

## Frail Social Vulnerability Questioning the Urban Sustainability in Himalayan Urban Centre

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### ABSTRACT

Social vulnerability in the Himalayan terrain is a result of interaction among the physical and socio-economic elements that control the community's livelihood. Darjeeling town is popularly known as the 'Queen of the Hills' and is located in the Eastern Himalaya (Darjeeling- Jalapahar ridge). However, this area has recently been experiencing profound challenges caused population pressure amid the urban area. The present study evaluates existence of social vulnerability, questioning the vision of sustainable development goals (i.e. SDG<sub>11</sub>) with the help of geospatial technology for a Himalayan urban unit i.e. Darjeeling Municipality, India. Based on criteria considered from the literature, ten key factors that contribute to social vulnerability were employed using the results of criteria weight and priority rank. In this present study, both empirical observation and computed Analytic Hierarchy Process (AHP) based spatial integration of various data have been incorporated. The final model was developed by maintaining an acceptable consistency ratio (< 0.1) and the receiver operating characteristic area under the curve (ROC-AUC) was performed to re-examine the study result, which shows 19.30%, 37.03%, and 27.10% of the region fall under very high, high, and moderately vulnerable conditions, respectively. The prevailing of this situation poorly replicated the vision of SDG<sub>11</sub> and created a challenging condition in front of urban planners for future resilience. The result indicates that most of the socially vulnerable wards are situated in the south, central, and western parts of the Darjeeling Municipality owing to the unplanned and haphazard growth of built environment.

**Keywords:** Darjeeling Municipality, Himalayan Hill Town, Social Vulnerability Index (SoVI), MCDM, AHP and SDG<sub>11</sub>.

### 1. INTRODUCTION

Vulnerability has a wide range of definitions from different perspectives. It is a frequently employed term in risk and hazard studies that are contextualised with climate change and environments (Cutter, 1996; Venkatesan and Ahmed, 2017). International Strategy for Disaster Reduction (ISDR) defines vulnerability as "The conditions determined by physical, social, economic, and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards" (ISDR, 2004). Recent studies indicated that urban areas globally are vulnerable to natural risks and stresses caused by climate change (Bixler *et al.*, 2021; Chang *et al.*,

2021; Majumder *et al.*, 2023). In 1800, only about 2 per cent of the world's population lived in urban areas, however currently, about 54 per cent of the world's population occupies urban areas, which is predicted to increase to over 67 per cent by 2050 (Andrey and Jones, 2008; Voskamp and Van de Ven, 2015). The majority of these populations belong to developing countries, in places such as India. In India, uncontrolled urban expansion and population concentration in potentially dangerous areas, including slums or unplanned settlements with poor living conditions and inadequate basic amenities, are frequently associated with urbanisation (Agarwal *et al.*, 2018; Dutt *et al.*, 1994). As a result, there are potentially more people who will be affected by a disaster (Bicknell

*et al.*, 2012; Revi, 2008). Concurrently, individuals in the mountain regions experience lesser access to fundamental amenities, inadequate physical access to services, and institutions, and greater dependency levels (*Dilshad et al.*, 2019; *Gerlitz et al.*, 2014). In addition, the Himalayas have experienced an increase in the number of urban centres, a rise in urban dwellers due to individuals migrating from rural and semi-urban areas to these urban centres, and an increase in the seasonally mobile populations, which includes leisure, religious travellers and recreational purposes (*Bharti et al.*, 2020; *Daniel et al.*, 2021).

Recent studies have shown an emerging relevance of social vulnerability assessment has prompted several initiatives to propose alternatives. Several efforts have been initiated to investigate societal vulnerability in various countries, such as the US (*Cutter and Finch*, 2008), Italy (*Frigerio and De Amicis*, 2016; *Kuhlicke et al.*, 2011). However, when compared to national and regional scales studies, less focus has been paid to an intra-city assessment of social vulnerability (*Armaş and Gavriş*, 2013; *Gu et al.*, 2018). However, all these studies had either limited comprehensive spatial analysis of social vulnerability or limited sustainability-based approaches used in this fragile urban unit, both of which made it challenging to comprehend SoVI in the setting of Himalayan urban unit.

