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Rethinking Development: Insights from Micro- and Meso-Level Socio-Economic Vulnerability Assessment of an Agrarian Heartland in Central India

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ABSTRACT

Vulnerability is central to policy-making, requiring systematic assessments to prioritise development, enhance adaptive capacity, and address climate risks in resource-limited, agriculture-dependent regions. Nearly half of India's districts exhibit strong agricultural growth but only moderate human development, leaving them outside priority interventions while lacking sustained progress. The study examines the socio-economic vulnerability of Sagar district, Madhya Pradesh, taking it as a representative case, through the Socio-Economic Vulnerability Index (SEVI), applied across the spatial scales: village/tehsil (micro) and district (meso). The SEVI framework integrates sensitivity and adaptive capacity dimensions, built on 22 socio-economic indicators, using data primarily drawn from census sources. Of Sagar's 1,869 villages, 75 per cent (1,395 villages) were classified as highly vulnerable, with clusters of the most (192 villages) and least (7 villages) vulnerable showing SEVI values ranging from 0.60 (Ranipura) to 0.09 (Bhajiya). Sagar tehsil exhibited the highest concentration of highly vulnerable villages. One-way ANOVA identified significant variability in 18 vulnerability indicators across tehsils and villages. Drivers such as high proportion of agricultural labour, extensive net sown areas, and remoteness of villages affected the entire district. At the same time, such problems as limited household assets, inadequate infrastructure, poor transportation, and low irrigation levels were concentrated in specific areas. The study highlights the unique vulnerabilities of districts that fall between the most backward and the most developed. These findings underline the need for spatially differentiated interventions, with the SEVI tool demonstrating its utility in shifting policy focus from district-level interventions to targeted village-level strategies. This approach can reduce development transaction costs, improve resource efficiency, and accelerate progress toward achieving the Sustainable Development Goals (SDGs) by 2030.

Keywords: Vulnerability, adaptive capacity, agricultural productivity, resilience, sustainability

JEL Codes: I32, O15, O18, R20, R58

I

INTRODUCTION

Climate change is now widely recognised as one of the greatest development challenges (Shove, 2010). Often referred to as the "mother of all externalities," its impacts are vast, disrupting agriculture, energy, health, and ecosystems on a global scale. These effects are felt unevenly, with those least responsible for climate change bearing the most severe consequences as it intensifies inequalities, undermines resilience, and ultimately exacerbates the conditions that lead to vulnerability (Tol, 2009). The Intergovernmental Panel on Climate Change (IPCC) defined vulnerability to climate change as "the degree to which a system is susceptible to or unable to cope with adverse effects of climate change, including climate variability and extremes" (McCarthy et al. 2001). This definition emphasises that vulnerability is a function of exposure, sensitivity, and adaptive capacity. Many studies on vulnerability to climate

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change have primarily focused on exposure-related aspects (Brooks et al., 2005; Cutter et al., 2003; O'Brien et al., 2004; Ford & Smit, 2004), neglecting the social drivers and unequal distribution of risk, thereby leaving deeper social factors unaddressed (Thomas et al., 2018). Despite the multidisciplinary nature of vulnerability, most researchers agree that it is predominantly a socially constructed phenomenon (Bohle et al. 1994; Cutter et al., 2003; Blaikie et al., 2004; Downing et al., 2005; Jeganathan et al., 2021; Maiti et al., 2015; Krishnan et al., 2019; Tasnuva et al., 2021). This view is also supported by Kelly and Adger (2000), who argued that vulnerability is primarily determined by *current* conditions rather than future events. Even the definition used by the IPCC has been refined in its later reports, stating that "vulnerability is the propensity or predisposition to be adversely affected and encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and lack of capacity to cope and adapt" (IPCC, 2022). In this perspective, vulnerability is understood as comprising only sensitivity and adaptive capacity, with exposure treated as an external factor (George et al., 2023). Cutter et al. (2003) emphasised that socio-economic conditions play a greater role in shaping vulnerability than mere geographical setting, a view Cutter (1993) had also articulated earlier. Inequalities in the social and economic spheres intensify the conditions that lead to socio-economic vulnerability (Cutter et al., 2003). Assessments of socio-economic vulnerability, therefore, focus on how regional social and economic attributes influence susceptibility to hazards (Malakar & Mishra, 2016). Such evaluations aim to disentangle the interplay of vulnerability drivers and highlight those areas most prone to risk (Kienberger et al., 2009). Vulnerability has become a central theme in policies across diverse areas, from violence against women to natural disasters, shaping governance at local, national, and international levels (Brown, 2015). Furthermore, studies have highlighted the importance of vulnerability assessments in setting development priorities and monitoring progress (Biswas and Nautiyal, 2023). Therefore, understanding and addressing socio-economic vulnerability is crucial for promoting resilient development.

India's agriculture sustains 17.2 per cent of the global population with just 9 per cent of the world's arable land (Goyal and Surampalli, 2018), making it the second-largest rice producer (Shahbandeh, 2022) and responsible for 20 per cent of global millet production (GOI, 2022), positioning India as a critical part of the world's breadbasket. The Indian agricultural sector serves as a primary source of livelihood for approximately 42.3 per cent of the population and contributes 18.2 per cent to the nation's GDP at current prices (GOI, 2024). However, evidence shows that India's agriculture is highly vulnerable to climate shocks (Aufhammer et al., 2012; Choudhary & Sirohi, 2020). With 68.9 per cent of its rural population dependent on agriculture and 82 per cent of its farmers classified as small and marginal (Census of India, 2011), a large portion of the population is exposed to climate risks, heightening their vulnerability. Ranked 7th out of 180 on the Germanwatch Global Climate Risk Index 2021 (Germanwatch, 2021), India's susceptibility to climate impacts is significant. Yet, recent growth trends in India's agriculture sector have highlighted its resilience to external shocks, such as the COVID-19 pandemic (Choudhary and Sirohi, 2022). Although the country has seen growth, regional variations continue to influence its adaptive capacity across states (Das et al., 2020).

While each Indian state has its own unique traits, Madhya Pradesh, positioned at the country's centre, reflects a wide range of national challenges, particularly in agricultural growth and climate vulnerabilities. Often called the "heart of India" due to its location, it encapsulates the diverse demographic and economic landscapes of the country and exemplifies the broader challenges and opportunities faced by the agriculture sector in addressing climate vulnerabilities. Madhya Pradesh, has nearly 72 per cent of its population residing in rural areas, with the majority dependent on agriculture for their livelihoods (Census of India, 2011). The primary sector remains the cornerstone of the state's economy, with its contribution to the Gross State Value Added (GSVA) rising significantly from 33.85 per cent in FY 2011-12 to 45.53 per cent in FY 2023-24 at current prices (Madhya Pradesh Economic Survey, 2023-24). Although the state’s economy is expanding, notable regional differences exist, with economic growth unevenly distributed across districts and within districts, extending down to the tehsil and village levels (Chaurasia, 2011). Given agriculture’s critical role in the state’s economy, any decline in output due to climate shocks can have profound repercussions on both economic stability and the livelihoods of rural communities, where the majority of the impoverished population resides and remains particularly vulnerable due to their heavy dependence on agriculture (Mall et al., 2011). This underscores the importance of assessing the vulnerability of rural regions where agriculture is the primary economic contributor.

Numerous studies in India have assessed vulnerabilities (Choudhary and Sirohi, 2022; Dasgupta et al., 2019), often using the district as a spatial unit, which overlooks the deeper social and economic constructs of vulnerability at sub-district levels, such as tehsils and villages. In-depth, micro-level studies at the village or community level are essential for revealing the subtle vulnerabilities that broader assessments may overlook (Krishnan et al., 2019). There have been relatively few studies focused on examining socio-economic vulnerability at the sub-district or village level in India (Mohammad et al. 2025; Atufa et al., 2023; Umamaheswari et al., 2021; Mohammad, 2021; Suvetha, 2021; Sathya, 2021; Seenivasan, 2021; Seenivasan et al., 2022). As vulnerability is the flip side of resilience, conducting micro-level studies is crucial for assessing vulnerabilities and designing targeted interventions that address immediate risks, build long-term adaptive capacities, foster resilient and equitable communities, and ensure sustainable and inclusive development (Choudhary and Sirohi, 2022). These interventions, tailored to local needs, ultimately support the reduction of vulnerability and enhance overall resilience. Against this background, the present work seeks to address three central aspects of vulnerability within a district: its magnitude (how much), its spatial variation (where), and its underlying drivers (why). The analysis focuses on the social and economic dimensions of vulnerability at both the meso (district) and micro levels, encompassing blocks, Gram Panchayats, and villages. The agriculturally dependent district of Madhya Pradesh was selected as the study area, and the assessment was conducted using the Socio-Economic Vulnerability Index (SEVI), a structured framework specifically developed for this purpose. This has significant implications for identifying and prioritising administrative units for development interventions, as well as for customising location-specific strategies to strengthen community resilience.

