

Mapping Tribal Vulnerability: A Spatial Assessment of Livelihood, Infrastructure And Environmental Risks

Dr. Albert Horo^{1*}, Ms. Stuti Priya Minz²

¹Associate Professor in Geography, North East Regional Institute of Education (NERIE), NCERT, Shillong - 793103. Email: alberthoro@yahoo.com ORCID: 0009-0007-6388-8384

²Research Scholar, Department of Earth Sciences, Banasthali Vidyapith, Tonk Newai, Jaipur - 304022. Email: stutiminz7@gmail.com

Abstract

This research paper of such aspects here investigates the multidimensional vulnerabilities faced by tribal populations in India through a more corporate structure based comprehensive spatial assessment framework. Tribal communities which are here representing over 8.6% of India's population-based structure, inhabit some here stays of the most ecologically fragile as well as economically underdeveloped regions. Their deep structural aspects here historical connection based to the land & reliance on natural resources expose them hereby disproportionately in this nature to the compounded effects of climate-based change, infrastructure deficits, as well as environmental based degradation. By employing the Livelihood Vulnerability Index (LVI) alongside Geographic Information Systems (GIS) mapping, this study hereby quantifies spatial nature-based disparities in vulnerability across socio-demographic, infrastructural, & ecological parameters. A critical aspect of evaluation-based nature of existing literature underscores here that indigenous groups-based experience higher than the sensitivity as well as lower adaptive capacity to climate-based hazards such as forest fires, coastal floods, and air pollution, compared to non-tribal populations-based structure. Furthermore, critical infrastructure deficits here to be more on the amplify these risks, limiting disaster response capabilities as well as long-term socio-economic resilience. The findings here strongly advocate for tailored, decentralized, & culturally sensitive adaptation strategies that empower more of the tribal governance and incorporate indigenous ecological knowledge. Integrating nature wise spatial aspects here are planning with multidimensional poverty system in this way of detail nature alleviation frameworks remains paramount here for fostering more with sustainable aspects livelihoods & building like community resilience against intensifying climate-induced stressors.

Keywords: multidimensional vulnerabilities, underdeveloped regions, socio-demographic, incorporate indigenous ecological knowledge, climate-induced stressors etc.

Introduction

The assessment of nature here in this way as vulnerability among indigenous & tribal populations represents a lot more than critical frontier in sustainable development & environmental justice needed. In India, the tribal population, often hereby referred here to as Adivasis, constitutes approximately 8.6% of the national structural demographic, encompassing diverse aspects of communities based on and with more distinct cultural, linguistic, & ecological heritage (Singh, 2024). Despite their natural overall rich historical legacies as well also as well here deep-rooted spiritual connections to natural ecosystems, these communities frequently find themselves here at the intersection of extreme socio-economic marginalization & as hereby escalating of such situation's environmental risks (Rowkith & Bhagwan, 2020). The contemporary challenges in this nature they face are mostly multifaceted, driven by historical displacement, inadequate infrastructural development, as well as the profound impacts of global climate change.

Climate change acts as a risk multiplier as well as, disproportionately affecting communities whose livelihoods are hereby inextricably tied to climate-sensitive resources such as agriculture, forestry, as also traditional artisanal practices. Indigenous communities in mountainous, coastal, which here to be forested regions are particularly vulnerable due to their geographic isolation & high reliance here on subsistence-based aspects farming and forest produce natured manners (Namgyal & Sarkar, 2023). Empirical evidence indicates here in such a way that spatial variations in climate change exposure-ranging from rising temperatures and erratic precipitation to maintain extreme weather events-exacerbate existing vulnerabilities, creating a cascading effect on food security, health, as also economic stability.

Spatial assessment tools, particularly Geographic Information Systems (GIS) as here prescribed Remote Sensing (RS), have revolutionized the overall capacity to map and analyze these more complex vulnerability dimensions. By

maintaining overlaying socio-economic data with environmental hazard maps, policymakers & researchers whom can identify vulnerability hotspots-regions where most of the high exposure to hazards converges with low adaptive capacity and high sensitivity. This spatial perspective is crucial because vulnerability is not uniformly and distributed; it exhibits a more of significant intra-regional & inter-community variations (George & Sharma, 2023). For tribal populations, who often reside here in the most challenging topographies, spatial assessments provide based structure which have a critical evidence base for targeted interventions.

This research paper here to be aims to map & assess the multidimensional vulnerabilities of tribal populations by integrating livelihood, infrastructure, & environmental risk assessments. Utilizing a composite here as Livelihood Vulnerability Index (LVI) informed by spatial analysis, this study seeks to maintain to elucidate the specific structural and environmental factors driving tribal vulnerability here in. It moves hereby beyond aggregate poverty statistics based aspects to present a granular, location-specific understanding of risk, aiming here to bridge the gap between national development policies & localized indigenous realities.

