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LEVELS OF SOCIO-ECOLOGICAL VULNERABILITY IN CHAMBA DISTRICT OF HIMACHAL PRADESH, INDIA

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Abstract

Vulnerability assessment is vital for understanding the impact of natural hazards and disasters in any region. Fragile mountainous ecosystems, frequently affected by flash floods, earthquakes, and landslides, are disrupting the socio-ecological balance, thereby increasing vulnerability in the hilly state of Himachal Pradesh in general, and Chamba district in particular. This study focuses on assessing socio-ecological vulnerability at tehsil level by considering twenty-nine indicators covering five dimensions, namely social, economic, institutional, infrastructural, and ecological. Socio-ecological vulnerability score reveals that Chamba and Bhattiyat tehsils are highly vulnerable whereas Holi and Pangi tehsils are not so much vulnerable to disasters. Correlation analysis indicates a strong positive correlation between infrastructural, economic, and social vulnerability with the composite socio-ecological vulnerability index. Thus, the weaknesses in these three components significantly contribute to the overall vulnerability of the district. Areas with poor infrastructure, economic marginalisation, and low social capital exhibit the highest vulnerability, suggesting a need for strengthening these components.

Keywords: Natural hazard, Socio-ecological vulnerability, Disaster risk reduction, Mountain ecosystem.

Introduction

Hazards denote the potential occurrence of natural phenomena capable of adversely impacting human life and both public and private assets. When a hazard event leads to loss of life, displacement, homelessness, destruction, and property or infrastructure damage, it evolves into a disaster. Disasters are the outcome of hazards intersecting with vulnerability and inadequate capacity or measures to mitigate risk (Singh, 2006). India's geo-climatic conditions and socio-ecological vulnerabilities make it particularly susceptible to natural hazards, leading to a staggering 431 major disasters over the past three decades (Mohapatra et al., 2025; NIDM, 2025). Various calamities take place in India, namely earthquakes, landslides, floods, droughts, cyclones, and avalanches, impacting 27 out of its 35 states and union territories. Nearly 58.6 per cent of its landmass faces earthquake risks, while approximately 12 per cent is prone to

floods and river erosion. Moreover, 68 per cent of land under cultivation is at risk to drought, while hilly regions face threats from landslides and avalanches (NIDM, 2025). In the context of mountainous region, communities experience a higher frequency of hazards and disasters as compared to other regions. Among these hazards, landslides and flash floods are the most common and destructive (Bansal and Kapoor, 2023; Kapoor and Singh, 2023; Kohli et al., 2023). Their localized and discrete nature, coupled with lack of awareness and inadequate risk reduction strategies, results in higher cumulative losses compared to other hazards (Husain, 2006). Natural hazards and disasters including floods, earthquakes, and landslides can significantly disrupt the socio-ecological system and create difficulties for people in the mountainous regions (Sharma and Mohapatra, 2023). In recent years, frequency of natural and anthropogenic catastrophes has increased in the entire Himalayan region making it one of the most vulnerable and fragile regions of the world (Maikhuri et al., 2017). In light of the above, this study analyses the socio-ecological vulnerabilities of Chamba district by addressing intricate relationships between people and their environment.

Objectives of the Study

Major objectives of the study are:

- to assess the levels of social, economic, institutional, infrastructural, and ecological vulnerabilities;
- to analyse the levels of socio-ecological vulnerability and
- to examine the association among all the five components with overall socio-ecological vulnerability in Chamba district.

Study Area

Chamba district spans over an area of approximately 6522 km², ranging from 32° 11′ 30″ N to 33° 13′ 6″ N latitudes and 75°49′ 00″ E to 77° 3′ 30″ E longitudes (Fig. 1). Situated amidst Dhaula Dhar, Hathi Dhar, and Zanskar ranges, the elevation in Chamba district varies between 559 Metres to 6162 Metres above mean sea level. Amidst these ranges lie three principal river valleys namely Beas, Ravi and Chenab. The district experiences diverse climatic conditions varying from semi-tropical to semi-arctic, owing to significant altitudinal variations. The average annual temperature in Chamba district is 13.3°C. October is the driest month of the district with 24 mm of rainfall, while July receives the highest precipitation of 398 mm. The soil in the region varies with respect to climatic conditions, slope, aspect, and altitude. About 31 per cent of the total area of the district is under alpine pastures to dense temperate forests. According to the 2011 census, the population of Chamba district is 519,080 persons. The literacy rate in the district is 72.17 per cent. The district has a population density of 80 persons per km². More than 70 per cent of the total population depends directly or indirectly upon agriculture for their livelihood. Majority of the population is engaged in agriculture, horticulture, animal husbandry and tourism sectors.

Database and Methodology

This study is based on secondary data acquired from different sources such as the Census of India, 2011, District Economic and Statistical Handbook 2016-17, District Disaster Management Plan, and other government reports. For assessing socio-ecological vulnerability, twenty-nine indicators across five key components have been selected (Table 1).