II

DATA AND METHODOLOGY

2.1 Study Area

Madhya Pradesh's 50 districts were screened by excluding urbanised districts like Indore, Bhopal, Jabalpur, and Gwalior, where the tertiary sector dominates, as well as districts contributing less than 2 per cent to the state's GVA. This narrowed the focus to regions with stronger primary sector contributions and higher economic significance. The screening process resulted in a total of 12 districts (Table 1), from which Sagar district was purposively selected for this study due to its significant contribution to Madhya Pradesh's Gross Value Added (GVA) and its unique socio-economic characteristics, representing a predominant agrarian economy combined with moderate levels of economic and human development.

Sagar contributes 3.13 per cent to the total GVA of Madhya Pradesh, with 44.4 per cent of its district GVA derived from the primary sector. This agricultural reliance places it alongside other agriculturally driven districts, such as Chhindwara (59.8%), Dhar (55.3%), and Rewa (53.5%). However, Sagar's socio-economic profile sets it apart. With a per capita income of ₹99,848 and a Human Development Index (HDI) of 0.563, Sagar demonstrates lower socio-economic outcomes compared to districts like Chhindwara (₹1,27,400, HDI 0.578) and Dhar (₹1,05,390, HDI 0.596), highlighting its developmental challenges. Despite these constraints, Sagar's population of 23,78,295 - among the largest in agriculturally dependent districts - underscores its importance as a representative case for rural livelihoods.

Further, the district’s reliance on agriculture exposes a significant portion of its population to climate-related risks, market fluctuations, and resource constraints, which are common challenges in agriculturally dominated regions. It can serve as a microcosm for understanding the interplay of socio-economic factors and guiding policies to reduce vulnerabilities, foster sustainability, and enhance resilience across the state and country, where agriculture remains the backbone of livelihoods. By focusing on Sagar, this study aims to explore the drivers and buffers of socio-economic vulnerability in agriculturally dependent regions. The findings from this case are highly relevant not only to Madhya Pradesh but also to India as a whole, where agricultural dependency and rural livelihoods play a crucial role in constructing socio-economic outcomes across various regions.

TABLE 1. SELECTION CRITERIA OF STUDY AREA

District	Primary Sector GVA (₹ Lakh) *	Total GVA (₹ Lakh) *	Contribution to State's GVA (%)	Primary GVA to total District GVA (%)	Per capita Income (₹)	HDI, 2005	Population
Chhindwara	18,90,162	31,58,379	3.42	59.8	1,27,400	0.578	20,90,306
Sagar	12,80,066	28,85,246	3.13	44.4	99,848	0.563	23,78,295
Dhar	15,29,611	27,67,087	3.00	55.3	1,05,390	0.596	21,84,672
Satna	11,25,234	25,99,038	2.82	43.3	95,853	0.516	22,28,619
Rewa	13,69,940	25,58,869	2.77	53.5	90,533	0.526	23,63,744
Singrauli	19,90,080	25,56,149	2.77	77.9	1,68,375	#	11,78,132
Dewas	11,44,716	24,99,710	2.71	45.8	1,27,723	0.627	15,63,107
Ratlam	10,77,643	23,54,428	2.55	45.8	1,30,944	0.589	14,54,483
Hoshangabad	10,96,585	21,29,139	2.31	51.5	1,42,317	0.595	12,40,975
Shajapur	12,45,156	21,25,529	2.30	58.6	1,17,125	0.605	15,12,353
Khargone	11,60,905	21,20,993	2.30	54.7	94,544	0.525	18,73,046
Shivpuri	11,38,111	18,86,610	2.04	60.3	92,479	0.49	17,25,818

Sources: MPHDRO, Directorate of economics & statistics, Madhya Pradesh
*Note - *at Current Prices 2020-21, #data not available for Singrauli district as it was formed later in 2008*

Sagar district, situated in the north-central region of Madhya Pradesh, between 23°10’–24°27’ N latitude and 78°5’–79°21’ E longitude (Figure 1), spans an area of 10,252 sq. km, ranking among the larger districts of the state (https://sagar.nic.in). The landscape is predominantly agricultural, sustained by rivers such as the Bina and Gadhera that flow across the region and support farming activities. Administratively, the district consists of 11 tehsils, 20 towns, and 2,075 villages, reflecting both rural and urban characteristics. For the present study, 1,869 inhabited villages with available census data were included. The remaining 206 villages were excluded, comprising 174 uninhabited villages and 32 for which complete information was not available for the chosen indicators. Towns were not considered, as the analysis focused solely on rural areas.

Sagar district's sex ratio is 893, below the state (930) and national (940) averages. Scheduled Castes constituted 21.1 per cent of the population, while Scheduled Tribes accounted for 9.3 per cent. Predominantly rural, 70.2 per cent of the district's population resided in villages, which is slightly below the state average of 72.37 per cent. Its population density was 232 persons/km², just under the state average of 236 (GOI, 2011). The literacy rate in Sagar district was 76.46 per cent, against the state average of 69.32 per cent. However, the female literacy rate lagged at 67.02 per cent, showing gender disparities in educational attainment. Despite these higher literacy rates, economic conditions continue to pose a challenge. The annual per capita income in 2020-21 was Rs. 99,848, which is below the state average, indicating a low economic capacity to deal with environmental stresses.

Agriculture remains the backbone of Sagar's economy, with 70.2 per cent of the population dependent on it. Of these, 20.24 per cent are cultivators, while 37.63 per cent work as agricultural labourers. The district receives an annual rainfall of around 1193 mm, which supports the cultivation of crops such as wheat, gram, paddy, and pulses, contributing significantly to the local economy. However, this dependence on agriculture makes the population vulnerable to climatic variability and market fluctuations.

In terms of health and infrastructure, according to the National Family Health Survey (2019-21), 98.6 per cent of households in Sagar had access to electricity, 86.7 per cent had access to improved drinking water sources, and 68.8 per cent had access to improved sanitation facilities. However, only 32.7 per cent of households used clean fuel for cooking, and just 27.5 per cent of the population was covered by health schemes or insurance, indicating gaps in basic amenities. Malnutrition remains a concern, with 42.7 per cent of children under 5 years stunted (height-for-age), and 15.2 per cent wasted (weight-for-height), though these figures are higher than the state averages (35.7%) for height-for-age and lower (19%) for weight-for-height. Sagar’s economy and health indicators reflect moderate development, with noticeable improvements in literacy but challenges in nutrition and economic resilience due to heavy reliance on agriculture.