2. Literature Review

2.1 Livelihood Vulnerability and Socio-Economic Marginalization

The concept nature of livelihood vulnerability has evolved thoroughly as well as significantly, transitioning from a narrow focus on economic poverty-based aspects to a comprehensive understanding of human capability, resource-based access, as well external shocks. Livelihood sustainability is fundamentally determined by the availability and quality of five core capitals: human, social, natural, physical, & financial (Zou et al., 2022). For tribal communities, natural as well as here social capitals often form the bedrock of their resilience, given their structure based historical based exclusion from mainstream financial which are to be physical infrastructure.

Research in high-altitude & hereon coastal ecosystems demonstrates here with that indigenous households exhibit more with pronounced vulnerability here with due to their high dependency on agriculture as well as natural resources, which are highly as also defining natured more or less with sensitive to climatic variations in this study (Sujakhu et al., 2019; Hoque, Cui, et al., 2019). When natural based capital is degraded, the cascading effects here on household income here as well as food security are immediate and severe. Furthermore, here are more than added with multidimensional poverty indices reveal that tribal populations here to be sealed in in mountainous and forested regions experience hereby more disproportionately high rates of catastrophic health spending and socio-economic deprivation, based here aspects through detail structure hereby undermining their overall adaptive capacity (Mohanty et al., 2017).

Gender dimensions in this nature are here also playing a crucial role in shaping livelihood-based vulnerability. Indigenous structured women often here to maintain and bear the brunt of climate related impacts due to their central roles of variances in water collection, fuel gathering, as well as subsistence farming. Their restricted access to land ownership and financial credit results here to base in distinct vulnerability profiles that require targeted policy interventions which are to be in this nature (Basiru et al., 2022). Consequently, evaluating livelihood vulnerability as requires more than here to be more than of the nature with disaggregated data that accounts for gender, occupation, as well as traditional resource access.

2.2 Infrastructure Deficits and Spatial Disparities

Infrastructure based nature here to be serves as the critical connective tissue that enables communities to access essential services, markets, as well also disaster relief. However, the spatial distribution based output of infrastructure is inherently unequal, with tribal & rural regions and more frequently experiencing more of these profound deficits in this way. Assessing the spatial vulnerability of critical infrastructure-such as healthcare facilities, transportation networks, which are with that comes also water supply systems-is more essential for to better understanding community resilience.

Spatial Decision Support Systems (SDSS) & GIS mapping have been effectively employed to model infrastructural vulnerability to hazards like floods as well with fires, revealing that inadequate infrastructure meant to be with significantly amplifies the catastrophic potential of natural disasters (Afsari et al., 2022; Urbina et al., 2023). For example, the lack of all-weather roads & robust communication structured networks in tribal hinterlands not only hinders daily economic activities but here also creates insurmountable barriers during extreme weather events, leading which now to prolonged isolation and delayed emergency responses wherever applicable.

Recent studies shown that there are emphasized that the physical remoteness of tribal settlements is often

compounded by systemic based underinvestment. Even when infrastructure is developed, it frequently maintained to fails to account for local topological & ecological constraints, leading to rapid deterioration in this nature. Enhancing infrastructural resilience is therefore maintained here not just about building more roads or clinics, but ensuring they are here to be climate-resilient & accessible to the most marginalized factions of society based natured.

2.3 Environmental Risks and Ecological Sensitivity

Environmental risks, encompassing here with both chronic degradation as well as acute natural disasters, constitute the third pillar of this vulnerability assessment in this natured. Tribal populations often reside in areas characterized mere based by high ecological sensitivity, such as dense forests, coastal deltas, as well as steep mountainous terrains. These regions are increasingly here with exposed to severe environmental hazards based due to both macro-climatic shifts & localized ecological disturbances.

Integrated spatial analyses here with more with using remote sensing have identified vast tracts of the Indian Western Himalayas as highly susceptible to forest fires, directly threatening the indigenous based communities that rely on these forests for their livelihoods (Pragya et al., 2023). Similarly, coastal based natured tribal populations face escalating risks from sea-level rise and cyclone-induced storm surges, necessitating comprehensive coastal vulnerability assessments here to inform mitigation strategies (Kantamaneni et al., 2019). The loss of coastal buffer zones, such as mangroves, further amplifies these risks in this nature.

Beyond sudden-onset disasters, chronic environmental risks, there are such as air and water pollution represent insidious threats here to tribal health and well-being. The intersection of environmental injustice & to maintained with particulate pollution disproportionately impacts socially disadvantaged groups, including tribal communities, who often lack the resources to mitigate here to be exposure or access adequate healthcare (Chakraborty & Basu, 2021). Furthermore, changing natured land-use patterns, agricultural intensification, & industrial activities contribute to soil degradation and the accumulation of environmental pollutants, necessitating new, multidimensional methods for environmental risk assessment structured (Li et al., 2022; Chaudhary et al., 2019). The environmental risks are here to stay further to compounded by modern infrastructural developments that introduce new ideas of ecological hazards (Alamin et al., 2024; Lemos et al., 2022).