On the other hand, multiple studies on social vulnerability were carried out in India. For instance, *Arunachalam et al.*, (2023) conducted their research on the social vulnerability in the Chennai Metropolitan Area (CMA) that analysed 23 particular variables using Principal Component Analysis (PCA). However, it is important to highlight that, to date, no studies are mapping and

questioning social vulnerability in context of sustainability at urban scale in the Himalayas urban town. There has been no comprehensive spatial assessment or urban unit level social vulnerability study in the eastern Himalayas by using RS and GIS. For this reason, questioning the future sustainability is vital to fragile social vulnerability, which can efficiently measure nature and extent of vulnerability and their distribution at the urban scale. Based on the NITI Aayog 2023-24 index, West Bengal with Eastern Himalayan states (including Arunachal Pradesh, Assam) are lowest performers in overall score of SDG 11 (NITI Aayog, 2019). So far, initiatives to localize the SDGs have been state level only, with no attempt to localize at city or municipal level. Despite expected all the challenges of weak state or sub-national governance and institutional capability, a critical knowledge gap exists in analysing how social vulnerability questions sustainability and in controlling SDG localisation. Furthermore, the study is a unique attempt to assess social vulnerability with questions about SDGs which are purely based on socially and physically caused factors in Darjeeling Municipality, whereas most studies associate with social vulnerability in context of climate change, landslides and hazard-relevant events. As per the foregoing discussion in this study, we utilize a widely established approach i.e., MCDM-AHP where factor weight computation is adequately corrected to assess the multicollinearity through TOL and VIF. With a focus on physical and social factors, this article examines extent and distribution of social vulnerability by utilizing 10 factors in the Himalayan urban unit. This study first aims to identify, categorise and quantify the fragile social vulnerability affecting areas using AHP in Himalayan hilly urban town, i.e., the Darjeeling

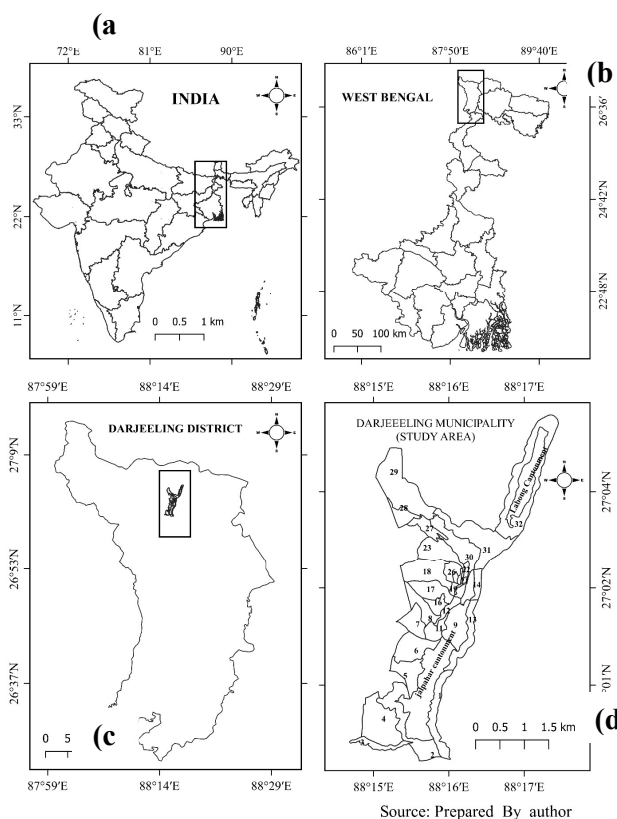
Municipality. Focussing on SDG 11, the second aim raises questions about sustainability in order to assess the SDG progress for urban future. At last, it is expected that this study will surely contribute to achieving New Urban Agenda (NUA) which is closely tied to the Sustainable Development Agenda 2030 and also provides a useful tool for planning and managing the vulnerability of

natural, socio-economic, and physically induced events.

## 2. MATERIAL AND METHODS

### 2.1. Location of the study area

Darjeeling Town is situated on the Darjeeling-Jalapahar ridge in the eastern Himalaya region (Fig. 1).



**Fig 1.** Location map of study area a) India, b) West Bengal, c) Darjeeling District and d) Study area i.e., Darjeeling Municipality.

Darjeeling Town is located in the district of Darjeeling, the state of West Bengal's northernmost region (O'Malley, 1907). It was founded by the British in 1850, making it one of the country's oldest municipal cities (Drew and Rai, 2016). Darjeeling serves as the district's

headquarters and is the largest of the district's hill towns. Darjeeling Municipality is located on this 'Y-shaped spur that surrounds the river valley of Rangit (O'Malley, 1907). Darjeeling Municipality lies between 26°31' N to 27°31' N latitude and 87°59' E to 88°53' E longitude. It covers an area of

10.7 square kilometres and is divided into 32 wards with two cantonments (Jalapahar cantonment in the southern part and Lebong Cantonment in the northern part) inside the municipal boundary (Koner and Samanta, 2021).