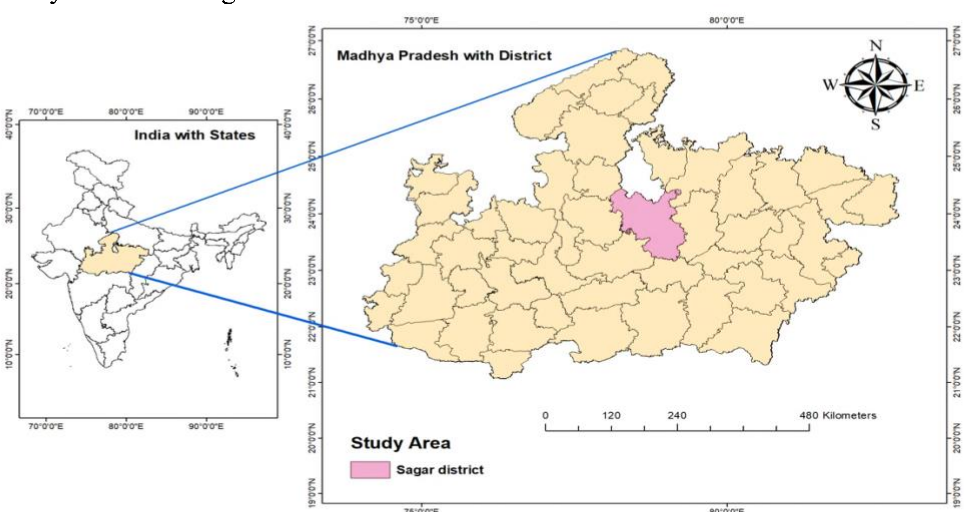

FIGURE 1. STUDY AREA SHOWING THE SAGAR DISTRICT IN THE STATE OF MADHYA PRADESH, INDIA

2.2 Socio-Economic Vulnerability Analysis

A variety of approaches have been utilised to examine physical and ecological vulnerabilities related to climate change; however, frameworks to understand social and economic vulnerability remain relatively limited (Biswas, 2023). In this study, socio-economic vulnerability is conceptualised as a function of two core components: sensitivity and adaptive capacity. *Sensitivity* refers to the degree to which socio-economic systems and households are affected by or respond to both adverse and beneficial external stresses, such as climate variability, economic downturns, or resource scarcity (McCarthy et al., 2001; Krishnan et al., 2019; Umamaheswari et al., 2021). It captures the first-order effects of stresses and reflects the overall health, social organisation, community networks, and collective resources within the system. *Adaptive capacity*, on the other hand, is defined as the ability of these systems to adjust to, cope with, and recover from the consequences of such stresses (McCarthy et al., 2001; Krishnan et al., 2019; Umamaheswari et al., 2021). Vulnerability, therefore, is conceptualised as a positive function of sensitivity and a negative function of adaptive capacity, implying that higher sensitivity and lower adaptive capacity lead to greater socio-economic vulnerability. The study assessed socio-economic vulnerability using the Socio-Economic Vulnerability Index (SEVI) framework, first introduced by Krishnan et al. (2019) and later applied in several studies (Mohammad et al., 2025; Atufa et al., 2023; Seenivasan et al., 2022; Umamaheswari et al., 2021). The framework is organised into two sub-indices, namely the Sensitivity Index (SI) and the Adaptive Capacity Index (ACI), which together rely on 23 indicators representing social and economic dimensions. In the present analysis, 22 indicators were employed because data on the fishing population were not available at the village level (Figure 2). The secondary data sources for these indicators are listed in Table 2. For each unit, values were scored and normalised to generate indicator-specific indices. Weights were assigned equally to social and economic categories, following the method of Krishnan et al. (2019), to calculate SI and ACI. The final SEVI for all villages was then derived from SI and ACI using the following formula:

$$\text{SEVI} = \frac{Socioeconomic\ Sensitivity\ Index\ (SI)}{1 + Socioecnomic\ Adaptitive\ Capacity\ Index\ (ACI)}$$

The Sensitivity Index (SI) and Adaptive Capacity Index (ACI) were both given equal importance when formulating the overall Socio-Economic Vulnerability Index (SEVI). For each tehsil and district, the SI, ACI, and SEVI were computed by averaging the index values derived from the respective villages.

TABLE 2. SEVI INDICATORS AND THEIR DATA SOURCES

Dimension	Sub-dimension	Indicators	Definition	Relationship	Source
Sensitivity	Social Sensitivity (SS)	SMF	Share of farm area held by small and marginal farmers (%)	Direct	AC
		AL	Percentage of agricultural labourers among total workers	Direct	AC
		FSM	Share of underweight children (1–14 years) as an indicator of food insufficiency	Direct	NFHS
		PD	Average number of residents per km² of village land	Direct	CI
		SCST	Percentage of the SC/ST community in the total village population	Direct	CI
Adaptive Capacity	Social Adaptive Capacity (SAC)	ES	Proportion of literate population and proportion of literate female population (%)	Direct	CI
		HA	Share of households with safe water, toilets, electricity, and clean fuel	Direct	CI
		HC	Housing quality based on ownership, rooms, type, and material (%)	Direct	CI
		CI	Number of schools, colleges, hospitals, and community spaces	Direct	CI
		PGR	Change in population (%) between 2001 and 2011	Inverse	CI
		GR	Number of females per 1000 males; penalised if extreme ratios	Direct	CI
Sensitivity	Economic Sensitivity (ES)	NSA	Share of cultivated land to total village area (%)	Direct	CI
		AR	Average yearly rainfall (mm) at block level (2011–2012)	Inverse	IMD
		DNR	Area under forests, pastures, water bodies as % of total village area	Inverse	CI
		DNT	Proximity to the nearest town based on Census distance classes	Direct	CI
		DNH	Distance to the closest healthcare facility as per Census categories	Direct	CI
Adaptive Capacity	Economic Adaptive Capacity (EAC)	TC	Households (%) with communication and transport access	Direct	CI
		EDR	Ratio of dependent (young/old) to working-age population	Inverse	CI
		AM	Distance to nearest market categorised by Census	Direct	CI
		NIA	Share of irrigated land to net sown area (%)	Direct	CI
		GD	Groundwater use as a percentage of available resource (2011–2012)	Inverse	CGB
		LP	Total livestock count based on the latest livestock census	Direct	LP

Data sources: CI (Census of India, 2001 and 2011), AC (Agricultural Census, 2010–2011), LC (Livestock Census, 2012), IMD (Indian Meteorological Department, 1951–2012), CGB (Central Groundwater Board, 2011–2012), and NFHS (National Family Health Survey, 2015–2016).

To ensure a representative overall score for the district, population-adjusted weightages were applied during the computation, accounting for variations in village population sizes. These village-level SI, ACI, and SEVI scores represented absolute values, which were then rescaled to amplify variability, resulting in the Rescaled

Sensitivity Index (SI-R), Rescaled Adaptive Capacity Index (ACI-R), and Rescaled SEVI (SEVI-R).

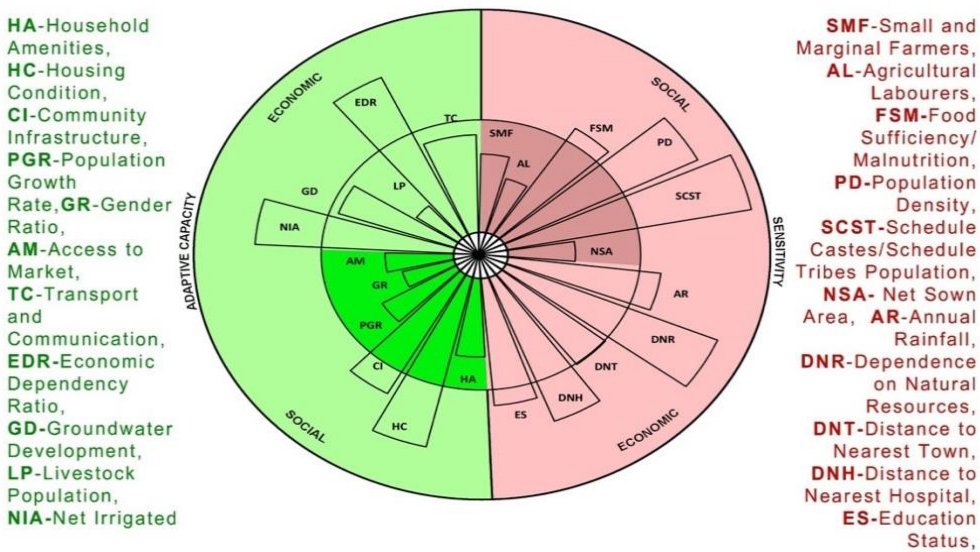

FIGURE 2. SEVI FRAMEWORK WITH INDICATORS ADOPTED FROM KRISHNAN et al. (2019)

This rescaling process ensures that the variability of these indices is enhanced, enabling a more accurate differentiation between villages based on their vulnerability, adaptive capacity, and sensitivity. A similar method was used to categorise Sensitivity, while the classification of Adaptive Capacity followed an inverse pattern, where higher scores reflect reduced vulnerability. These groupings enable a clearer understanding of each village's vulnerability status, providing essential insights for targeted interventions and data-driven policy decisions at the district level. Figure 3 presents a schematic overview of the entire Socio-Economic Vulnerability Assessment process.

