International Journal of Advance and Applied Research
www.ijaar.co.in
ISSN – 2347-7075 Impact Factor – 8.141
Peer Reviewed Bi-Monthly
Vol. 7 No. 4 January – February - 2026

Ward-Level Social Vulnerability Assessment in Kolhapur City Using a Composite Development Index

Dr. Prashant T. Patil[1], Dr. Sudhir K. Powar[2], Miss. Nikita Godemani[3] & Miss. Prajakta Chirmure[4]

[1,2] *Asst. Prof., Department of Geography, Shivaji University, Kolhapur, Maharashtra, India*

[3,4] *Research students, Department of Geography, Shivaji University, Kolhapur, Maharashtra, India*

Corresponding Author – Dr. Prashant T. Patil

DOI - 10.5281/zenodo.18490956

Abstract:

This paper assesses intra-urban social vulnerability across five administrative wards (A-E) of Kolhapur City, Maharashtra, using a multi-indicator framework centered on basic service accessibility. Ward-level secondary data on household water connections, educational infrastructure (primary schools, high schools and colleges), and hospital facilities were normalized to a 0-1 scale and combined through a weighted composite index to derive a Development Index. The indicator weights used in the composite were 0.20 (water), 0.30 (education) and 0.50 (healthcare), reflecting the relative importance assigned in the assessment. Results demonstrate strong spatial inequality in service provision. Ward E consistently records the highest normalized scores for water (1.00), education (1.00) and hospitals (1.00), yielding the maximum Development Index (1.00). Ward A attains a moderate Development Index (0.61). In contrast, Ward C (0.03) and Ward D (0.04) show the lowest composite performance, indicating high vulnerability associated with limited service access. Population distribution was used to interpret service pressure, with Ward B recording the largest population (217,143) and Ward C the smallest (68,848). The findings support ward-specific prioritization of investments in water supply, educational facilities and healthcare infrastructure to reduce vulnerability and strengthen urban resilience in Kolhapur.

Keywords: Social Vulnerability; Ward-Level Assessment; Water Connections; Education Infrastructure; Healthcare Accessibility; Normalization And Weighting; Development Index; Spatial Inequality.

Introduction:

Social vulnerability refers to the propensity of individuals and groups to be adversely affected by shocks and stresses, and to their capacity to anticipate, cope with, resist, and recover using available resources and institutions. In geography, vulnerability is treated as an explicitly place-based phenomenon because exposure, sensitivity, and coping capacity vary across space through settlement patterns, service provision, livelihoods, and social relations (Cutter, 1996; Adger, 2006; Füssel, 2007; IPCC, 2014).

The idea of vulnerability has multiple intellectual lineages. Political economy and entitlement perspectives show how insecurity is produced through unequal access to assets, rights, and public support systems, so that similar shocks can yield very different outcomes across social groups (Sen, 1981; Watts & Bohle, 1993; Bohle et al., 1994). A hazards tradition emphasizes how risk is shaped not only by the physical event, but also by social conditions that influence warning, mobility, shelter, treatment, and recovery (Cutter et al., 2003; Wisner et al., 2004). Risk scholarship further highlights that impacts often cascade through institutions and information, amplifying losses for already marginal populations (Kasperson & Kasperson, 2005). These perspectives converge on a central conclusion:

vulnerability is not simply "lack," but a measurable spatial expression of social structure interacting with systems that deliver safety and welfare.

Contemporary vulnerability frameworks in sustainability science formalize this interaction between human and environmental systems and emphasize feedbacks across scales, from household capacities to city governance (Turner et al., 2003; Birkmann et al., 2013). A major conceptual distinction also matters for applied work: vulnerability can be understood as an outcome observed after disturbance or as a contextual condition that exists prior to disturbance and shapes possible outcomes (O'Brien et al., 2007; Adger, 2006). For urban planning, contextual vulnerability is especially relevant because it can be assessed before crises and used to prioritize preventive investments and service equalization.

In Indian cities, including rapidly transforming secondary cities, social vulnerability is often expressed through uneven access to basic services and social infrastructure. Water security, health services, and education are not only development goals but also core determinants of coping capacity because they directly condition disease risk, labor productivity, emergency response ability, and long-term social mobility. The Commission on Social Determinants of Health stresses that health inequities are systematically shaped by social and material conditions, including service accessibility and living environments (CSDH, 2008). Likewise, global monitoring of drinking water, sanitation, and hygiene shows persistent gaps that translate into unequal health burdens and unequal resilience during disruptions (WHO & UNICEF, 2023). From a service-access perspective, "access" is not merely presence of facilities, but the degree of fit between population needs and the health or utility system in terms of availability, accessibility, affordability, accommodation, and acceptability (Penchansky & Thomas, 1981).