**2.2. Database and datasets**

A variety of controlling factors were selected based on extensive literature review on social vulnerability and existing social condition representation through wide thematic mapping of numerous variables using composite index (rank coefficient) to assess overall social vulnerability in Darjeeling municipality. The primary data for this study was also collected through a prepared

schedule. Primary data was collected for stockholders’ perceptions and ground truth points for validation purposes. To gather data, several data sources were employed, i.e., governmental organizations as well as international websites. After that, all datasets were acquired in different formats; all these format datasets were performed through pre-processing, cleaning, and reshaping with raster layer and thematic layer using ArcGIS 10.8 and QGIS 3.20 software for spatial mapping and visualisation purposes. The details about selected parameters, their source, weblink, specification, and rationale or importance are shown in [Table 1](#).

**Table 1.** Details about different selected datasets, type, data sources, weblinks, specification.

Type	Main Criteria	Data Type	Specification	Data Sources
Physical	Ground Slope	Aster Dem	30 m resolution	<a href="https://search.earthdata.nasa.gov/">https://search.earthdata.nasa.gov/</a>
	Surface Elevation	Aster Dem	30 m resolution	<a href="https://earthexplorer.usgs.gov/">https://earthexplorer.usgs.gov/</a>
	Relative Relief	Aster Dem	Thematic map	<a href="https://earthexplorer.usgs.gov/">https://earthexplorer.usgs.gov/</a>
	Dissection Index	Aster Dem	30 m resolution	<a href="https://earthexplorer.usgs.gov/">https://earthexplorer.usgs.gov/</a>
	Land use and land cover	Sentinel 2B	30 m resolution	<a href="https://earthexplorer.usgs.gov/">https://earthexplorer.usgs.gov/</a>
Social	Road Density	Open street Map (updated)	Thematic Map	<a href="https://www.openstreetmap.org/">https://www.openstreetmap.org/</a>
	Drinking water source Index	Census Data	Thematic Map	<a href="https://censusindia.gov.in/">https://censusindia.gov.in/</a>
	Vulnerable Population Index	Census Data	Thematic Map	<a href="https://censusindia.gov.in/">https://censusindia.gov.in/</a>
	Housing Quality Index	Census Data	Thematic Map	<a href="https://censusindia.gov.in/">https://censusindia.gov.in/</a>
	Service Quality Index	Census Data	Thematic Map	<a href="https://censusindia.gov.in/">https://censusindia.gov.in/</a>