2.3 SEVI Decision Matrix

The SEVI decision matrix serves as a key tool in identifying socio-economically vulnerable villages and guiding appropriate interventions. In this four-quadrant matrix, villages are positioned based on their Rescaled Sensitivity Index (SI-R) and Rescaled Adaptive Capacity Index (ACI-R) scores. Villages located in the quadrant where SI-R ≤ 0.50 and ACI-R < 0.50 are categorised as having low socio-economic vulnerability. In contrast, villages in the quadrant with SI-R > 0.50 and ACI-R ≤ 0.50 are classified as highly vulnerable. For these high-vulnerability villages, 22 sub-indicators are further scrutinised to pinpoint the key ‘drivers’ (indicators > 0.50 for sensitivity or ≤ 0.50 for adaptive capacity) and ‘buffers’ (indicators ≤ 0.50 for sensitivity or > 0.50 for adaptive capacity). ‘Drivers’ escalates vulnerability through high sensitivity or low adaptive capacity, while ‘buffers’ reduce vulnerability due to better adaptive capacity or lower sensitivity.

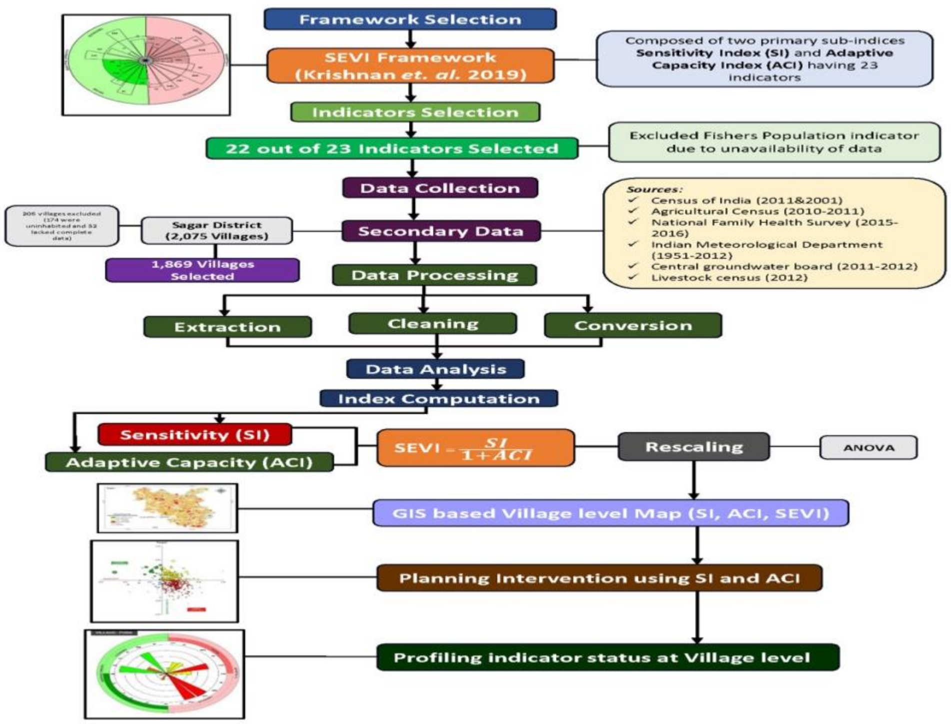

FIGURE 3. SCHEMATIC REPRESENTATION OF SOCIO-ECONOMIC VULNERABILITY ASSESSMENT

2.4 Statistical Analysis

One-way ANOVA was employed to identify significant differences among multiple independent groups. In this study, it was specifically applied to assess statistical variations between villages across the tehsils of Sagar district with respect to their socio-economic SI, ACI, and SEVI scores. To further illustrate the distribution and variability of these indicators and dimensions, box plots were generated, providing a clear view of central tendencies and data dispersion.

2.5 Data-Driven Limitation of the Study

One limitation of the study is its reliance on the Census of India, 2011 data, which, being over a decade old, may not fully capture the current socio-economic realities. However, in the Indian context, it remains the most recent and comprehensive village-level dataset available, as the next decennial census, scheduled for 2021, has been deferred (due to COVID-19 and political exigencies) and is now proposed to be conducted during 2025-2026. Once the new census data becomes available, this framework can be seamlessly adapted to bring a temporal-spatial comparison. This would enable not only a more accurate evaluation of current socio-economic vulnerabilities but also an opportunity to monitor and analyse the progress achieved over the past one and a half decades. This adaptability highlights the enduring relevance and utility of the SEVI framework in supporting evidence-based long-term planning and policy formulation.

III

RESULTS

3.1 Socio-Economic Sensitivity of the Villages

The socio-economic sensitivity of villages in Sagar district, evaluated using the Socio-Economic Sensitivity Index (SI), ranged from 0.13 to 0.78, with a median value of 0.51, indicating a high level of socio-economic sensitivity (0.5-0.75). The overall SI of the tehsils found to range between 0.49 (Garhakota, Kesli and Sagar) and 0.53 (Malthon). Interestingly, eight out of eleven tehsils in the Sagar district, viz., Banda (0.52), Bina (0.5), Deori (0.51), Khurai (0.51), Malthon (0.53), Rahatgarh (0.5), Rehli (0.52), Shahgarh (0.51), had *high* sensitivity. In contrast, Garhakota (0.49), Kesli (0.49) and Sagar (0.49) had *low* sensitivity, though only by a small margin. Based on rescaled SI scores (SI-R), out of all the villages, 80 per cent exhibited *high* socio-economic sensitivity (ranging from >0.5 to ≤0.75). In comparison, only 16 per cent had *low* socio-economic sensitivity (ranging from >0.25 to ≤0.5), indicating a significant concern that requires immediate attention (Figure 7a). Of the 1869 villages studied, sensitivity was *highest* for Patheriya Raiyatwari village (0.78) in Sagar tehsil due to *very high* proportion of small and marginal farmers (40 per cent) population, and its location being farther from the nearest town and hospital. This is uniformly the case with villages having relatively high sensitivity. In contrast, Bhajiya village of Kesli tehsil had the *least* sensitivity (0.13) among all, likely due to its proximity to the nearest town and health facilities.

Consequently, SI values across villages in different tehsils of Sagar district showed varying degrees of variation, indicating differences in socio-economic sensitivity within the region. Kesli [0.13 (Bhajiya) to 0.64 (Gutauri Bairagi)], and Sagar [0.20 (Jaisinagar) to 0.78 (Patheriya Raiyatwari)] tehsils exhibited a wide variation of around 0.5, reflecting significant differences in socio-economic sensitivity. In contrast, tehsils like Banda [0.29 (Sonpur) to 0.68 (Ranipura)], Bina [0.19 (Etawa) to 0.67 (Dhawai)], Rahatgarh [0.30 (Berkheri Gopal) to 0.67 (Patheriya Bedni)], Deori [0.31 (Padrai None) to 0.66 (Narayanpur)], Garhakota [0.32 (Ranguwan) to 0.66 (Murga)], Rehli [0.33 (Gopalpura) to 0.66 (Ankhi Khera)], Khurai [0.33 (Gular) to 0.68 (Kanera Gond)], Shahgarh [0.30 (Simariya Kalan) to 0.65 (Lidhour)], and Malthon [0.35 (Dhaurra) to 0.66 (Patharpura)] displayed variations ranging from 0.3 to 0.4, indicating a relatively moderate degree of variation in socio-economic sensitivity across these tehsils. The proportion of villages with low sensitivity was 14 per cent in Banda, 18 per cent in Bina, 20 per cent in Deori, 28 per cent in Garhakota, 26 per cent in Kesli, 16 per cent in Khurai, 4 per cent in Malthon, 22 per cent in Rahatgarh, 16 per cent in Rehli, 9 per cent in Sagar, 14 per cent in Shahgarh, while the rest of the villages (80-90%) of the eleven thesils had *high* sensitivity.