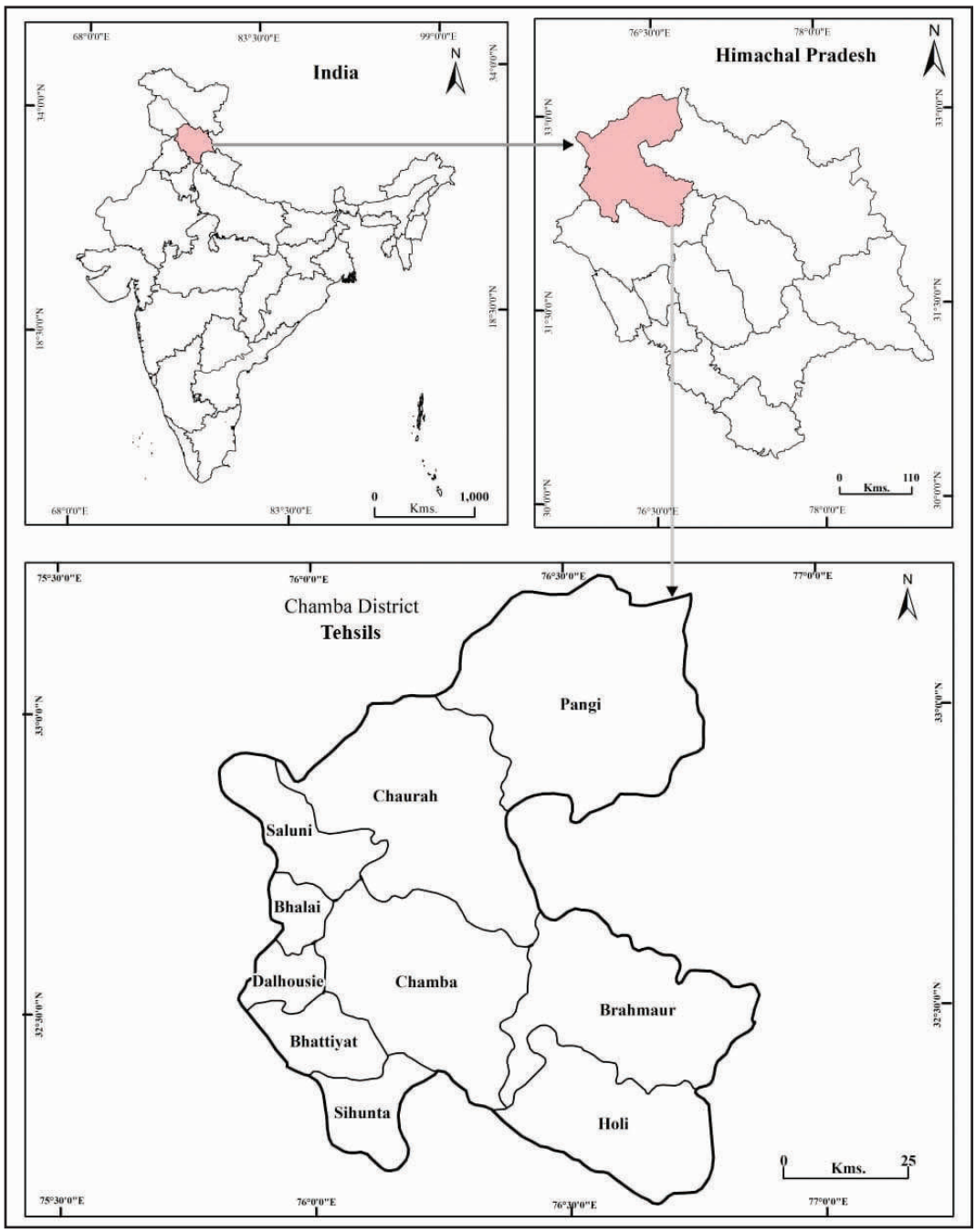

India
Himachal Pradesh
Chamba District
Tehsils
Pangi
Chaurah
Saluni
Bhalai
Dalhousie
Chamba
Brahmaur
Bhattiyat
Sihunta
Holi
N
0 Kms. 1,000
0 Kms. 110
0 Kms. 25

Fig. 1

Table 1

Chamba District: Components, Indicators and Sources of Data for Tehsils

Components	Indicators	Data Sources
Social	• Percentage of illiteracy	District Census Handbook, 2011
	• Percentage of villages not having telephone facilities	District Census Handbook, 2011
	• Percentage of villages not having availability of newspapers	District Census Handbook, 2011
	• Percentage of villages not having mobile health facility	District Census Handbook, 2011
	• Density of population (km^2)	District Census Handbook, 2011
	• Percentage of SC/ST Population	District Statistical Handbook 2016-17
	• Total number of deaths per thousand population	District Census Handbook, 2011
Economic	• Per capita income (Rs.)	District Statistical Handbook 2016-17
	• Percentage of population below poverty line	District Census Handbook, 2011
	• Percentage of population not covered by commercial Bank	District Census Handbook, 2011
	• Percentage of cultivable land to total agricultural land	District Census Handbook, 2011
	• No. of livestock loss in a year	District Census Handbook, 2011
	• Percentage of agricultural crop loss	District Census Handbook, 2011
Institutional	• Percentage of villages not having medical facilities	District Census Handbook, 2011
	• Percentage of villages not having educational facilities	District Census Handbook, 2011
	• No. of public distribution system	District Census Handbook, 2011
	• No. of self-help groups	District Census Handbook, 2011
Infrastructure	• Percentage of villages not having medical shop	District Census Handbook, 2011
	• Percentage of villages not having drinking water facilities	District Census Handbook, 2011
	• Percentage of villages not having Pucca road	District Statistical Handbook 2016-17
	• Percentage of villages not having taxi/bus/Auto stoppage	District Statistical Handbook 2016-17
	• Percentage of villages not having power supply	District Census Handbook, 2011
	• No. of villages not having all weather road facilities	District Statistical Handbook 2016-17
	• Percentage of kuchha houses	District Statistical Handbook 2016-17
	• Percentage of houses damaged due to disaster	District Census Handbook, 2011
Ecological	• Percentage of people affected by soil erosion	Soil and Land use Survey of India, 2022
	• No. of forest fires in a year	India State of Forest Report 2023
	• Percentage of Forest cover density	Soil and Land use Survey of India, 2022
	• No. of Trees uprooted in a year	District Disaster Management Authority, 2022-23

Source: Compiled by Authors.

As vulnerability reflects negative dimensions of human adaptation, therefore all the indicators which demonstrate positive side of human capacity have been inversed to indicate their negative dimension of human adaptation. Hence, all the indicators are unidirectional having positive functional relationship with vulnerability (Table 1).

For vulnerability mapping, the study draws upon the frameworks developed by Jana et al. (2017, 2024). All indicators have been standardized using min-max normalization techniques used in United Nations Development Programme (UNDP) for the calculation of Human Development Index (HDI). Component-wise scores have been calculated by aggregating standardized indicators, and equal weight has been assigned to each indicator. Socio-ecological vulnerability indices have been constructed under the following four steps:

Standardization of Indicators

Each indicator has been standardized by using min-max normalization to maintain consistency in scale and comparability. All the five components average value lies between 0 and 1. Zero represents lowest vulnerability whereas one represents highest vulnerability. Following equation has been adopted for the indicators having direct relationship with vulnerability such as density of population:

$$I_x = \frac{I_a - I_{min}}{I_{max} - I_{min}} \quad (1)$$

Following equation has been adopted for the indicators having inverse relationship with vulnerability such as rate of literacy:

$$I_x = \frac{I_{max} - I_a}{I_{max} - I_{min}} \quad (2)$$

Where I_x = Standardized indicator value, I_a = Actual indicator value for a tehsil, I_{max} = Maximum value of the indicator across tehsils, and I_{min} = Minimum value of the indicator across tehsils.

Calculation of Component-wise Vulnerability Score

Each component's vulnerability score is computed by summing the standardized values of its indicators and dividing by the number of indicators in that component.

Calculation of Overall Vulnerability Score

The overall vulnerability score for each tehsil has been computed by summing up the scores of all the components and dividing by number of components i.e., 5.

Categorization of Vulnerability

Tehsils have been classified into different vulnerability levels based on standard deviation from the mean vulnerability index as Higher Vulnerability => Mean + 1σ, Moderate Vulnerability =< Mean – 1σ ≤ x ≤ Mean + 1σ and Low Vulnerability =< Mean – 1σ. Thus, to prepare maps, the tehsils have been classified into three groups namely low, moderate, and high socio-ecological vulnerability zones by using mean and Standard Deviation (SD).