A further reason to assess vulnerability at the intra-urban scale is that cities are heterogeneous. Ward-to-ward differences in density, age structure, socio-economic status, and service distribution commonly create sharp gradients of risk. Empirical research repeatedly demonstrates that vulnerability indicators and their relationships with hazards are spatially variable and context-dependent, so city-wide averages can conceal high-risk pockets (Cutter & Finch, 2008; Rufat et al., 2015; Fekete et al., 2009). At the same time, there are enduring methodological challenges: vulnerability is multidimensional and not directly observable, so indices require careful decisions about indicator selection, normalization, and weighting (Tate, 2012). Public-sector practice has therefore favored transparent composite measures such as the Social Vulnerability Index approach in emergency management, which operationalizes social vulnerability through interpretable socioeconomic and demographic variables (Flanagan et al., 2011).

Composite indicator construction is particularly useful when the aim is to compare administrative units and identify priority areas for targeted interventions. However, composite indices are only as credible as their methodological clarity. International methodological guidance emphasizes (i) explicit theoretical framing, (ii) defensible indicator choice, (iii) robust normalization, (iv) sensitivity checks for weighting and aggregation, and (v) clear communication of uncertainty (OECD & JRC, 2008; Tate, 2012). In urban studies, such indices are strengthened further when interpreted through spatial accessibility concepts that link service distribution with the effort required to reach opportunities. Classic accessibility theory

shows that urban outcomes are shaped by how easily people can reach activities and services, and later reviews highlight how different accessibility measures can support planning decisions when used consistently and transparently (Hansen, 1959; Geurs & van Wee, 2004).

Policy frameworks also underline why these measurements matter. The 2030 Agenda for Sustainable Development calls for reducing inequalities and ensuring access to basic services, while disaster-risk frameworks emphasize prevention and the reduction of vulnerability as a primary strategy (UN General Assembly, 2015; UNISDR, 2015). The New Urban Agenda similarly frames equitable access to services and inclusive urban development as central to sustainable urbanization (UN General Assembly, 2016). At the applied scale of city governance, this translates into a practical question: Which wards are structurally more vulnerable because their demographic pressures and service access conditions reduce coping capacity?

Against this background, the present study develops a ward-level assessment of social vulnerability in Kolhapur City by focusing on service-linked determinants that are directly relevant to urban resilience and planning. Using secondary administrative data for 2024 and a transparent composite index approach, the study evaluates differences among the city's administrative wards using indicators reflecting demographic pressure and the availability of essential services, with special focus on household water connections, education facilities, and healthcare infrastructure. The purpose is not only to rank wards, but to interpret why disparities arise and how they can inform targeted improvements in basic services and social infrastructure. Such an approach is scientifically grounded in established vulnerability theory and practically aligned with contemporary frameworks that prioritize equity, resilience, and evidence-based urban governance (Adger, 2006; Cutter et al., 2003; Birkmann et al., 2013; Flanagan et al., 2011; IPCC, 2014).

Objectives:

1. To assess resource accessibility across wards in Kolhapur City.
2. To identify comparatively vulnerable ward areas based on service deficits.
3. To map and interpret ward-wise social vulnerability using a composite index approach.

Study Area:

Kolhapur is the headquarters of Kolhapur District in southern Maharashtra. The city is located at approximately 16º 42' minutes North latitude and 74º14' minutes East longitude, at about 650 m above mean sea level, on the right bank of the Panchaganga River. The urban area is influenced by the physiographic transition between the Western Ghats to the west and the rolling plains to the east, which shapes settlement distribution and service provision. The present assessment is organized by five wards (A-E) used in the project dataset.