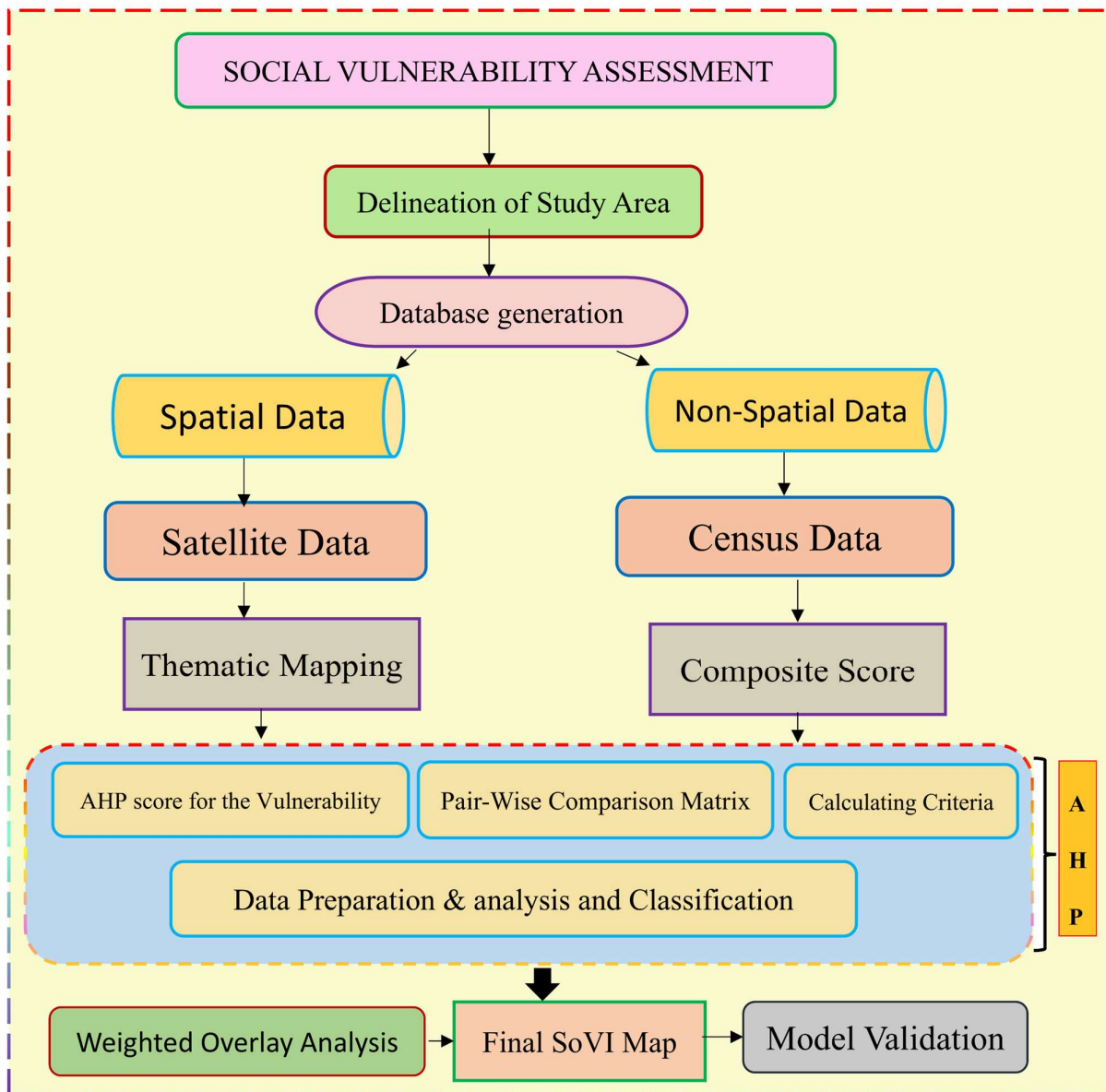
The essential description of the parameter, sub-classes, and spatial variation are discussed in the

following subsection of this paper. A qualitative survey was conducted for perception about urban

amenities, municipal services, and water availability in the study area. A structured, closed-ended schedule was prepared for data collection.

**2.3. Methodology**

To measure the social vulnerability assessment in the Darjeeling municipality, the following methods were considered in the current study and association methodological flowchart is shown in Fig. 2.



**Fig. 2.** Schematic presentation of Methodological workflow adopted in the study area.

**Computation process of composite index for measuring vulnerability**

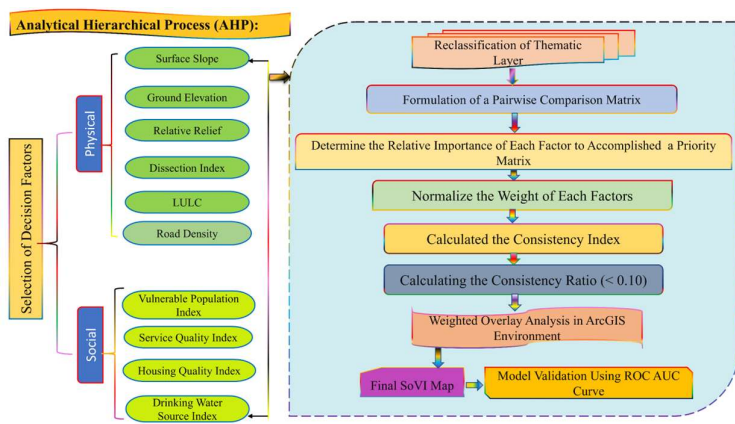
Creating a composite index is a difficult task. Its phases include a variety of choices and possibilities that influence the quality and reliability of the results. Concerning the choice of theoretical framework, the availability of data, the selection of more representative indicators, and their treatment to compare and aggregate them in this method (Fanchette *et al.*, 1974; Murthy *et al.*, 2015). The Composite Index is created by combining various factors or indicators. In the present study, an attempt is made here to apply the techniques of data standardization like ranking, simple quotient, and Z-value for computing composite scores. For this purpose, the attributes of demography have been considered at the ward level for the Darjeeling municipality of Darjeeling district for the year 2011. For constructing the composite index, we simply used the ranking method and it is one of the easiest and quickest ways to compute a composite score when dealing with multivariate data and diverse units of measurement (Kendall, 1939).