Results and Discussion

Social Vulnerability

Social vulnerability reflects the levels of resilience among communities based on their access to education, healthcare, communication and overall demographic composition. By recording high social vulnerability scores, the tehsils of Chamba (0.58) and Chaurah (0.55) have exhibited high social vulnerability (Table 2; Fig 2). Chamba and

Table 2
Chamba District: Component-wise and Socio-ecological Vulnerability Composite Scores

Tehsil	Social	Economic	Institutional	Infrastructure	Ecological	Composite
Chamba	0.58	0.57	0.30	0.67	0.58	0.54
Chaurah	0.55	0.35	0.38	0.60	0.39	0.45
Saluni	0.32	0.39	0.51	0.78	0.24	0.45
Dalhousie	0.47	0.34	0.49	0.52	0.40	0.44
Bhattiyat	0.38	0.61	0.83	0.41	0.44	0.53
Sihunta	0.40	0.42	0.62	0.42	0.32	0.44
Bhalai	0.39	0.31	0.55	0.54	0.45	0.45
Brahmaur	0.43	0.50	0.37	0.65	0.61	0.51
Pangi	0.29	0.32	0.20	0.23	0.54	0.32
Holi	0.28	0.40	0.39	0.05	0.40	0.30
Mean	0.41	0.42	0.46	0.48	0.44	0.44
S. D.	0.10	0.10	0.18	0.22	0.11	0.08

Source: Compiled by Authors.

Chaurah tehsils are highly vulnerable, because of higher percentage of illiteracy that limit people's awareness and preparedness related to natural hazards and disasters. Moreover, lack of information and communication services like telephone, newspapers and internet access restrict the flow of information. Inadequate mobile health clinics in remote areas have made the people more vulnerable. In addition, high population density increases the risk of casualties in the event of a disaster, while marginalized groups, namely the scheduled castes and scheduled tribes, often face greater socio-economic disadvantages, exacerbating their vulnerability. Conversely, Holi and Pangi tehsils have witnessed low social vulnerability scores of (0.28) and (0.29) respectively (Table 2). This indicates that these tehsils have comparatively stronger resilience, because these two tehsils have less density of population, and rate of mortality. These two tehsils have also a smaller number of villages that do not have access to newspapers, internet through common centres and individuals have access to telephone facilities. The study further reveals that six tehsils namely Brahmaur, Saluni, Bhalai, Dalhousie, Bhattiyat, and Sihunta have registered moderate social vulnerability scores ranging between 0.31 and 0.51 (Table 2; Fig. 2). In these tehsils, a significant number of villages are not having internet cafés, mobile health clinics and, percentage of scheduled castes and scheduled tribe population is relatively high.

Economic Vulnerability

Economic vulnerability is mostly influenced by income levels, financial access, and dependency on agro-based livelihoods. Out of ten tehsils, Bhattiyat (0.61) and Chamba (0.57) tehsils have recorded higher economic vulnerability scores (Table 2; Fig. 3). High economic vulnerability of Bhattiyat and Chamba tehsil reflects greater susceptibility to economic shocks and disturbances. This has been due to limited access to commercial banks that restricts financial inclusion, affecting credit availability. Another important factor responsible for high economic vulnerability is the high percentage of population living below