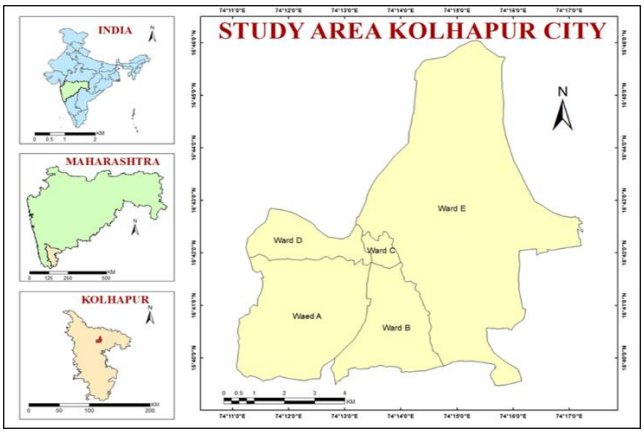

Fig 1. Location Map

Source: based on Diva GIS and ArcGIS mapping software

Data and Methods:

The analysis uses ward-level secondary data compiled in the project report for the year 2024, covering: (i) total household water connections; (ii) educational institutions (primary schools, high schools and colleges); (iii) hospital facilities; and (iv) ward population. To enable comparison across wards, each service indicator was normalized to a 0-1 scale. Weighted scores were computed by multiplying normalized values by indicator weights (water = 0.20, education = 0.30, hospitals = 0.50). The Development Index for each ward was calculated as the sum of the weighted scores across the three service indicators. Population was analyzed separately to interpret the pressure on services and the likely implications for vulnerability.

Normalization (0-1) was applied to each indicator for comparability.

The composite Development Index (DI) was computed as:

$$DI_i = 20 \times W_i + 0.30 \times E_i + 0.50 \times H_i$$

Where,

W_i, $E_i$and H_i are the normalized ward-level scores for water, education and hospitals, respectively.

Results:

Table 1. Ward-wise water connections in Kolhapur City (2024).

Ward	Total water connections	Norm.	Weighted score (0.20)
A	35270	0.91	0.18
B	19433	0.44	0.09
C	4556	0.00	0.00
D	5910	0.04	0.01
E	38207	1.00	0.20

Source: Municipal Corporation, Kolhapur

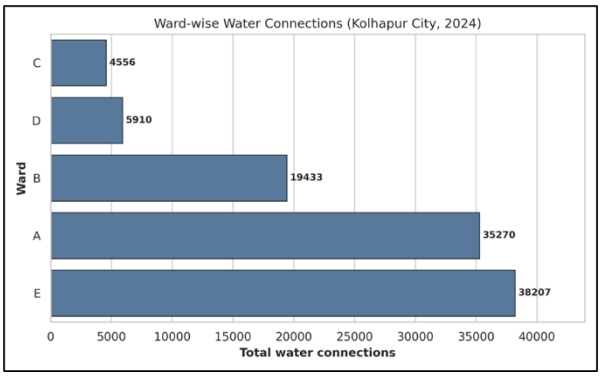

Chart 1: Ward-wise Water Connections (Kolhapur City, 2024)

Source: Based on Table 1

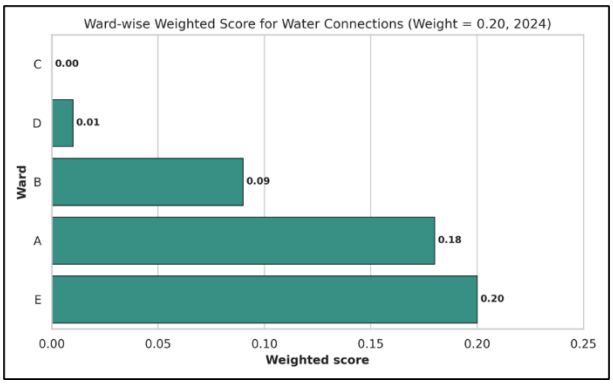

Chart 2: Ward-wise Weighted Score for Water Connections (Weight= 0.20)

Source: Based on Table 1

Table 2. Ward-wise educational infrastructure in Kolhapur City (2024).

Ward	Primary schools	High schools	Colleges	Total	Norm.	Weighted score (0.30)
A	33	14	5	52	0.56	0.17
B	27	15	5	47	0.48	0.15
C	10	5	2	17	0.00	0.00
D	15	6	3	24	0.11	0.03
E	42	27	10	79	1.00	0.30