The decomposed social-sensitivity and economic-sensitivity indices provide more valuable insights. The Sagar district exhibited low social sensitivity (range = 0.17–0.8, median = 0.37) and high economic sensitivity (range = 0.11-0.8, median = 0.66) (Figure 4c). All eleven tehsils exhibited similar patterns, with social sensitivity ranging from 0.33 in Rahatgarh to 0.41 in Kesli, and economic sensitivity ranging from 0.58 in Kesli to 0.72 in Malthon. Higher social sensitivity was largely attributed to the greater proportion of small and marginal farmers, agricultural labourers, and elevated population density. Limited access to urban centres, healthcare facilities, and a higher share of non-agricultural labourers contributed substantially to economic sensitivity, indicating challenging demographic and social conditions (Figure 4a). Most sensitivity indicators cannot be easily addressed through short-term interventions and will require long-term strategies. In the near term, emphasis should be placed on enhancing adaptive capacity, as discussed in the following section.

3.2 Socio-Economic Adaptive Capacity of the Villages

The adaptive capacity of the Sagar district as a whole was *low* (0.42), with ACI values ranging from a low of 0.14 to a high of 0.63 across villages. Among the eleven tehsils, Banda tehsil had the lowest ACI (0.38), and Deori, Shahgarh (0.47) had the highest as compared to Bina, Garhakota (0.44), Kesli (0.46), Khurai (0.42), Malthon (0.44), Rahatgarh (0.41), Rehli (0.40) and Sagar (0.40). Based on rescaled ACI scores, nearly half (42%) of villages had *low* adaptive capacity (>0.25 to ≤0.5). In comparison, a few (1%) suffered from *very low* capacity to adapt (Figure 7b). Of all villages, Gaurjhamer village in Deori tehsil had the highest ACI score (0.63) due to various factors, viz., a higher proportion of literate population (82.1%), including females (75.7%), better community infrastructure and market access. Conversely, Senkuwa Raiyatwari village in Sagar tehsil recorded the *lowest* adaptive capacity index (ACI) value (0.22) due to poor performance across multiple indicators. These included limited household assets, inadequate community infrastructure, insufficient communication and transport facilities, a low proportion of irrigated land, and a small number of livestock, primarily cattle (Figure 4b).

The adaptive capacity index (ACI) values across villages in all tehsils of Sagar district exhibited a similar range of variation, indicating a uniform distribution of adaptive capacity throughout the tehsils and at the district level as well. The variation in ACI values ranged consistently between 0.2 to 0.3 in all eleven tehsils: Banda [0.23 (Fatehpur Munjapta) to 0.46 (Bhadrana)], Bina [0.29 (Jugpura) to 0.52

(Bardora)], Deori [0.29 (Foota Tal) to 0.63 (Gaurjhamer)], Garhakota [0.25 (Manegaon) to 0.53 (Chanauva Bujurg)], Kesli [0.29 (Rengajholi) to 0.58 (Deori Naharmau)], Khurai [0.29 (Janraho) to 0.53 (Bardha)], Malthon [0.29 (Ubayada) to 0.57 (Malthon)], Rahatgarh [0.28 (Pepalkhedi) to 0.53 (Sihora)], Rehli [0.24 (Mahendra) to 0.53 (Patan Buzurg)], Sagar [0.14 (Badera) to 0.52 (Semrabag)], and Shahgarh [0.30 (Chakk Gora Katya) to 0.57 (Amarmaoh)]. This consistent range of variation highlights an even distribution of adaptive capacity across the district, with no significant disparities observed among the tehsils.

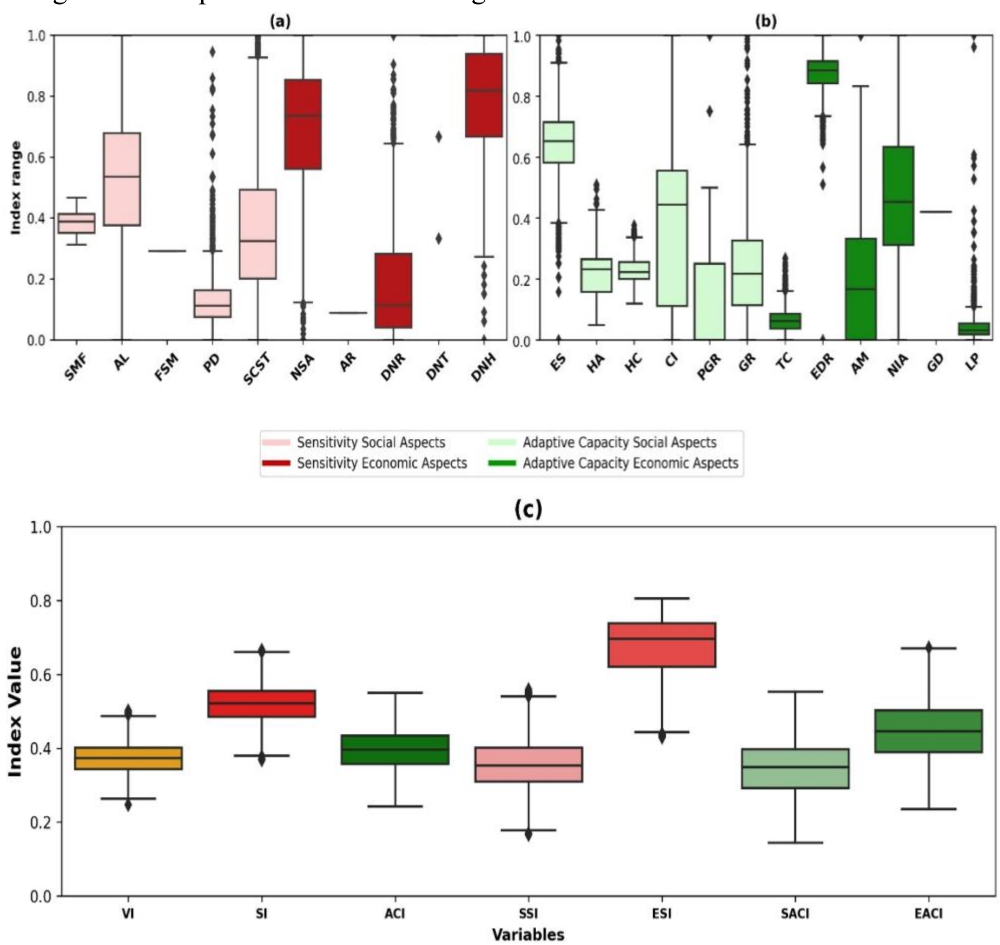

FIGURE 4 (A, B) CALCULATED INDICES FOR ALL INDICATORS RELATED TO THE SOCIAL AND ECONOMIC DIMENSIONS OF SENSITIVITY (A) AND ADAPTIVE CAPACITY (B) IN SAGAR DISTRICT. FIGURE 4 (C) ESTIMATED INDICES FOR SAGAR DISTRICT. ABBREVIATIONS: SSI – SOCIAL SENSITIVITY INDEX, ESI – ECONOMIC SENSITIVITY INDEX, EACI – ECONOMIC ADAPTIVE CAPACITY INDEX, SACI – SOCIAL ADAPTIVE CAPACITY INDEX, SI – SENSITIVITY INDEX, ACI – ADAPTIVE CAPACITY INDEX, VI – VULNERABILITY INDEX (SEVI).

The differences become more pronounced when the social and economic components of adaptive capacity are considered separately. In Sagar district, the social component of adaptive capacity (AC-S) varied between 0.1 and 0.63, with a median of 0.34. The economic component (AC-E) showed a wider range, from 0.07 to 0.72, with a median value of 0.45 (Figure 4c). Similar characteristics were exhibited in all eleven tehsils. The primary factors contributing to the lower AC-S were inadequate household amenities, poor housing conditions, and a low gender ratio (Figure 4b). Similarly, the AC-E score was negatively impacted by limited transport and communication infrastructure, a high economic dependency ratio (EDR), restricted market access, and low livestock population (Figure 4b).

3.3 Socio-Economic Vulnerability of the villages

To compare SEVI components and assess village and tehsil vulnerability, indices were recalculated using normalisation based on regional minimum and maximum values. This method, assuming similar characteristics among neighbouring areas, highlights subtle variations in socio-economic vulnerability and enables tailored interventions (Krishnan et al., 2019).