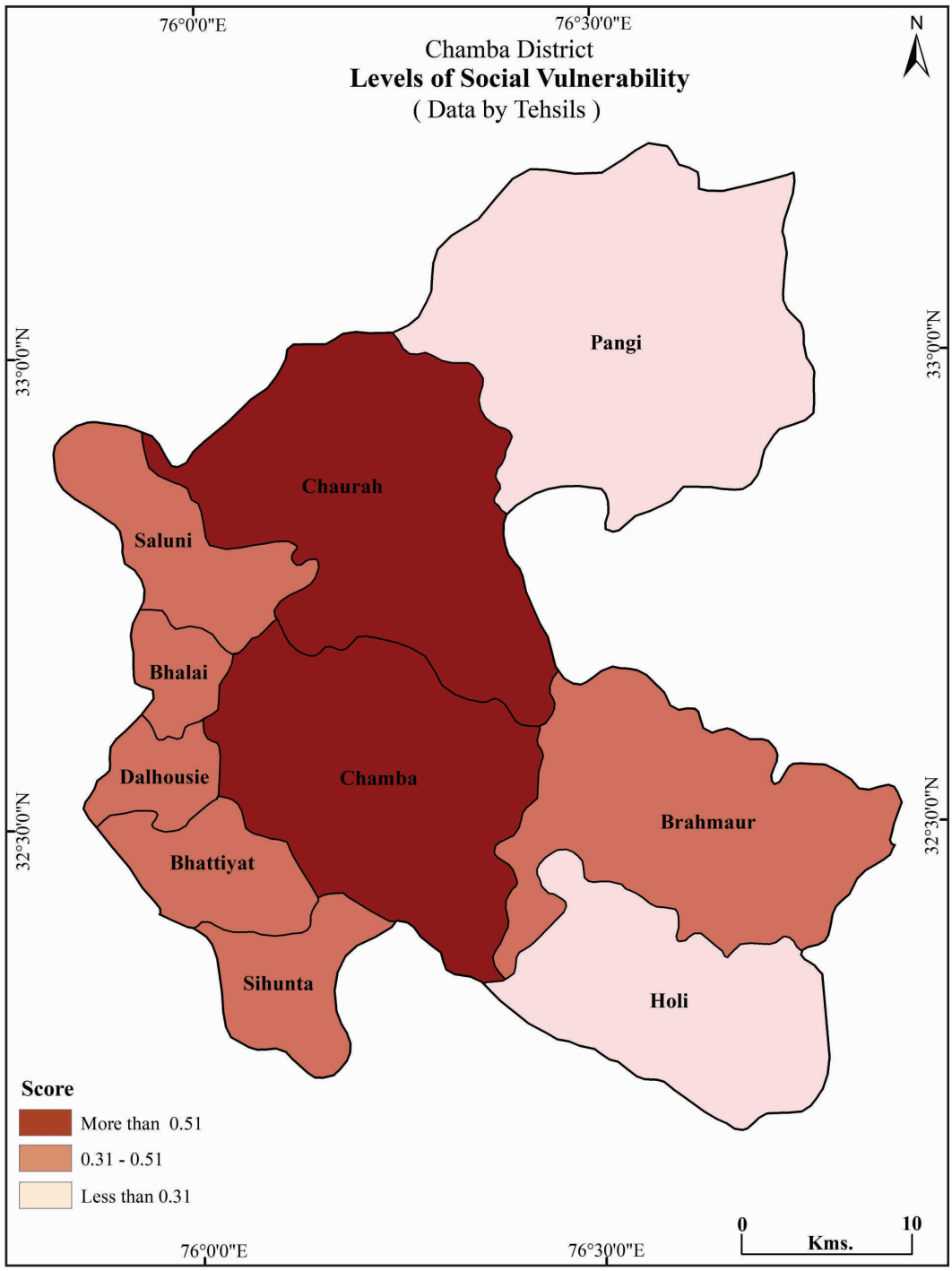
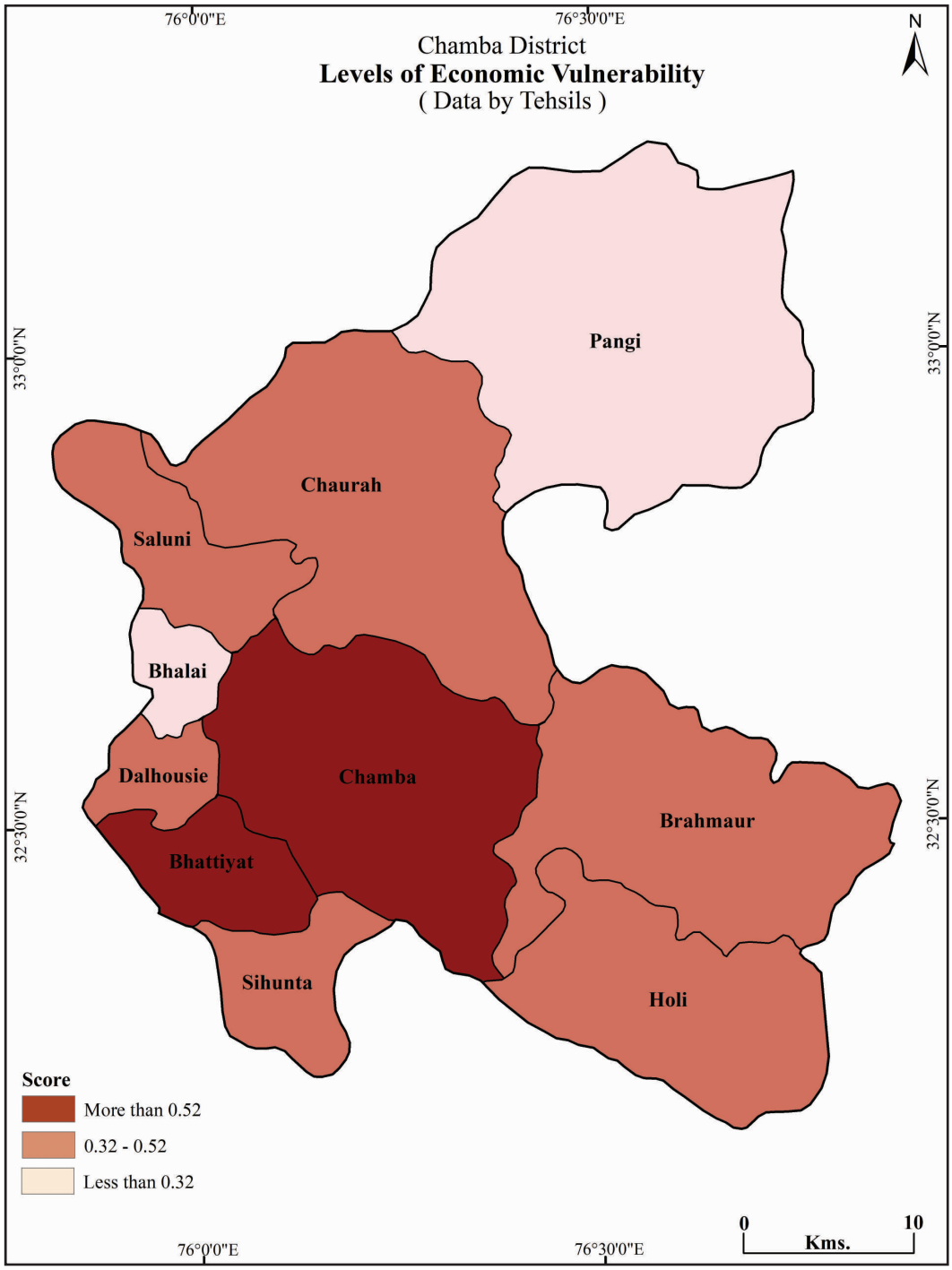

76°0'0"E
76°30'0"E
N
Chamba District
Levels of Social Vulnerability
(Data by Tehsils)
33°0'0"N
32°30'0"N
Pangi
Chaurah
Saluni
Bhalai
Dalhousie
Chamba
Brahmaur
Bhattiyat
Sihunta
Holi
Score
More than 0.51
0.31 - 0.51
Less than 0.31
0
10
Kms.

Fig. 2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76°30'0"E
N
Chamba District
Levels of Economic Vulnerability
(Data by Tehsils)
33°0'0"N
32°30'0"N
Pangi
Chaurah
Saluni
Bhalai
Dalhousie
Chamba
Brahmaur
Bhattiyat
Sihunta
Holi
Score
More than 0.52
0.32 - 0.52
Less than 0.32
0
10
Kms.

Fig. 3

poverty line. Additionally, the loss of livestock population that serves as a significant asset for rural economies, leads to economic distress. These factors collectively affect the financial stability and adaptive capacity of households and communities. On the contrary, Bhalai (0.31) and Pangi (0.32) tehsils have recorded lower economic vulnerability scores (Table 2). This indicates that these tehsils have high financial inclusion, credit availability and a smaller number of people living below poverty line. Rest of the six tehsils such as Dalhousie, Chaurah, Saluni, Holi, Brahmaur and Sihunta have witnessed moderate economic vulnerability scores ranging between 0.32 and 0.52 (Table 2; Fig. 3). These tehsils have comparatively a smaller population that has not been served by commercial banks, incurred agricultural losses, loss of livestock, and availability of cultivable land. Per capita income in these tehsils is also neither very high nor very low, resulting moderate economic vulnerability.

Institutional Vulnerability

Institutional capacity plays a vital role in disaster preparedness, response, and recovery. Bhattiyat tehsil (0.83) has exhibited significantly higher institutional vulnerability score, indicating a greater vulnerability in its institutional capacity to respond to and recover from crises (Table 2; Fig. 4). The absence of medical and educational facilities in many villages decreases the community's access to essential services. Limited healthcare access further enhances the vulnerability in Bhattiyat tehsil. Moreover, lack of a well-functioning public distribution system increases food insecurity by making relief efforts less effective. Further, due to lack of self-help groups that contribute to community-based resilience by providing financial and social support, the tehsil has witnessed higher institutional vulnerability. Conversely, Pangi (0.20) tehsil have demonstrated comparatively lower institutional vulnerability score. Pangi tehsil has better public distribution system and strong presence of self-help groups. It has also adequate number of educational and health institutions that impart training through disaster mock drills. Therefore, Pangi tehsil has a relatively stronger institutional framework or lower susceptibility to such disruptions. Rest of the eight tehsils namely Chamba, Brahmaur, Chaurah, Holi, Dalhousie, Saluni, Bhalai, and, Sihunta have registered moderate institutional vulnerability scores ranging between 0.28 and 0.64 (Table 2; Fig. 4). It is because of the average numbers of public distribution system, self-help groups and availability of number of educational facilities per lakh population in these tehsils.