**The GIS-based multicriteria decision making approach**

MCDM is a useful technique for making or analysing complex decisions and difficulties based on some appropriate alternative selections (Malczewski and Liu, 2014). MCDM allows data storage, analysis, modification, and visualisation for decision making. This present study assigned weightage to the factors based on the analytical Hierarchical Process (AHP). Following that, we constructed this AHP model to identify the Social Vulnerability in Darjeeling municipality.

**Analytical hierarchical process (AHP) for social vulnerability assessment**

The AHP is the most often used criterion weighting approach in multi-criteria decision-making (MCDM) situations (Alzouby *et al.*, 2019; Liu *et al.*, 2020). Prof. Thomas L. Saaty created AHP as one of the MCDM methodologies in the 1960s (Saaty, 2012). (Saaty, 1984) employs a nine-point recording scale to score the relative preference of each element on a one-to-one basis. In the present study, we considered 10 factors for evaluating the performance of alternatives in pair-wise comparisons in the Analytical hierarchical model. The weightage of each element was calculated using AHP Method (Saaty, 1984). Then, we calculated the Consistency Ratio (CR) (Fig. 3).



**Fig. 3.** Flow chart of steps involved in the implementation of AHP in this study area

### **Multi-collinearity (MC) test for social vulnerability**

Multicollinearity is a statistical analysis in which numbers of independent elements in a multiple regression model are highly correlated, implying the ability to predict one from the other linearly from the others with a non-trivial level of precision (Pourghasemi *et al.*, 2017; Saha, 2017). Consequently, prior to generating a vulnerability map, we conducted a multi-collinearity test among the independent variables. In MC testing, the two most commonly used methods, variance inflation factors (VIF) and tolerance (TOL), have been extensively used (Saha *et al.*, 2023). Therefore, in this work, we used VIF and TOL methodologies to identify multi-collinearity issues among the factors impacting vulnerability

### **Validation of Social Vulnerability Assessment**

It is necessary to validate the resulting vulnerability maps and determine their predictive power to construct a reliable model. Thus, assessment of social vulnerability maps appears to be pivotal for the purpose of the current paper. In this study, one prominent and well accepted measure, namely area under the receiver operating characteristic curve (ROC), was used to evaluate the model. ROC is a graphical plot that determines the model's performance in a diagnostic test (Egan, 1975; Gayen *et al.*, 2020). As a result, ROC and AUC analyses were used in this work to validate the performance of AHP model. The AUC for AHP model gives a result of about 92.7 per cent, indicating that results range from satisfactory levels (0.7-0.9).

## **RESULTS AND DISCUSSION**

### **Vulnerability Controlling Factors**

Social vulnerability assessment is integrated with several factors, such as social, demographic, economic, physical, Health, etc (Arunachalam *et al.*, 2023; Xie and Meng, 2023). In the current study, total number of ten factors were identified and used AHP model to predict the vulnerability and its spatial analysis. Physical factors closely associated with vulnerability assessment like slope, elevation, slope, Relative Relief, NDVI, and LULC. On the other hand, social factors like population, urban services, housing and water are more vital for measuring SoVI in mountainous ridge regions. Therefore, total ten factors or indicators were selected for social vulnerability assessment. The Spatial distribution of each controlling factor is vital to understanding the vulnerability and identifying most vulnerable wards in study area.

### **Multi-collinearity (MC) analysis**

For overall social vulnerability assessment, a total of ten criteria were selected for MC test. After this MC test, we consider these ten criteria for the present study. For this reason, in this study, VIF and tolerance are used to check each criterion. After MC test, the result of ten selected criteria (Table 2) shows that all of the criteria, namely VIF (<5) and TOL (>0.1), are within range value. So, results revealed that there are no MC problems in selected datasets. The highest VIF values show lowest TOL level. The highest and lowest VIF values are found in vulnerable service index (2.84) and road density (1.29), respectively, whereas the highest and lowest TOL values are found in road density (0.77) and vulnerable service index (0.35), respectively.