The overall SEVI for Sagar district, calculated from the rescaled SI and ACI, was low at 0.36 (Figure 4c). However, values varied widely across villages, with Bhajiya village in Kesli tehsil showing the lowest vulnerability (0.09) and Ranipura village in Banda tehsil the highest (0.54). This average value masks the substantial heterogeneity observed: more than half of the villages (1,395, 75%) were classified as highly vulnerable, while 275 villages (14%) were considered to have low vulnerability. A very small proportion of villages (<1%, 7 villages) were found to be least vulnerable, and 192 villages (10%) were classified as very highly vulnerable. The socio-economic vulnerability levels for all 1,869 villages are depicted in Figure 7c, and Table 3 lists the 20 most vulnerable villages.

3.4 Intervention Planning Using the SEVI Decision Matrix

The socio-economic SI and ACI of villages in each tehsil were mapped on a two-dimensional decision matrix (Figure 5). At the tehsil level, the proportion of highly vulnerable villages varied: 71 per cent (117) in Banda, 16 per cent (24) in Bina, 24 per cent (54) in Deori, 2 per cent (21) in Garhakota, 21 per cent (37) in Kesli, 40 per cent (68) in Khurai, 33 per cent (59) in Malthon, 33 per cent (44) in Rahatgarh, 56 per cent (66) in Rehli, 55 per cent (199) in Sagar, and 15 per cent (16) in Shahgarh (Figure 5). This analysis highlights the tehsils where targeted interventions are most needed. While Sagar district's overall vulnerability was low, the research, using the decision matrix, successfully pinpointed villages that were highly sensitive and had limited capacity to adapt, highlighting the uneven distribution of socio-economic factors within the district (Figure 5).

3.5 Distribution and Variability of Vulnerability Indicators

One-way ANOVA was conducted to examine significant differences in the mean values of indicators across villages. Among the 22 SEVI indicators, four (SMF, FSM, AR, GD) were excluded because data were available only at the district or tehsil level. The analysis revealed heterogeneous variances for the remaining 18 indicators, indicating that socio-economic vulnerability varies significantly across census villages for nearly all indicators. A similar pattern was observed at the tehsil level, as one-way ANOVA showed that the mean values of these 18 indicators differed significantly across tehsils at the 5 per cent significance level. Thus, significant differences exist between tehsils in the mean values of 18 out of the 22 SEVI indicators.

TABLE 3. THE TOP 20 VILLAGES IN THE SAGAR DISTRICT RANKED ACCORDING TO THEIR SEVI VALUES

Tehsils	Villages	Total Population	Rank Based on		
			SEVI	SI-R	ACI-R
Banda	Ranipura	361	1	2	1855
Sagar	Patheriya Raiyatwari	520	2	1	311
Banda	Fatehpur Malgujari	58	3	4	1854
Khurai	Kanera Gond	467	4	3	1772
Banda	Fatehpur Munjapta	157	5	38	1866
Khurai	Parasari	92	6	9	1812
Sagar	Khanpur	219	7	7	1789
Khurai	Khiriya Thansingh	136	8	13	1796
Banda	Abdapur	421	9	25	1843
Rehli	Ankhi Khera	457	10	15	1787
Khurai	Bandri	246	11	6	1685
Bina	Balarkhedi	200	12	11	1684
Khurai	Jamuniya Dhiraj	362	13	10	1670
Banda	Chakk Bharti Nagar	376	14	72	1863
Banda	Jharai	426	15	29	1815
Rehli	Ghughari Kheda	162	16	54	1851
Banda	Tagiya	690	17	27	1784
Deori	Bhonrgarh	490	18	19	1648
Kesli	Gutauri Bairagi	39	19	35	1808
Banda	Ranipura	362	20	31	1783

However, the statistical distribution of the rescaled SEVI (SEVI-R), Sensitivity Index (SI-R), and Adaptive Capacity Index (ACI-R) differs substantially. The SEVI-R (0.613 ± 0.12) and SI-R (0.587 ± 0.11) exhibit negatively skewed distributions, indicating that more values are concentrated at higher scores (Figure 8). This suggests that in the study areas, higher vulnerability and sensitivity are more prevalent, with fewer instances of low vulnerability and sensitivity. In contrast, the ACI-R (0.522 ± 0.12) shows a more symmetrical distribution, indicating that adaptive capacity values are more evenly distributed across the study areas, with no clear dominance of either high or low scores (Figure 8). The negative skewness in SEVI-R and SI-R suggests that the higher values of vulnerability and sensitivity are driving the distribution, while the more even distribution of ACI-R reflects a balanced range of adaptive capacities across the study areas.

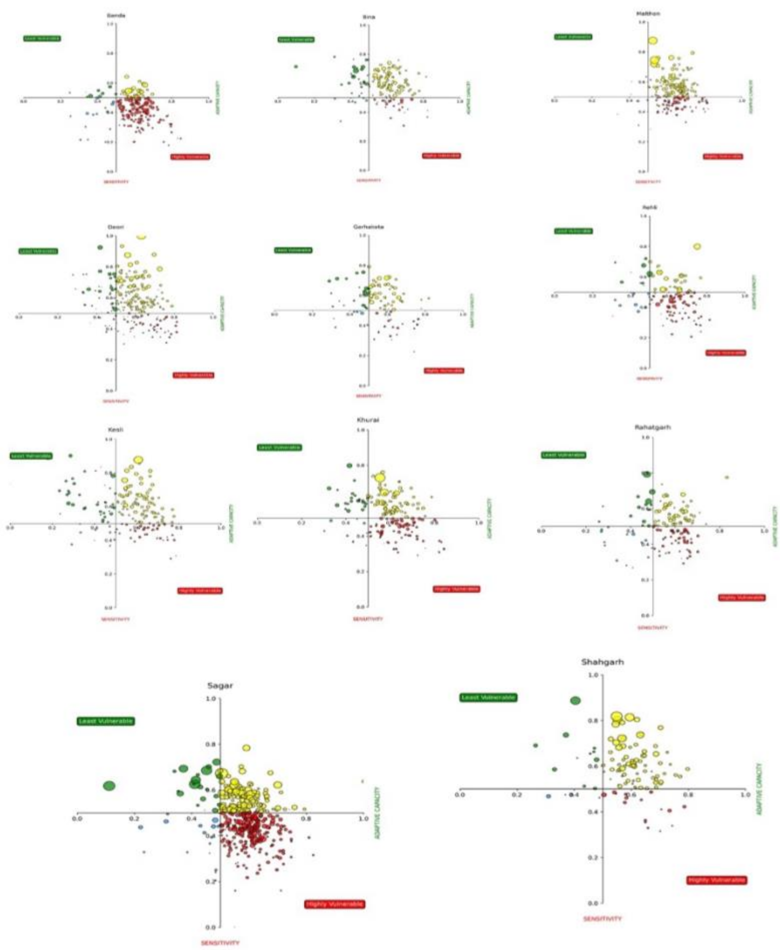

FIGURE 5. DECISION MATRIX FOR VILLAGES ACROSS VARIOUS TEHSILS IN SAGAR
Note: Circles represent "villages"; size of circles, "population of villages"; colour, "SEVI"; and position of circles represents "status of vulnerability"

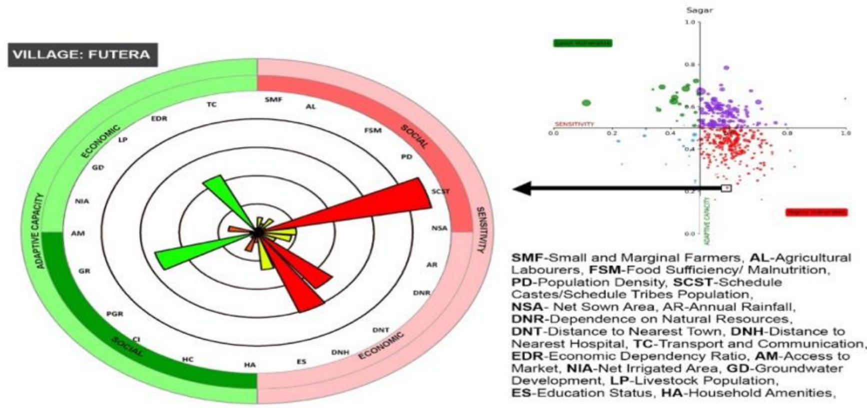

FIGURE 6. THE SEVI FRAMEWORK FOR FUTERA VILLAGE IN SAGAR TEHSIL DISPLAYS DRIVER AND BUFFER INDICATORS.