Infrastructure Vulnerability

Infrastructure is a critical determinant of a region's resilience to recover from natural calamities. Tehsil Saluni (0.78) exhibits higher infrastructure vulnerability score, suggesting a greater vulnerability in their infrastructure systems to withstand and recover from problems such as floods, landslides, or earthquakes (Table 2; Fig. 5). Saluni tehsil exhibits higher infrastructure vulnerability, because of poor access to drinking water and medical facilities. Other important factors responsible for high vulnerability of Saluni tehsil have been the lack of pucca roads, all-season roads, and fewer public transport facilities in many villages that significantly delay emergency response and relief distribution. The absence of electricity disrupts communication networks and essential

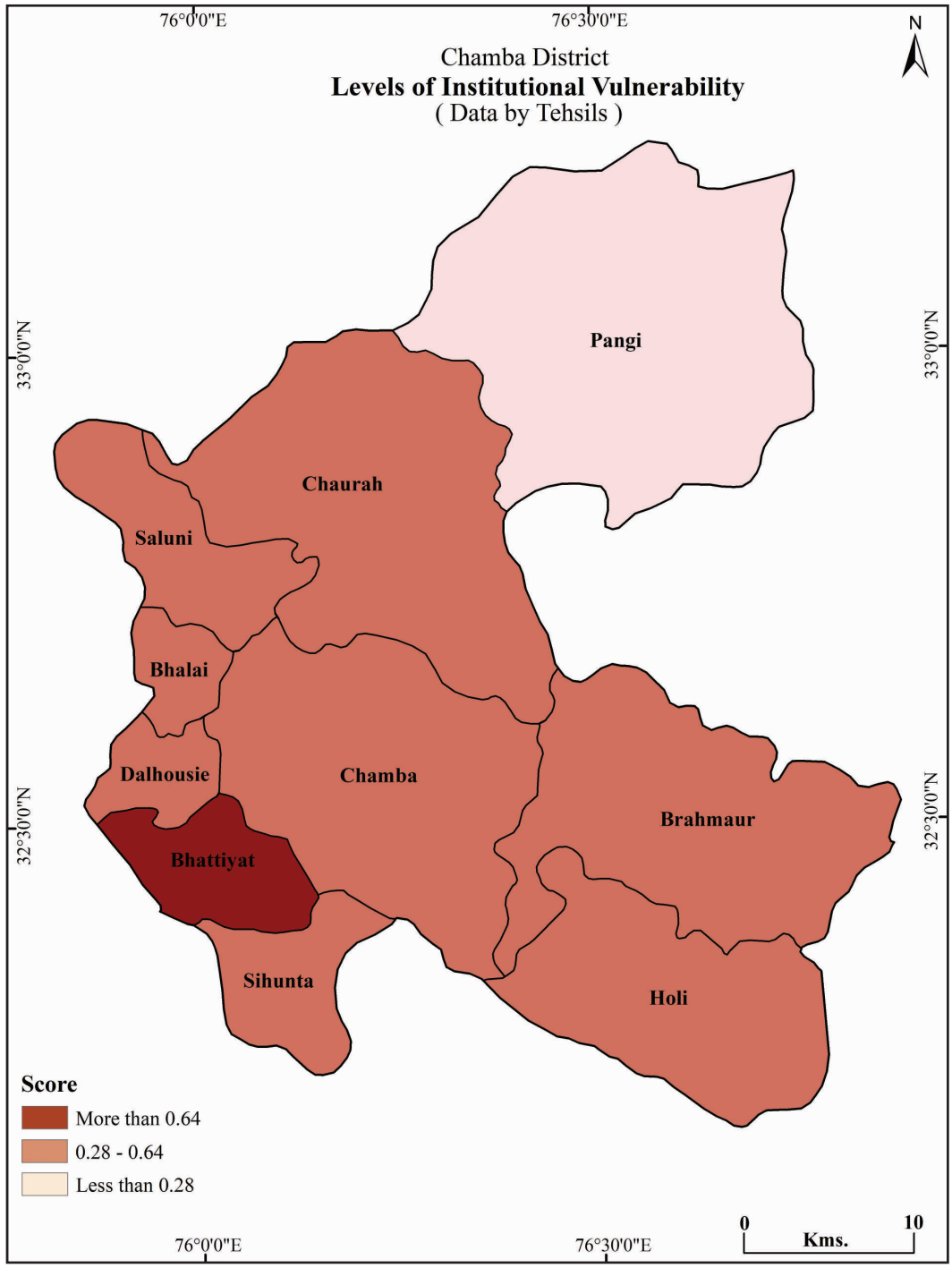
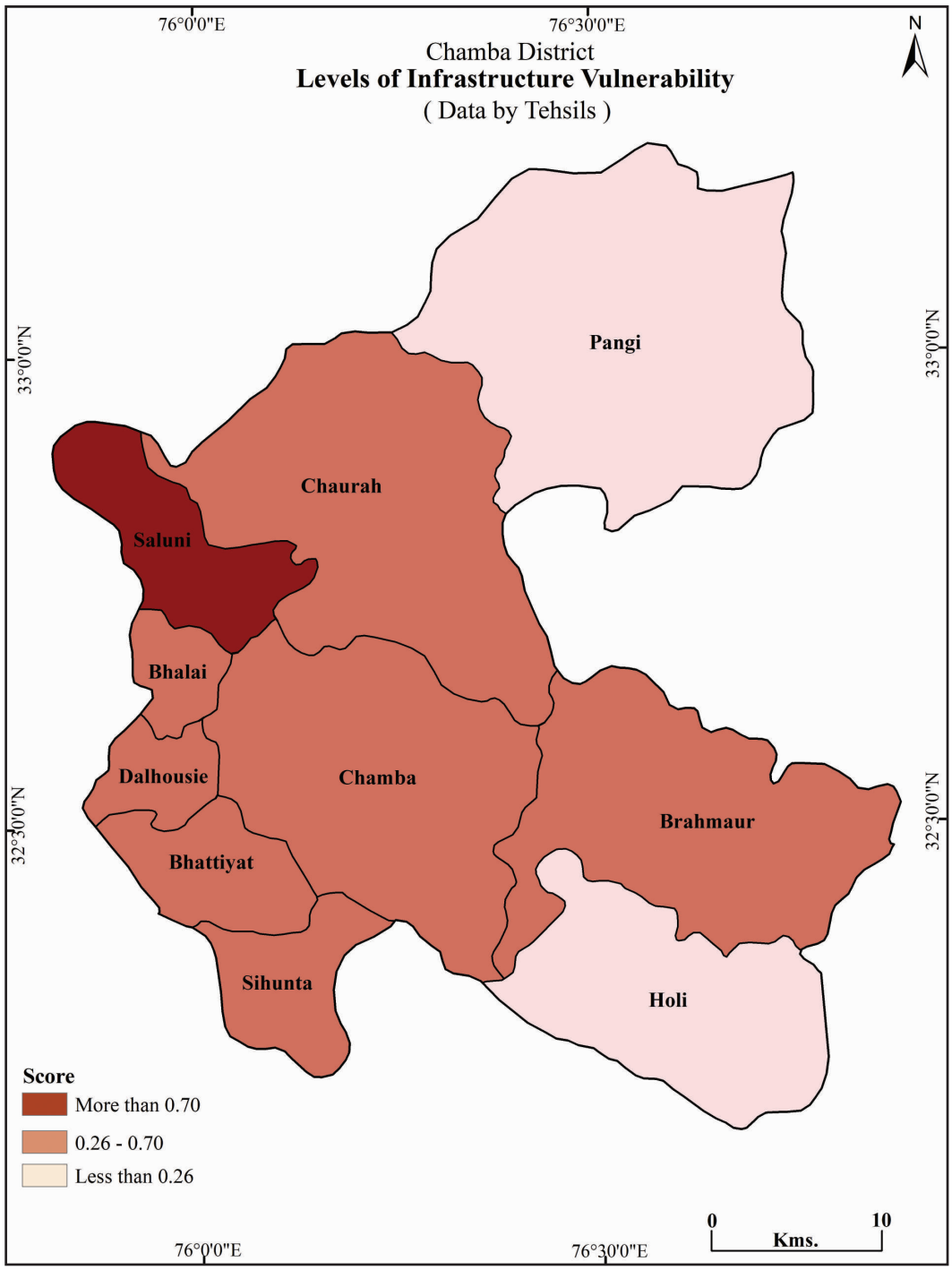