Source: Google Earth and Municipal Corporation, Kolhapur

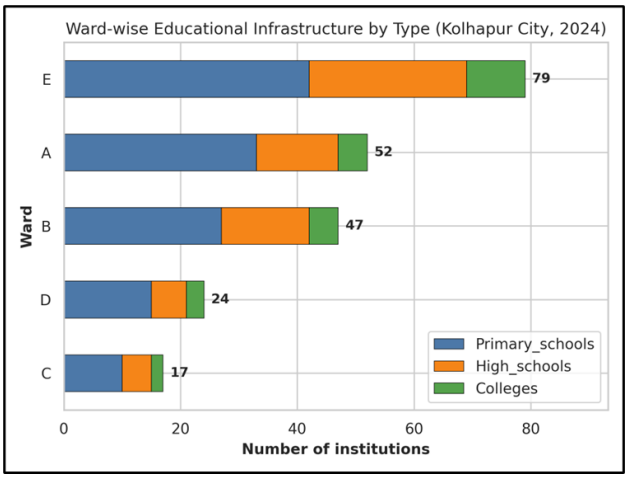

Chart 3: Ward-wise Educational Infrastructure by Type (Kolhapur City, 2024)

Source: Based on Table 2

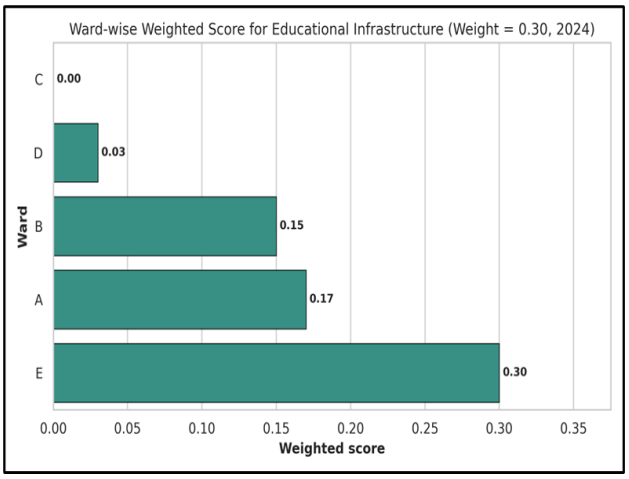

Chart 4: Ward-wise Weighted Score Educational Infrastructure by Type (Weight= 0.20)

Source: Based on Table 2

Table 3. Ward-wise hospital facilities in Kolhapur City (2024).

Ward	Total hospitals	Norm.	Weighted score (0.50)
A	44	0.52	0.26
B	13	0.12	0.06
C	9	0.06	0.03
D	4	0.00	0.00
E	81	1.00	0.50

Source: Google Earth and Municipal Corporation, Kolhapur

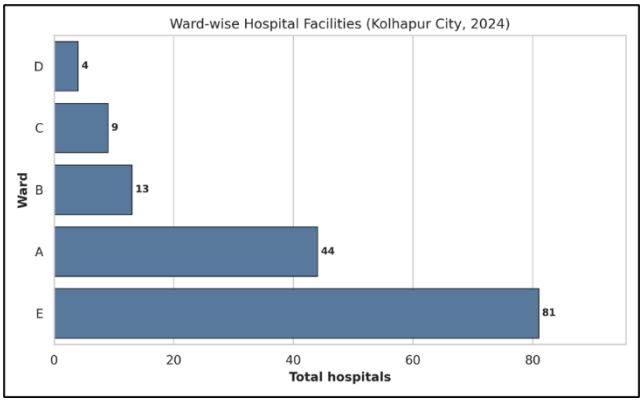

Chart 5: Ward-wise Hospital Facilities (Kolhapur City, 2024)

Source: Based on Table 3

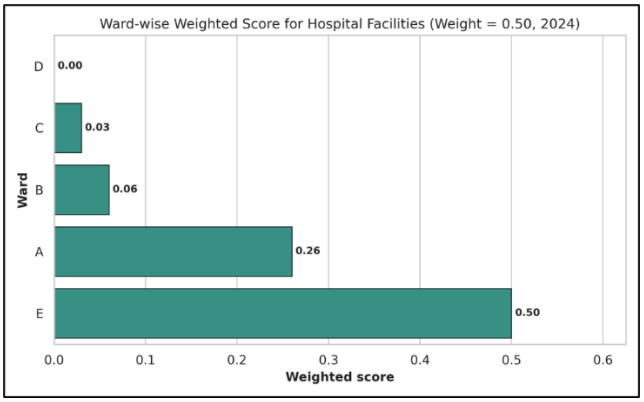

Chart 6: Ward-wise Weighted Score Hospital Facilities (Weight= 0.50)

Source: Based on Table 3

Table 4. Ward-wise population in Kolhapur City (2024).