**Table 2.** Multicollinearity (MC) results of selected criteria

Criteria	Tolerance	R <sup>2</sup>	VIF
Slope	0.66	0.35	1.53
Elevation	0.76	0.25	1.33
LULC	0.65	0.35	1.54
NDVI	0.61	0.39	1.65
RR	0.68	0.32	1.46
RD	0.77	0.23	1.29
VPI	0.40	0.60	2.52
VDWI	0.55	0.45	1.83
VHI	0.41	0.59	2.45
VSI	0.35	0.65	2.84

**3.3 Assessment of selected factors weightage**

The present study considered ten major influencing factors (elevation, slope, LULC, road density, NDVI, relative relief, vulnerable population index, vulnerable drinking water index, vulnerable housing Index, and vulnerable service index) in developing a social vulnerability assessment. In AHP matrix, the maximum eigen value (Cmax) =11.2848, RI =1.49, CI =0.1428, CR= 0.0958 and n = 10. In general, the CR value should be below 0.10, and in this study, we obtained a CR value of = 0.0958. The weights were properly assigned to the factors, as evidenced by this CR score. As a result, it is acceptable to assert that such factors and subfactors can be included in the AHP analysis.

The relative importance of each component in the study is represented in [Table 3](#). According to the AHP method, the drinking water source Index (39.66%), Service Quality Index (17.57%), the Housing Quality Index (17.41%), and Vulnerable Population index (13.53%) were the most essential parameters in establishing SoVI. On the other hand, road density (3.31%), LULC (1.99%), relative relief (3.02%), slope (5.98%), NDVI (1.47%), elevation (6.06%) was identified as the least significant elements for social vulnerability assessment.

**Table 3.** Priority and Rank of each parameter.

Criteria	Priority (%)	Rank
Slope	5.98	6
Elevation	6.06	5
Relative relief	3.02	8
NDVI	1.47	10
LULC	1.99	9
Road density	3.31	7
Vulnerable drinking water	29.66	1
Vulnerable population	13.53	4
Vulnerable housing	17.41	3
Vulnerable service	17.57	2
Total	100.00	

**3.4 Assessment of Social Vulnerability in Darjeeling Municipality**

In this present study, the ten influencing parameters were used to create a social vulnerability map. Based on the weighted overlay method (WoE) method in the ArcGIS 10.4 environment, social vulnerability map was classified into four categories using Jenk’s rule. The results indicate that the study area has very high (27.54%), high (39.53), low (26.97), and very low (5.98%) areas. A very highly vulnerable area was found in the central, eastern fringe, south-western, and lower parts of the wards in Darjeeling Municipality. More precisely, a very high vulnerability zone was prominently found in 1, 4, 5, 8, 9, 13, 14 15, and 26 number wards in Darjeeling municipality (Fig. 4). The very high vulnerability score indicates that the wards have a low quality of urban services. The highly vulnerable zone was found in the northern part, western fringe wards and southern parts of

Darjeeling municipality. More specifically, a high vulnerability zone was highly found in 2, 6, 7, 11, 28, and 31 wards of the study area. Lower service quality, vulnerable population, and drinking water are the primary elements that contribute to high level of vulnerability. In the north-western, northern parts and central some wards were found as low vulnerability zones in the study area. In detail, 6, 7, 11, 17, 18, 28, and 29 number wards are characterized by low vulnerable zone. A steep slope, high elevation and lower quality of housing index were characteristics of this zone. The very low vulnerability zone was randomly found in some parts of northern and southern parts of the study region. Labong and Jalapahar cantonment areas in Darjeeling municipality were not considered in the vulnerability mapping due to data unavailability.