76°0'0"E
76°30'0"E
N
Chamba District
Levels of Institutional Vulnerability
(Data by Tehsils)
33°0'0"N
32°30'0"N
Pangi
Chaurah
Saluni
Bhalai
Dalhousie
Chamba
Brahmaur
Bhattiyat
Sihunta
Holi
Score
More than 0.64
0.28 - 0.64
Less than 0.28
0
10
Kms.

Fig. 4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76°30'0"E
N
Chamba District
Levels of Infrastructure Vulnerability
(Data by Tehsils)
33°0'0"N
32°30'0"N
Pangi
Chaurah
Saluni
Bhalai
Dalhousie
Chamba
Brahmaur
Bhattiyat
Sihunta
Holi
Score
More than 0.70
0.26 - 0.70
Less than 0.26
0
10
Kms.

Fig. 5

services, further increasing the level of infrastructural vulnerability. The housing sector is also a key concern, as a high percentage of kuchha houses and frequent house damage due to disasters highlight structural weaknesses, making them more susceptible to earthquakes, landslides, and floods. Conversely, tehsils like Holi (0.05) and Pangi (0.23) have demonstrated comparatively lower infrastructure vulnerability scores (Table 2). These two tehsils have a smaller number of villages and out of these two, Holi tehsil has the least number of villages. In comparison to other larger tehsils, these two tehsils have better infrastructural facilities such as drinking water facilities, all weather roads, power supply and pucca houses as a result, least percentage of houses have been damaged due to disasters.

Seven tehsils namely, Bhattiyat, Sihunta, Dalhousie, Bhalai, Chaurah, Brahmaur, and Chamba have recorded moderate infrastructural vulnerability scores ranging between 0.26 and 0.70 (Table 2; Fig. 5). It has been observed that, mean (0.48) and SD (0.22) values of infrastructural scores are the highest among all the five components of social, economic, institutional, infrastructural and ecological (Table 2). Wide variations in SD values reflect that there is a wide deviation among score values of all the seven tehsils. Therefore, these seven tehsils can be further grouped in to two categories on the basis of infrastructure vulnerability scores such as, low moderate (less than 5.00) and high moderate (more than 5.00). There are two tehsils namely Bhattiyat (0.41) and Sihunta (0.42) that fall in the category of low moderate and the other five tehsils namely Chamba (0.67), Brahmaur (0.65), Chaurah (0.60), Bhalai (0.54), and Dalhousie (0.52), fall in the category of high moderate, because these tehsils have more percentage of villages not having pucca and all-weather road facilities and percentage of kuchha houses.

Ecological Vulnerability

Ecological factors influence the region's susceptibility to environmental hazards. Tehsils namely Brahmaur (0.61) and Chamba (0.58) have witnessed relatively higher ecological vulnerability scores (Table 2; Fig. 6). These tehsils have exhibited high level of ecological vulnerability due to large scale deforestation, soil erosion, biodiversity loss and incidences of forest fire. Soil erosion directly affects land stability, leading to landslides. Forest fires pose a significant threat to biodiversity, livelihoods, and air quality, while a high deforestation rate accelerates land degradation and increases disaster risks. Unsustainable land use practices contribute to environmental degradation, making these tehsils more vulnerable to climate-related disasters. Conversely, Saluni (0.24) and Sihunta (0.32) tehsils, by recording low ecological vulnerability scores have depicted a relatively healthier ecological state due to high percentage of density of forest cover and less area affected by forest fires and soil erosion. Rest of the six tehsils such as Chaurah, Dalhousie, Holi, Bhattiyat, Bhalai and Pangi have recorded moderate levels of ecological vulnerability scores ranging between 0.33 and 0.55, because the percentage of people affected by soil erosion, and the number of trees uprooted are neither high nor too low in these tehsils (Table 2; Fig. 6).