Ward	Population
A	206,933
B	217,143
C	68,848
D	84,536
E	205,134

Source: Google Earth and Municipal Corporation, Kolhapur

Table 5. Composite Development Index (sum of weighted scores) by ward.

Ward	Water score	Education score	Hospital score	Development Index
A	0.18	0.17	0.26	0.61
B	0.09	0.15	0.06	0.30
C	0.00	0.00	0.03	0.03
D	0.01	0.03	0.00	0.04
E	0.20	0.30	0.50	1.00

Source: Based on the results of Table 1,2, and 3

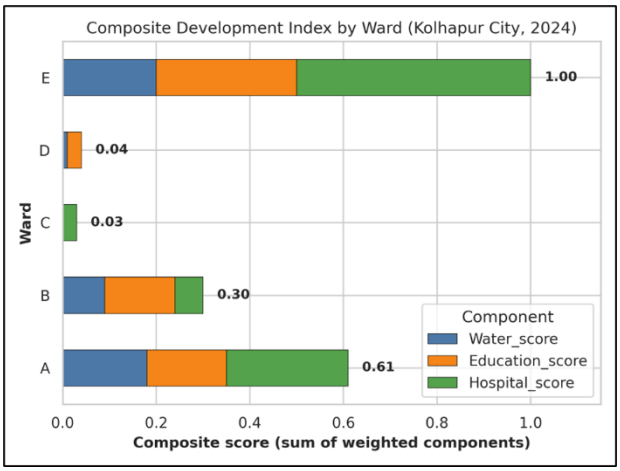

Chart 7: Composite Development Index by Ward (Kolhapur City, 2024)

Source: Based on Table 5

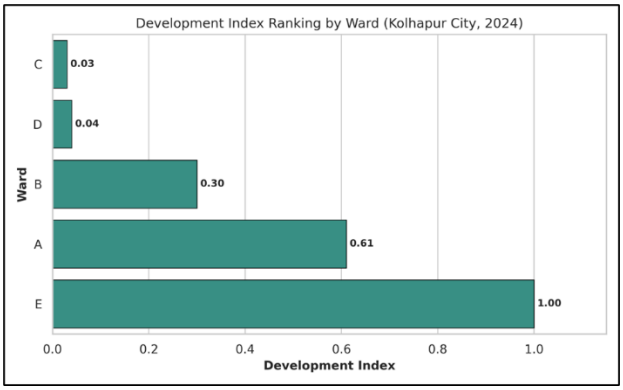

Chart 8: Development Index Ranking by Ward (Kolhapur City, 2024)

Source: Based on Table 5

The ward-wise results indicate marked inequalities across the three service indicators. Ward E records the highest performance for all services, producing the maximum Development Index (1.00). Ward A ranks second (0.61) and Ward B is moderate (0.30). Wards C (0.03) and D (0.04) represent the lowest composite performance and are identified as the most vulnerable wards in the study. Population levels suggest that Ward B has the highest service pressure due to the largest population (217,143), while Ward C has the smallest population (68,848) but still exhibits severe service deficits, indicating a clear priority for targeted infrastructure strengthening.

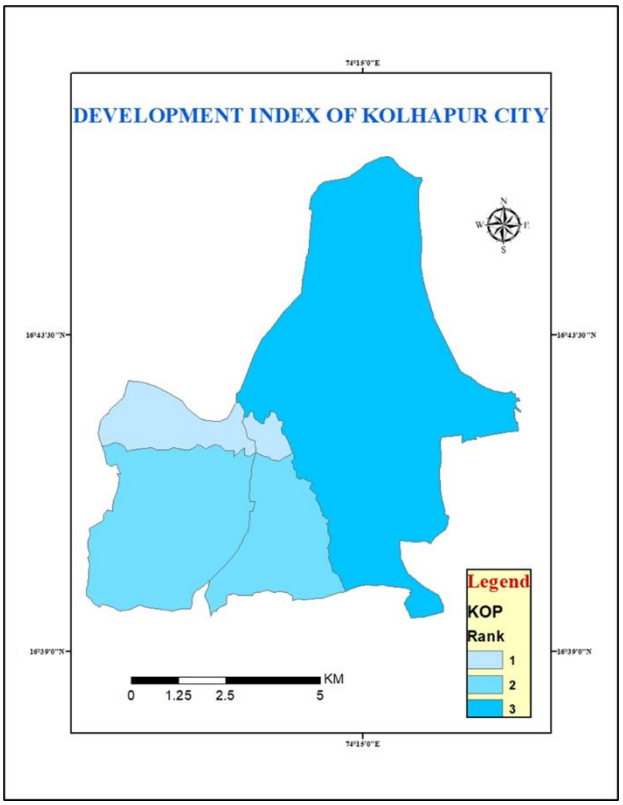

Fig.2 Development Index of Kolhapur City

Source: based on output of Table 5

Discussion:

The composite index highlights that vulnerability in Kolhapur is closely associated

with uneven access to basic urban services. The strong dominance of Ward E in all three indicators suggests comparatively favorable service endowment, whereas the low scores of Wards C and D reflect cumulative service disadvantages. Given the large weight assigned to healthcare (0.50), deficits in hospital availability strongly influence the Development Index and can magnify vulnerability during health shocks and emergencies. The assessment therefore supports a planning approach that prioritizes wards with simultaneous deficits in water connectivity, education infrastructure and healthcare availability, while also considering population pressure and potential future growth.

Conclusion and Recommendations:

The ward-level social vulnerability assessment demonstrates clear intra-urban inequality in Kolhapur City. Ward E shows the highest composite service accessibility (Development Index = 1.00), while Wards C and D show the lowest values (0.03 and 0.04) and should be treated as priority areas for intervention. Based on the three service domains used in the composite index, policy actions should focus on: (i) improving water connections and last-mile service in low-scoring wards; (ii) strengthening educational infrastructure through additional schools and colleges where deficits are severe; and (iii) expanding healthcare access, especially in wards with the lowest hospital availability. Future work can extend the indicator set to include socio-economic variables (income, housing quality, age structure) and validate the index through field-based vulnerability surveys.

References:

1. Adger, W. N. (2006). Vulnerability. Global Environmental Change, 16(3), 268–281. https://doi.org/10.1016/j.gloenvcha.2006.02.006
2. Birkmann, J. (Ed.). (2006). Measuring vulnerability to natural hazards: Towards disaster resilient societies. United Nations University Press.
3. Birkmann, J., Cardona, O. D., Carreño, M. L., Barbat, A. H., Pelling, M., Schneiderbauer, S., Kienberger, S., Keiler, M., Alexander, D., Zeil, P., & Welle, T. (2013). Framing vulnerability, risk and societal responses: The MOVE framework. Natural Hazards, 67(2), 193–211. https://doi.org/10.1007/s11069-013-0558-5
4. Bohle, H. G., Downing, T. E., & Watts, M. J. (1994). Climate change and social vulnerability: Toward a sociology and geography of food insecurity. Global Environmental Change, 4(1), 37–48. https://doi.org/10.1016/0959-3780(94)90020-5
5. Brooks, N., Adger, W. N., & Kelly, P. M. (2005). The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation. Global Environmental Change, 15(2), 151–163. https://doi.org/10.1016/j.gloenvcha.2004.12.006
6. Chambers, R. (1989). Editorial introduction: Vulnerability, coping and policy. IDS Bulletin, 20(2), 1–7. https://doi.org/10.1111/j.1759-5436.1989.mp20002001.x
7. Commission on Social Determinants of Health. (2008). Closing the gap in a generation: Health equity through action on the social determinants of health (Final report). World Health Organization.
8. Cutter, S. L. (1996). Vulnerability to environmental hazards. Progress in Human Geography, 20(4), 529–539. https://doi.org/10.1177/030913259602000407