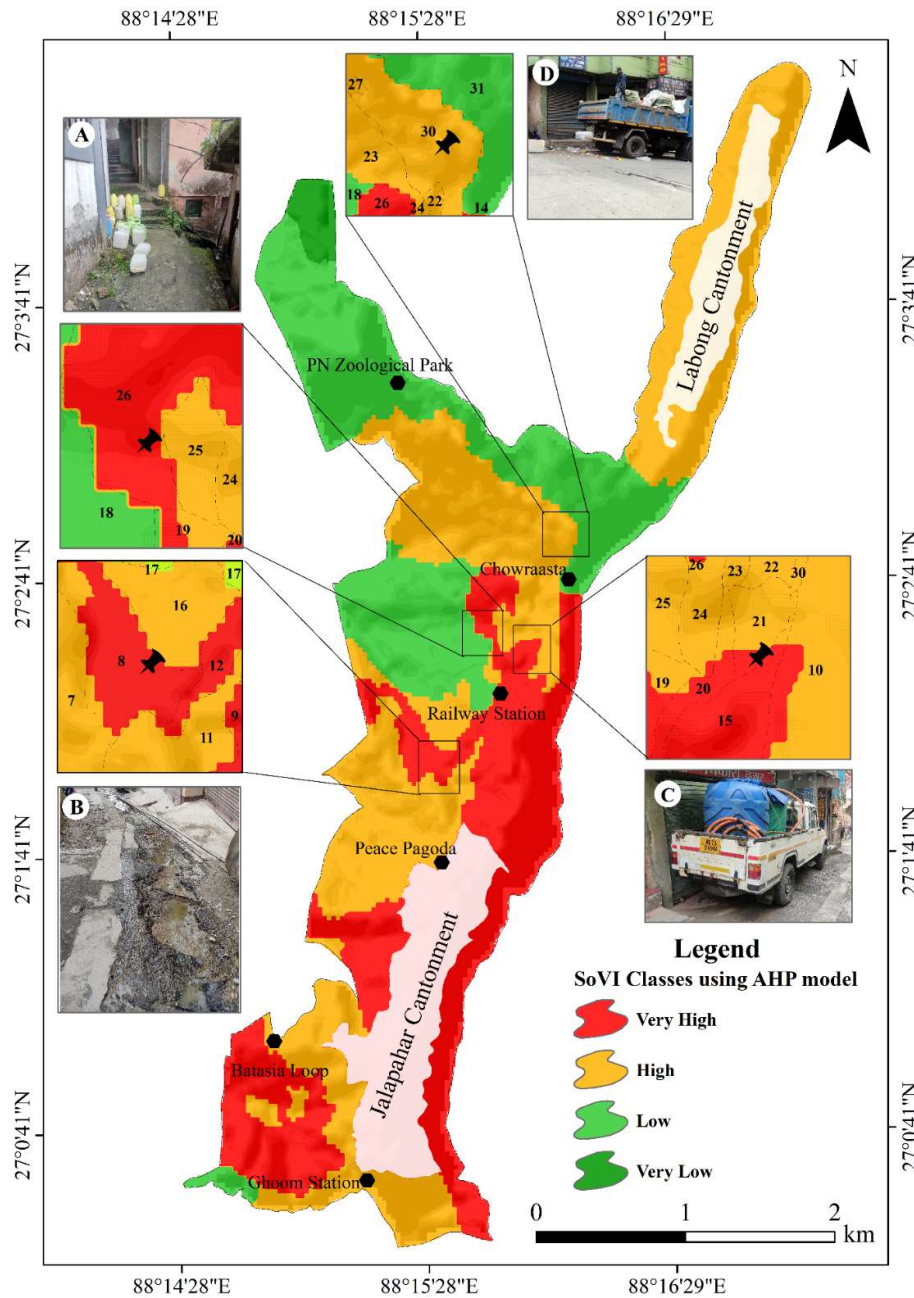


Fig. 4. Social vulnerability map of Darjeeling municipality using AHP method

**Stockholder’s Perception based on questionnaire survey**

The Census of India (1961) categorizes houses depending on the primary wall and roof materials. The material used to build houses reflects the

social-economic conditions of households in an area. Different types of housing conditions were found in municipality and it was observed that housing conditions were not uniformly distributed in all wards of Darjeeling Municipality. It has been

observed that 62% of respondents have roofs built with cement in the sampled (12, 15, 19, 20, 21, 30) wards of Darjeeling town. Only 28% of respondents have tin roofs and just 6 per cent of respondents have asbestos roofs in the study area. Along with other types of roofs found in 18, 23, and 31 sampled wards, they used plastic or polythene with bamboo or wooden sticks. The wall made of bricks or cement (52 per cent of respondents) was prominently found in 10, 11, 15, 21, and 22 wards. About 30 per cent of respondent house walls were made of Wood mostly observed in 23, 31, and 32. Although stone and bamboo walls of houses are also reported in some parts of 23 and 31 wards. This housing condition reflects that poor economic situation and occurrence of poverty were reflected in the types of houses in the study area. Additionally, recent NITI Aayog 2023-24 index revealed that still West Bengal has not fulfilled of SDG 11 target on urban households in the Kachha houses.