Socio-ecological Vulnerability

The study reveals that Chamba (0.54) and Bhattiyat (0.53) tehsils have registered

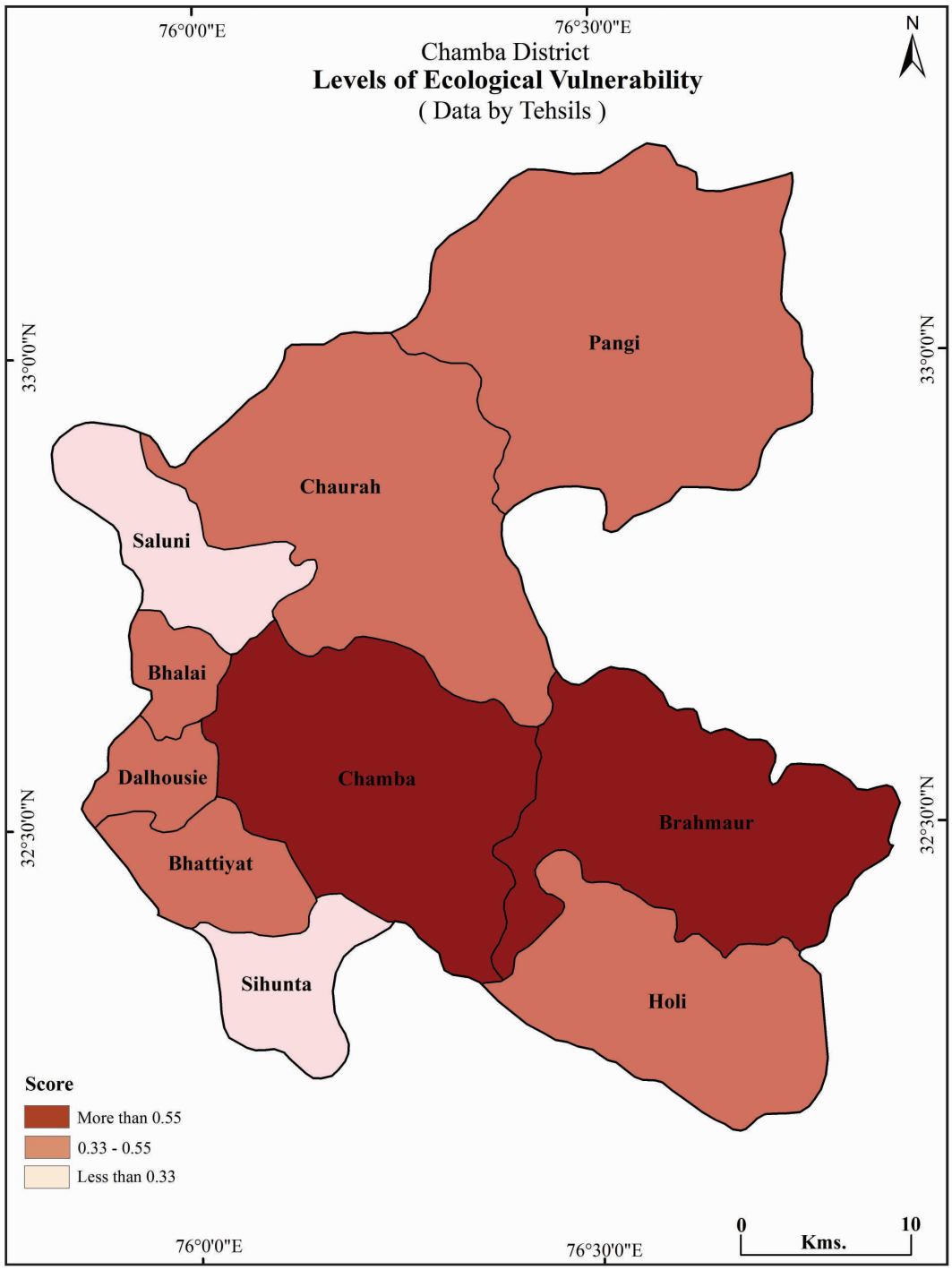
76°0'0"E
76°30'0"E
N
Chamba District
Levels of Ecological Vulnerability
(Data by Tehsils)
33°0'0"N
32°30'0"N
Pangi
Chaurah
Saluni
Bhalai
Dalhousie
Chamba
Brahmaur
Bhattiyat
Sihunta
Holi
Score
More than 0.55
0.33 - 0.55
Less than 0.33
0
10
Kms.

Fig. 6

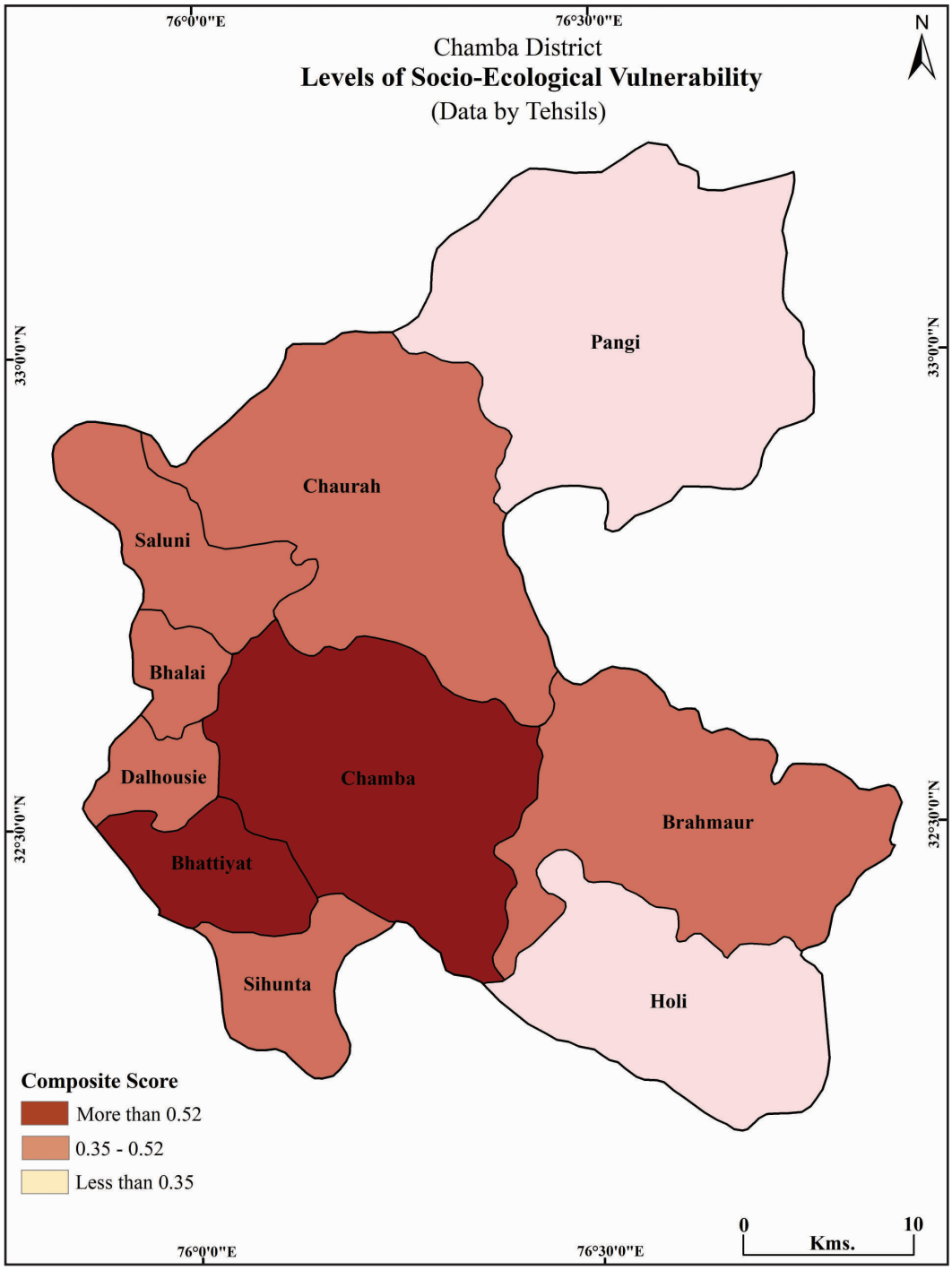
Chamba District
Levels of Socio-Ecological Vulnerability
(Data by Tehsils)
N
76°0'0"E
76°30'0"E
33°0'0"N
32°30'0"N
Pangi
Chaurah
Saluni
Bhalai
Dalhousie
Chamba
Brahmaur
Bhattiyat
Sihunta
Holi
Composite Score
More than 0.52
0.35 - 0.52
Less than 0.35
0
10
Kms.