9. Cutter, S. L., Boruff, B. J., & Shirley, W. L. (2003). Social vulnerability to environmental hazards. Social Science Quarterly, 84(2), 242–261. https://doi.org/10.1111/1540-6237.8402002
10. Cutter, S. L., & Finch, C. (2008). Temporal and spatial changes in social vulnerability to natural hazards. Proceedings of the National Academy of Sciences, 105(7), 2301–2306. https://doi.org/10.1073/pnas.0710375105
11. Eakin, H., & Luers, A. L. (2006). Assessing the vulnerability of social-environmental systems. Annual Review of Environment and Resources, 31, 365–394. https://doi.org/10.1146/annurev.energy.30.050504.144352
12. Fekete, A., Damm, M., & Birkmann, J. (2009). Validation of a social vulnerability index in context to river-floods in Germany. Natural Hazards and Earth System Sciences, 9(2), 393–403. https://doi.org/10.5194/nhess-9-393-2009
13. Flanagan, B. E., Gregory, E. W., Hallisey, E. J., Heitgerd, J. L., & Lewis, B. (2011). A social vulnerability index for disaster management. Journal of Homeland Security and Emergency Management, 8(1), Article 3. https://doi.org/10.2202/1547-7355.1792
14. Füssel, H. M. (2007). Vulnerability: A generally applicable conceptual framework for climate change research. Global Environmental Change, 17(2), 155–167. https://doi.org/10.1016/j.gloenvcha.2006.05.002
15. Gallopín, G. C. (2006). Linkages between vulnerability, resilience, and adaptive capacity. Global Environmental Change, 16(3), 293–303. https://doi.org/10.1016/j.gloenvcha.2006.02.004
16. Geurs, K. T., & van Wee, B. (2004). Accessibility evaluation of land-use and transport strategies: Review and research directions. Journal of Transport Geography, 12(2), 127–140. https://doi.org/10.1016/j.jtrangeo.2003.10.005
17. Hansen, W. G. (1959). How accessibility shapes land use. Journal of the American Institute of Planners, 25(2), 73–76. https://doi.org/10.1080/01944365908978307
18. Intergovernmental Panel on Climate Change. (2014). Climate change 2014: Impacts, adaptation, and vulnerability. Part A: Global and sectoral aspects (C. B. Field et al., Eds.). Cambridge University Press. https://doi.org/10.1017/CBO9781107415379
19. Kasperson, R. E., & Kasperson, J. X. (Eds.). (2005). The social contours of risk (Vols. 1–2). Earthscan. https://doi.org/10.4324/9781849772556
20. O'Brien, K., Eriksen, S., Nygaard, L. P., & Schjolden, A. (2007). Why different interpretations of vulnerability matter in climate change discourses. Climate Policy, 7(1), 73–88. https://doi.org/10.1080/14693062.2007.9685639
21. Organisation for Economic Co-operation and Development, & European Commission, Joint Research Centre. (2008). Handbook on constructing composite indicators: Methodology and user guide. OECD Publishing. https://doi.org/10.1787/533411815016
22. Penchansky, R., & Thomas, J. W. (1981). The concept of access: Definition and relationship to consumer satisfaction. Medical Care, 19(2), 127–140.

https://doi.org/10.1097/00005650-198102000-00001

23. Rufat, S., Tate, E., Burton, C. G., & Maroof, A. S. (2015). Social vulnerability to floods: Review of case studies and implications for measurement. International Journal of Disaster Risk Reduction, 14, 470–486. https://doi.org/10.1016/j.ijdrr.2015.09.013
24. Sen, A. (1981). Poverty and famines: An essay on entitlement and deprivation. Oxford University Press.
25. Tate, E. (2012). Social vulnerability indices: A comparative assessment using uncertainty and sensitivity analysis. Natural Hazards, 63(2), 325–347. https://doi.org/10.1007/s11069-012-0152-2
26. Turner, B. L., II, Kasperson, R. E., Matson, P. A., McCarthy, J. J., Corell, R. W., Christensen, L., Eckley, N., Kasperson, J. X., Luers, A., Martello, M. L., Polsky, C., Pulsipher, A., & Schiller, A. (2003). A framework for vulnerability analysis in sustainability science. Proceedings of the National Academy of Sciences, 100(14), 8074–8079. https://doi.org/10.1073/pnas.1231335100
27. United Nations General Assembly. (2015). Transforming our world: The 2030 Agenda for Sustainable Development (A/RES/70/1). United Nations.
28. United Nations General Assembly. (2016). New Urban Agenda (A/RES/71/256). United Nations.
29. United Nations Office for Disaster Risk Reduction. (2015). Sendai Framework for Disaster Risk Reduction 2015–2030. UNDRR.
30. Wisner, B., Blaikie, P., Cannon, T., & Davis, I. (2004). At risk: Natural hazards, people's vulnerability and disasters (2nd ed.). Routledge.
31. Watts, M. J., & Bohle, H. G. (1993). The space of vulnerability: The causal structure of hunger and famine. Progress in Human Geography, 17(1), 43–67. https://doi.org/10.1177/030913259301700103
32. World Health Organization, & United Nations Children's Fund (UNICEF). (2023). Progress on household drinking water, sanitation and hygiene 2000–2022: Special focus on gender. WHO & UNICEF.