The municipal authority is responsible for water supply in the municipality area. The centralised system built by the British in the early nineteenth century is no longer enough for the entire city and is also not affordable to all classes of people in this town (Koner and Samanta, 2021). It is evident from respondents that Most of the respondents (36 per cent) collect water from Jhoras in normal season. Whereas 28 per cent of respondents collect drinking water from the municipality pipeline in normal season. The rest of the respondents also collected drinking water from springs, porters, hand carts and private water vehicles. A different picture was found in the crisis season in Darjeeling municipality. In crisis season i.e., summer season becomes more acute due to peak tourist arrival when most of Jhoras becomes dry (Moitra, 2008). In this crisis season, social, political and economic

systems are disturbed as each person is involved in collection of water. The majority of respondents (more than 50 per cent) collect water from 40-80 meters and beyond 80 meters distance in the outer boundary of 23, 27, 31, and 32 wards. During the field survey, it was observed that more than larger numbers of women are involved in water collecting process as well as adolescents' children also are involved in this process. The children and youth (below 20 years old) and Students are the most vulnerable part because they are also involved in this system.

It was found that most of the households (62% of respondents) haphazardly dumped solid waste near the roadside, downslope area and open space or drainage channel in the 7, 9, 13, and 31 wards. Additionally, it is observed during field survey that local urban authority manages the solid waste in wards 15, 20, 21, and 24. At the state level, West Bengal's municipal solid waste (MSW) process achievement is also far from SDG 11 target reported by NITI Aayog 2023-24. About 76% of respondents replied that they used their toilet in the sampled 22, 24, and 25 wards. Whereas about 24% of respondents indicated they have no own toilet facilities in the sampled 31,32 wards. Not only that, but West Bengal is falling behind in terms of individual household toilet construction targets as per NITI Aayog Report 2023-2024. All of these highlight concerns because an organised development planning progress and plan of action at the municipal level are required integrated urban planning with the SDGs. The spatial integration of freely available data along with the help of GIS platform is able to depict the less advanced wards within a municipal boundary, and this attempt will help the planner to implement the social welfare schemes in the particular areas. When the urbanization of developing nations is

taking place in small and medium centres like Darjeeling town, the target to provide adequate, safe and affordable houses for all, the provision of basic services and up gradation of slums etc. will be incorporated in the assessment process of the social vulnerability induced citizen's basic needs, where stockholders' perception plays a vital role for the spatial analysis in spatial information system.

### **CONCLUSION**

The present study aimed to provide social vulnerability of Himalayan mountainous urban units and demonstrated how frail social vulnerability raises questions about future urban sustainability in specific SDG 11. Furthermore, some major factors contributing to local social vulnerability were identified and analysed based on the results of weighted factors. And at last, overall social vulnerability assessment has also been performed using AHP method. According to the results of overall social vulnerability, there is high to severe vulnerability in the central, eastern fringe, south-western, and lower parts of the wards in Darjeeling Municipality (wards no. 1, 4, 5, 8, 9, 13, 14 15, and 26). Major causes of very high vulnerability are mainly socioeconomic factors like high population density, low service quality, water scarcity and some physical factors. Better socioeconomic conditions, specifically water supply, service quality, sewage facility and housing conditions, can increase the resistance power of highly vulnerable wards, and these wards need more attention from Darjeeling Municipality. Regions of high vulnerability may require special attention in terms of planning and preparedness, whilst low vulnerability areas may benefit from the majority of programmes offered by municipality. According to Samanta and Koner, (2016), the

administration collapses to provide necessary urban services due to multiple actors involved in the same services from different organizations in regard to water sustainability, and no pro-poor water policies have been adopted, despite the presence of 37 notified slums (23 % of total urban population). Further, lack of political and administrative effort impedes the existing supply system and exacerbates the present situation (Mondal and Roychowdhury, 2019). To addressing the urban issues in Darjeeling Municipality, a comprehensive urban planning for future sustainable development as well as long term goal and master plan preparation, are expected to facilitate immediate alleviation from present crisis. The spatial distribution of social vulnerability map is decisive for hazard management, socioeconomic growth of town and future planning. Methodologically, social vulnerability assessment methodology gives useful information to disaster management practitioners (Guo and Kapucu, 2020). The spatial mapping of social vulnerability provided would be of notable benefit to stakeholders, urban local bodies (ULBs) and thus contribute to addressing Sustainable Development Goals<sub>11</sub> making cities safe, inclusive, resilient and sustainable. This study is vital for hazard management, as well as in identifying the socioeconomically vulnerable community to build the community resilience.

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### CONFLICT OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. The authors also declare there is no conflict of interest in publication of this paper.

### FUND DECLARATION

All the expenditure has been supported by authors for this study. There is no funding support from any agency for pursuing the study.

### DATA AVAILABILITY

This paper is based on the secondary data, and these are freely available in the Census website, Govt of India. Maps are prepared based on the base map provided by Municipal authority and primary data which are collected from the field. All processed data are available with authors and will provide on request.

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