Note: Bar lengths indicate index values (0 to 1), while colours represent their nature: red and orange denote drivers for high sensitivity or low adaptive capacity (red for sensitivity >0.5 and orange for adaptive capacity ≤0.5). Green and yellow indicate buffers for low sensitivity or high adaptive capacity (yellow for sensitivity ≤0.5 and green for adaptive capacity >0.5).

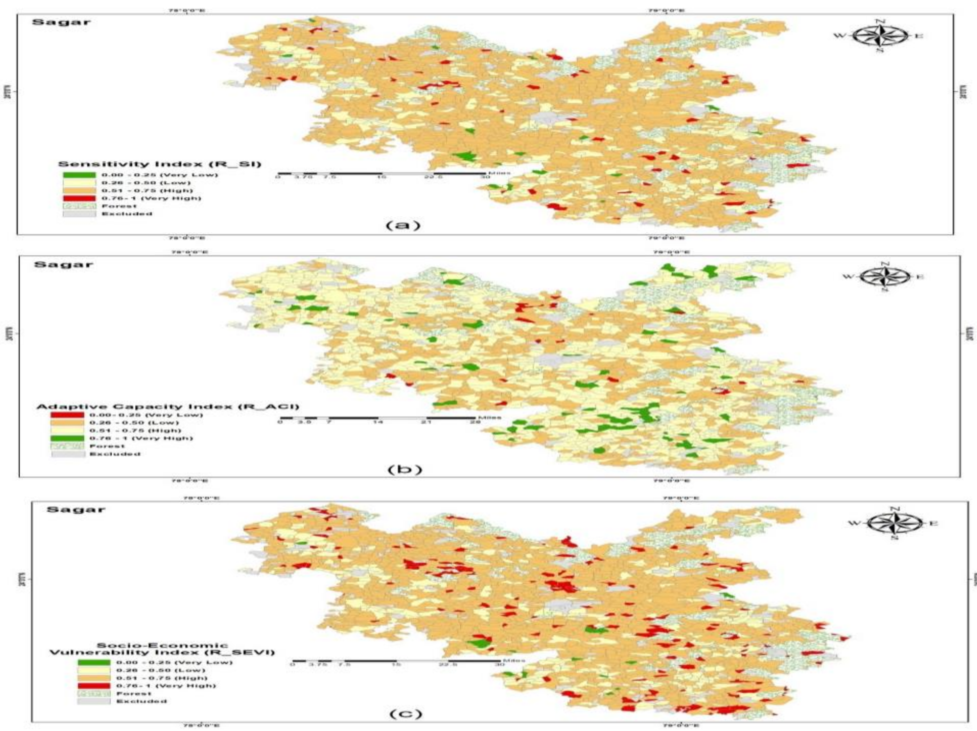

FIGURE 7. SPATIAL ILLUSTRATIONS OF (A). SE-SENSITIVITY (SI-R), (B).SE-ADAPTIVE CAPACITY (ACIR) AND (C). SOCIO-ECONOMIC VULNERABILITY INDEX (SEVI-R) FOR SAGAR DISTRICT

3.6 Drivers and Buffers of Vulnerability

In the highly vulnerable regions, certain indicators were identified as drivers of vulnerability, as they either increased sensitivity or lowered adaptive capacity. On the other hand, variables that reduced vulnerability, either by enhancing adaptive capacity or lowering sensitivity, were referred to as buffers. Eight key drivers of high vulnerability were identified in Sagar, viz. high number of agricultural labourers (AL), extensive net sown areas (NSA), far distances to the nearest town (DNT) and hospital (DNH), combined with poor housing condition (HH), gender disparities, weak transport and communication (T&C) infrastructure, and limited access to markets (AM), collectively intensify Sagar's vulnerability. These factors create structural challenges with agrarian economies, amplifying the disparity in access to essential services and support systems. It was clear from representative villages (Figure 6) that high vulnerability is structural, due to a predominantly agrarian economy with a sizable population of agricultural labour, which is exacerbated by a farther distance to towns and health facilities. A detailed depiction of the status of key determining factors for Futera, a representative village in Sagar tehsil, is illustrated in a sunburst plot (Figure 6). This visualisation serves as a comprehensive framework for designing targeted intervention strategies.

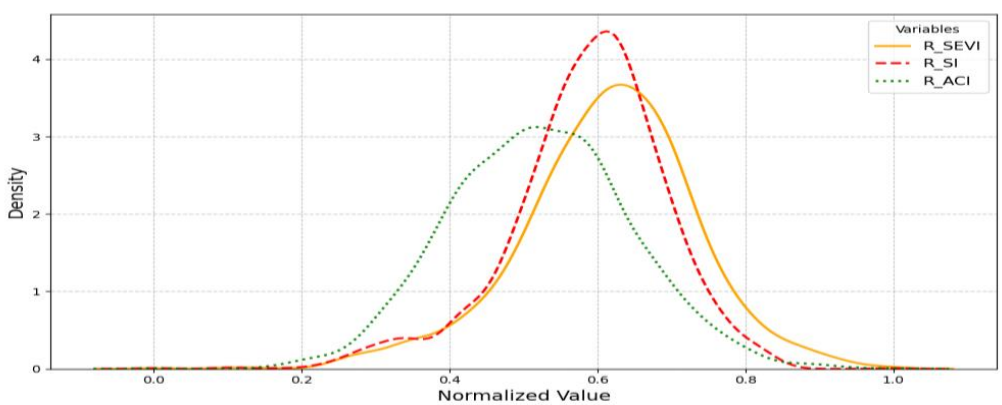

FIGURE 8. DENSITY PLOTS OF THE SENSITIVITY INDEX, ADAPTIVE CAPACITY INDEX, AND SOCIO-ECONOMIC VULNERABILITY INDEX ARE PRESENTED. THE X-AXIS REPRESENTS THE NORMALIZED INDEX VALUES, RANGING FROM 0 TO 1.

Similarly, six key buffers of vulnerability, which stabilised 'sensitivity' and enhanced 'adaptive capacity', were identified viz. DNR, PD, SC/ST population (SCST), malnutrition (FSM), ES and EDR. Villages characterised by lower dependence on natural resources (DNR), lower population density (PD), and a balanced socio-economic composition, particularly a smaller share of Scheduled Caste/Scheduled Tribe (SC/ST) population, demonstrated reduced vulnerability levels. Additionally, these areas exhibited lower malnutrition rates (FSM), better educational outcomes (ES), and more favourable economic dependency ratios (EDR).

These factors collectively enhanced their adaptive capacity while lessening sensitivity, thereby positioning them to better cope with external challenges.

IV
DISCUSSION

An overall socio-economic vulnerability score of Sagar (0.36) reflects low vulnerability at the meso level (district); however, it masks the widespread and persistent challenges experienced by agricultural communities within the district (Frazier et al., 2014). The micro-level (village) analysis reveals a deeper structure of vulnerability across villages. Out of 1,869 villages, *more than half* (1,395 or 75%) were identified as socio-economically highly vulnerable, and 10 per cent (192 villages) were classified as very highly vulnerable, which is a matter of concern. These findings also underscore the critical importance of micro-level studies, as broader macro- or meso-level analyses may present an overly optimistic picture, failing to capture the complexities and disparities at the grassroots level. The overall Sensitivity Index (0.51) and Adaptive Capacity Index (0.42) scores indicate that the district has high sensitivity and low adaptive capacity levels. These conditions contribute to significant disparities among villages, arising from the intersection of high sensitivity and low adaptive capacity. This variation across villages creates heightened vulnerability, jeopardising the livelihoods of dependent communities in differing magnitudes. Recent research conducted at the *district* level in Madhya Pradesh also indicated a vulnerability score of 0.349 for Sagar district, almost comparable to the present study (Kumar and Mohansundari, 2024). Another climate vulnerability study classified Sagar district as highly vulnerable (0.63) compared to the state average (0.528), attributing this to the absence of area crop insurance, insufficient forest cover, low road density, inadequate groundwater availability, a limited number of doctors per 1,000 people, and underdeveloped horticulture, with similar challenges observed in an eastern Madhya Pradesh district (Dasgupta et al., 2020). However, despite their usefulness, these studies are difficult to compare due to differing methods and units of analysis. Unlike them, our study examines *villages* and *tehsils* using a comprehensive set of indicators, whereas they focus on aggregate *district*-level measures.