Fig. 7

higher levels of socio-ecological vulnerability composite scores (Table 2, Fig 7). Chamba tehsil has recorded high scores in all the components of socio-ecological vulnerability, except institutional vulnerability score (0.30) whereas Bhattiyat tehsil has recorded high socio-ecological vulnerability composite score due to two components namely institutional (0.83) and economic (0.61) vulnerability scores (Table 2). These two tehsils are the most socio-ecological vulnerable, because of poor infrastructure, higher percentage of illiteracy, large number of people living below the poverty line, a smaller number of health services and a fewer number of banks in proportion to total population and high incidence of forest fires. On the contrary, Holi (0.30) and Pangi (0.32) tehsils have registered lower levels of socio-ecological vulnerability composite scores. Both the tehsils have witnessed low scores in all the five components except high ecological vulnerability score (0.54) recorded by Pangi tehsil (Table 2). The low level of socio-ecological vulnerability in these tehsils is attributed to better access to public services, healthcare and education services as compared to other tehsils. Having recorded a combination of high as well as low scores in various components of socio-ecological vulnerability, the tehsils like Dalhousie, Sihunta, Chaurah, Saluni, Bhalai, and Brahmaur tehsils have witnessed moderate socio-ecological vulnerability composite scores ranging between 0.35 and 0.52 (Table 2). It has been observed that, mean (0.44) value of socio-ecological vulnerability score is not high whereas SD (0.08) values of score are the least. This low value of SD (0.08) reflects that there is least deviation in socio-ecological vulnerability score values among all the ten tehsils (Table 2).

Relationship between the Components of Socio-Ecological Vulnerability

The study reveals strong positive correlation between infrastructural (0.76), economic (0.67), and social (0.66) vulnerability scores with the composite socio-ecological vulnerability score (Table 3). This suggests that weaknesses in these three components significantly contribute to the overall vulnerability of the tehsils, emphasizing the need for targeted improvements in these areas. Strengthening infrastructure, economic stability, and social resilience can play a crucial role in reducing overall socio-ecological vulnerability.

The social vulnerability component exhibits a moderate positive correlation with infrastructure (0.57) and weak relationship with economic vulnerability (0.27). This may be interpreted as tehsils with weaker social capital often struggle due to inadequate

Table 3

Chamba District: Relationship among Socio-ecological Vulnerability Indices

Components	Social	Economic	Institutional	Infrastructure	Ecological	Composite
Social	1.00					
Economic	0.27	1.00				
Institutional	-0.10	0.34	1.00			
Infrastructure	0.57	0.17	0.10	1.00		
Ecological	0.28	0.34	-0.47	-0.10	1.00	
Composite	0.66	0.67	0.41	0.76	0.21	1.00

Source: Compiled by Authors.

infrastructure and economic instability. Both social and economic vulnerabilities have displayed a strong positive correlation with the composite vulnerability score (0.66 and 0.67 respectively). This highlights the critical role of social factors like literacy levels, healthcare accessibility, and population density and economic factors like per capita income, percentage of population living below poverty line and crop loss determine the disparities in overall socio-ecological vulnerability.

Institutional vulnerability presents a low positive correlation with economic (0.34) vulnerability, but a moderate positive correlation with the overall composite score (0.41). However, the negative correlation between institutional and ecological vulnerability (−0.47) suggests that the tehsils with stronger governance and institutional frameworks are better equipped to manage environmental risks, thereby reducing ecological degradation. The infrastructure component demonstrates the strongest positive correlation (0.76) with the composite vulnerability score, highlighting the critical role of infrastructure in mitigating the overall vulnerability. The positive correlation between infrastructure and social vulnerability (0.57) suggests that poor infrastructure often contributes to weaker social structures, thereby increasing the overall vulnerability.

In contrast, a weak but positive correlation between ecological vulnerability scores and the composite score (0.21), suggests that although the environmental factors contribute to vulnerability, yet they are not the dominant factors influencing socio-ecological vulnerability. However, the negative correlation between institutional and ecological vulnerability (−0.47) highlights the importance of effective governance in mitigating the environmental risks through sustainable land management, conservation policies, and disaster preparedness initiatives.

Conclusions

The analysis of the composite score of socio-ecological components provides a critical insight about the socio-ecological vulnerability of Chamba district in general and all the ten tehsils in specific. Chamba and Bhattiyat tehsils have emerged to be the most vulnerable tehsils in the district. It is because of poor infrastructure, higher rate of illiteracy, large number of people residing below the poverty line, a smaller number of health services, fewer number of banks and high incidence of forest fires. These parameters have significantly contributed in making these tehsils highly socio-ecological vulnerable. On the other hand, Pangi and Holi tehsils have been found to be less vulnerable as these tehsils have better access to public services, healthcare and educational facilities as compared to other tehsils. The correlation matrix highlights strong positive correlation between infrastructure, economic, and social vulnerabilities with overall socio-ecological vulnerability. Thus, the tehsils with poor infrastructure tend to have higher overall vulnerability, suggesting significant investments in roads, healthcare, communication networks, and disaster-resilient construction is required to ensure overall upliftment of these teshils.

This study, therefore, can be useful in disaster risk reduction by integrating infrastructure development, economic empowerment, social well-being, institutional capacity-building, and environmental sustainability in Chamba district of Himachal Pradesh. This comprehensive analysis provides insights for development planners and policymakers

enabling them to identify areas of strengths and weaknesses across tehsils of Chamba district and highlights the need for tailor-made interventions accordingly. By addressing these interconnected vulnerabilities, policymakers can develop a comprehensive disaster risk reduction strategy, to ensure sustainable development and enhanced resilience across Chamba district.

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