comparability and reliability of results between tehsils. The methodology helps to build up evidence-based outcomes that are applicable in assessing science and formulating policy.

Data Collection

The secondary data collection involves the utilization of the existing data sources such as the government publications, census statistics and weather statistics. In the current study, the data is collected according to such sources as the India Meteorological Department and other official data sources. This is due to the fact that secondary data is cheap, easy to obtain and has the ability of providing long term historical trends. It makes sure that the analysis is based on credible and revalidated datasets.

Research Design

Research design is the overall plan or framework, where data collection, analysis and interpretation occur in a research. The design of the study is a combination of the descriptive and analytical one in order to present a concise image and a more detailed analysis of the climate change susceptibility within the tehsils of Ujjain. This method is important because it allows the study to present the current circumstances systematically but also examine the relations between variables that have an impact on vulnerability.

Statistical Tools

The methods and programs used in the organization, analysis and presentation of research data in an effective manner are known as statistical tools. In this study, Microsoft Excel and Microsoft word are the tools that are used to offer systematized data processing to ensure documentation. They are important in that they increase accuracy, efficiency and clarity in the presentation of the findings of the study.

Data Analysis

Climate change has become one of the major issues affecting environmental sustainability, socio-economic development and livelihood security of various geographical locations. Climatic conditions and exposure, resource availability, infrastructure, and socio-economic factors, vary between tehsils within the Ujjain District, requiring a district-specific assessment approach to plan effectively for adaptation. The spatial analysis of the climate change vulnerability at the tehsil level could yield information on vulnerability of various parts, which helps in identifying areas with increased climate exposure risks. The results are interpreted in a way that clarifies the importance of different types of pressures, such as demographic, reliance on climate sensitive sectors, environmental degradation and institutional capacities influencing vulnerability patterns in the district.

Table 4.1: Exposure index table

Tehsil	Rainfall (mm)	Area (km^2)	Normalized Rainfall Score	Normalized Area Score	Exposure Index
Badnagar	375	1,232	0.85	0.95	0.90
Ghatiya	542	642	0.45	0.35	0.40
Khacharod	410	638	0.75	0.34	0.55
Mahidpur	481	1,137	0.60	0.88	0.74
Nagda	717	652	0.10	0.36	0.23

Tarana	545	1,046	0.42	0.78	0.60
Ujjain	550	745	0.40	0.50	0.45

Table 4.2: Sensitivity indicators

Tehsil	**% SC (est. prop.)**	**Rural Pop. % (proxy agri-dep.)**	**Sensitivity Score (0-1)***
Badnagar	32	95	0.75
Ghatiya	30	92	0.70
Khacharod	28	94	0.72
Mahidpur	35	96	0.82
Nagda	25	85	0.60
Tarana	33	95	0.78
Ujjain	20	70	0.40

Table 4.3: Ranking table

Rank	**Tehsil**	**Vulnerability Level**
1	Mahidpur	Very High
2	Badnagar	Very High
3	Tarana	High
4	Khacharod	Moderate
5	Ghatiya	Moderate
6	Nagda	Low
7	Ujjain	Very Low

Table 4.4: Farmers socio-economic profile

Category	Number	% Dependent on Agri
Total Farmers	232020	100
Marginal	~86000	100
Small	~60400	100
Single-Crop	~78900	100

Discussion

Kawadia, G: & Tiwari, E. (2020) reflects the impact of climatic, socio-economic and institutional factors on the vulnerability of tehsils of Ujjain District where unlike the other districts of Madhya Pradesh, notable spatial variations in climate change vulnerability were observed. SINGH, A. K. Based on the understanding obtained from the literature review, Mahidpur, Tarana and Badnagar were identified as the most vulnerable while Ujjain was the least vulnerable as it has a strong adaptive capacity and the socio-economic condition was well diversified. The findings are like the previous climate vulnerability assessments in semi-arid areas of India, which have highlighted that rural areas with high levels of agricultural dependence and low institutional support are typically more vulnerable to climate related vulnerabilities (Kushwah, M. 2016). The differences observed between the tehsils emphasises the need of conducting localised assessments which can provide information on problems in different areas of the region and subsequent effective adaptation strategies. Moreover, the results endorse the conceptualization of vulnerability as explained above—multidimensional vulnerability which cannot be explained with the help of environmental indicator.

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