The micro-level analysis effectively identified the underlying causes of vulnerabilities in highly vulnerable regions. The findings reveal that the sensitivity index exhibits a negatively skewed distribution, in contrast to the symmetric distribution of the adaptive capacity index, indicating that very high sensitivity values are the primary contributors to vulnerability. The heightened sensitivity of these villages is primarily driven by a high proportion of agricultural labour, a significant population of small and marginal farmers, extensive net sown areas, and their remote locations, often far from the nearest towns and hospitals. This pattern is consistently observed across villages with relatively high sensitivity levels. Similar findings have been reiterated in recent studies of Sagar districts. Agricultural labour in Sagar district faces heightened vulnerability from chronic pesticide exposure, leading to health issues such as muscle pain, blurred vision, skin disease, cardiac problems, and difficulty walking, as highlighted in a survey by Kori et al. (2018).

Sagar district has 462,938 main workers and 93,589 part-time workers engaged in agriculture, generating 9.18 crore person-days of employment, which far exceeds the required 7.65 crore and reveals a 20 per cent disguised unemployment rate, underscoring the vulnerability of small and marginal farmers (IGG, 2020). With its extensive net sown area and higher rainfall (>1000 mm), Sagar district is more suitable for crops like paddy compared to other water-scarce districts in Bundelkhand (Chand et al., 2020). Still, this reliance on rainfall increases the vulnerability of local communities to monsoon failures. At Sagar district hospital, 29.2 per cent of children are born underweight, with maternal education identified as a key determinant (Chaurasia et al., 2020), highlighting the role of social determinants in exacerbating health risks for both mothers and children. The cited literature corroborates the findings of the present study, supporting the identified causes of vulnerability and further emphasising the significance of the SEVI methodology used in this analysis.

The analysis revealed the spatial distribution of vulnerability hotspots within the district, highlighting variations in the underlying causes of vulnerability across villages. Most of the vulnerable villages were concentrated in Sagar (199) and Banda (117) tehsils, emphasising the need for targeted, village-specific interventions. For example, Patheriya Raiyatwari (Sagar tehsil) was identified as highly vulnerable due to a large population of small and marginal farmers and its remote location - far from the nearest town and hospital - factors that were also associated with heightened vulnerability in studies by Tao et al. (2018), Quattrochi et al. (2020), and Lopes et al. (2021). In contrast, villages like Senkuwa Raiyatwari (Sagar tehsil) faced vulnerability due to different set of factors, such as limited household assets, inadequate community infrastructure, poor communication and transport facilities, a low proportion of irrigated land, and a small number of livestock - challenges that were also documented by Anderloni (2012), Obolensky (2019), Khaled (2019), Brugere (2003), and Vandamme (2010). These findings demonstrate that while individual villages face unique challenges, district-wide issues such as a high proportion of agricultural labour, extensive net sown areas, and remoteness from towns and health facilities are common across the region. This underscores the need for a two-pronged approach: spatially differentiated interventions tailored to clusters of specific village-level vulnerabilities, and a broader district-level mission to address systemic issues impacting the region as a whole.

V

POLICY IMPLICATIONS

A scientific vulnerability assessment is essential for designing and implementing targeted development interventions effectively. This study applied the

Socio-Economic Vulnerability Index (SEVI) to assess the vulnerability of an agriculturally dependent district at both meso- and micro-levels, with direct implications for interventions at the district, tehsil, and village levels. The findings revealed the deeper socio-economic constructs underlying vulnerability, emphasising the need for district-level missions to address consistently underperforming indicators across villages. Additionally, it highlighted the necessity of cluster-specific interventions to tackle persistent, localised challenges. This assessment can also serve as a blueprint for revising existing policies and forming new ones to address district-level challenges, while providing a replicable framework for assessing vulnerabilities in other districts. At a broader scale, SEVI can support state- and national-level policy formulation, ensuring more effective resource allocation and tailored interventions. While central and state-sponsored schemes such as *Pradhan Mantri Awas Yojana* (housing for all), *Pradhan Mantri Fasal Bima Yojana* (crop insurance), *Swachh Bharat Mission* (sanitation), *Pradhan Mantri Kisan Samman Nidhi* (income support for small and marginal farmers), *Mahatma Gandhi National Rural Employment Guarantee Scheme* (100 days of rural employment), *Pradhan Mantri Gram Sadak Yojana* (rural road construction), *Jal Jeevan Mission* (access to clean drinking water), *and Shyama Prasad Mookerjee Rurban Mission* (bridging the rural-urban divide) aim to enhance agriculture and rural development, their implementation can be significantly optimised/prioritised through vulnerability assessments like SEVI.

By leveraging these assessments, policies can be customised to address the specific challenges faced by vulnerable clusters, ensuring equitable distribution of benefits. For instance, regions with high socio-economic sensitivity could prioritise improvements in rural infrastructure, healthcare access, and basic amenities. In contrast, areas with low adaptive capacity might benefit more from targeted investments in education, skill development, and livelihood diversification. Moreover, the framework has the potential to *reduce transaction costs* associated with development interventions and ensure that resources are allocated where they are most needed. This strategic, evidence-based approach ensures policy actions are aligned with local needs, fostering sustainable development while minimising the risk of overlooking critical areas of concern. The SEVI framework thus emerges as a powerful tool for integrating local vulnerabilities into broader developmental goals, enhancing the efficiency and impact of policy interventions.

VI

CONCLUSION AND WAY FORWARD

From a development economics perspective, vulnerability embodies the deficits and disparities in socio-economic development at the community or regional scale. In the era of climate change, *vulnerability* has evolved as the contemporary parallel to *poverty*, characterised by its multi-dimensionality, with social, economic, and ecological factors forming the crux of sensitivity and adaptive capacity.

Acknowledging *vulnerability as the flipside of resilience*, this meso- and micro-level study systematically addresses critical dimensions of vulnerability: its magnitude (*how much*), spatial distribution (*where*), and underlying causes (*why*) within a district. The study used the SEVI framework, a flexible and replicable tool, to identify vulnerability hotspots, ensuring focused efforts on pressing needs and fostering efficiency in reducing vulnerability and development costs. The study has selected an agriculturally progressive district (Sagar) from central India for the socio-economic vulnerability assessment at the village level, as a representative of the agrarian economy. The study has clearly distinguished between villages within the district that have higher/lower vulnerabilities and also identified uniform as well as village- or cluster-specific causes of vulnerability. These findings had significant implications for targeted, location-specific interventions. The assessment highlighted how high sensitivity values, compounded by inadequate adaptive capacity, exacerbated the vulnerability levels. By effectively identifying these underlying causes, the study emphasised the need for special attention from the government and policymakers to reduce vulnerability and improve adaptive capacity at both village and tehsil levels.

India has 640 districts, with 115 considered ‘backward’ and thus prioritised under the Transformation of Aspirational Districts Program (TADP) to fast-track development through regular progress monitoring of key socio-economic indicators. Among the remaining 525 districts, such as Sagar, which exhibit a higher level of agricultural dependence, with their share of district GDP often exceeding 40 per cent, show only *moderate* (around the mean) HDI levels. These districts, often excluded from such programs, face distinct challenges as they lie in the middle of the development spectrum, neither the most backward nor the most developed. Despite their critical economic role, they remain underrepresented in targeted development initiatives, leaving their specific structure of vulnerabilities unaddressed. This study has identified the unique set of challenges faced by such predominantly agrarian districts, using Sagar as a case, to underscore the importance of a tailor-made development solution. By offering a replicable framework for vulnerability assessment, it provides valuable insights to guide inclusive and efficient development strategies, ensuring that they don’t fall into the category of ‘backward’ or aspirational districts.

This study transcends mere statistics and indices, aiming to empower farm and farmless rural households in the face of an uncertain climate future. The findings have far-reaching implications beyond Sagar district, offering valuable tools and insights for broader replication. They directly contribute to achieving the 2030 Sustainable Development Goals, particularly SDG 1 (No Poverty), SDG 2 (Zero Hunger), SDG 10 (Reduced Inequalities), and SDG 13 (Climate Action). The study highlights the importance of addressing socio-economic vulnerabilities to build resilience, promote sustainability, and foster a more equitable society.

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