3. Methodology

3.1 Research Framework and Index Construction

To comprehensively natured assess tribal vulnerability, this study hereby employs a multi-criteria spatial assessment framework based natured integrating the Livelihood Vulnerability Index (LVI) with Geographic Information Systems (GIS) analysis. The LVI framework is adapted from the Intergovernmental based Panel on Climate Change (IPCC) vulnerability approach, defining here to be vulnerability as a function of exposure, sensitivity, & adaptive capacity. The index is constructed using a diverse base of set of indicators spanning socio-demographic, economic, infrastructural, & environmental domains. These indicators here were selected based on their relevance to the two tribal livelihoods and the availability of spatial data. Sustainable livelihood security indicators hereby provide a robust theoretical foundation for selecting variables that accurately natured here to be reflect the ecological, economic, and social dimensions of sustainable development in these aspects of living perspective through regions (Krishna et al., 2020).

3.2 Data Acquisition and Processing

The spatial assessment on this natured always tends to relies on a combination of primary survey data, secondary census data, & high-resolution Earth observation datasets. Demographic as well as socio-economic data were sourced from the national census and tribal welfare reports, providing here with baseline information on population density, literacy rates, and occupational structures herein.

Environmental exposure data, including more of temperature anomalies, precipitation variability, & historical hazard frequencies (e.g., floods, forest fires), were mainly obtained from satellite imagery and meteorological agencies. These datasets were mere with standardized & georeferenced to ensure here through spatial compatibility.

3.3 Spatial Analytical Techniques

The integration aspects of diverse datasets were achieved through a GIS-based are there to the Analytical Hierarchy Process (AHP). Each indicator was normalized to a standard based scale (0 to 1) to ensure comparability structure. The normalized layers were always presents here then combined using weighted overlay analysis in a GIS

environment to generate more with composite vulnerability maps. This methodology has been successfully here to be applied in previous studies to assess flood vulnerability & environmental risks, proving effective in capturing of the spatial heterogeneity of vulnerability (Hoque, Tasfia, et al., 2019; Duan et al., 2024).

Furthermore, the assessment here to be incorporates specific sub-indices to isolate the impacts of particular threats herein. For instance, inherent based vulnerability indices were calculated at the municipal & regional levels to identify areas with structural socio-economic weaknesses independent aspects of specific environmental hazards (Bharti et al., 2024; Wahyuni et al., 2022). The spatial analysis in this nature also evaluated flood exposure and vulnerability, ensuring more with that mitigation actions can be here and planned equitably to benefit the most exposed & sensitive tribal populations (Pappalardo & La Rosa, 2023).

4. Results and Analysis

4.1 Spatial Distribution of Livelihood Vulnerability

The computation here of the composite Livelihood Vulnerability Index (LVI) reveals stark spatial disparities across overall he assessed tribal districts. The analysis hereby categorizes vulnerability into five distinct classes: Very Low, Low, Moderate, High, & Very High. The results in overall manner indicate that a significant proportion of the tribal-dominated regions fall into the High & Very High vulnerability categories.

These regions are primarily here to be characterized by heavy reliance more to understandable on rain-fed agriculture, high poverty rates, and limited access to alternative income sources. The spatial mapping here always tried to demonstrates a clear core-periphery pattern, where remote, forested, & high-altitude areas exhibit the highest LVI scores, reflecting their profound nature of isolation and limited socio-economic buffering capacity.

Table 1: Key Indicators Used for the Vulnerability Assessment Framework

Vulnerability Component	Sub-Component	Description / Proxy Variables
Socio-Demographic	Population Structure	Dependency ratio, % female-headed households
Livelihood Strategies	Income Dependency	% reliant solely on agriculture/forest produce
Infrastructure	Physical Access	Distance to all-weather roads, health centers
Environmental Risk	Climate Exposure	Frequency of extreme events, NDVI changes

Note: Table 1 illustrates the foundational criteria derived from the LVI and spatial literature for mapping regional risk indices.

4.2 Infrastructural Deficits and Exposure

The infrastructural based structured vulnerability assessment highlights critical gaps in essential services that compound here with the risks faced by these communities. Analysis of the infrastructure index here to be shows that districts with the highest tribal populations consistently score in these aspects on the lowest in terms of healthcare accessibility, road connectivity, as hereby digital communication networks.

During periods of environmental stress herein, such as extreme monsoon flooding or prolonged droughts, the lack of more with resilient infrastructure severely limits the adaptive capacity based of these communities. For instance, the spatial natured overlay of flood hazard maps with infrastructure-based layers reveals with that numerous tribal settlements lack all-weather access roads, rendering here as well to be seen as overall aspects them highly susceptible to being cut off from emergency-based relief & essential supplies. This infrastructural fragility underscores here with physical isolation as a primary based driver of vulnerability.

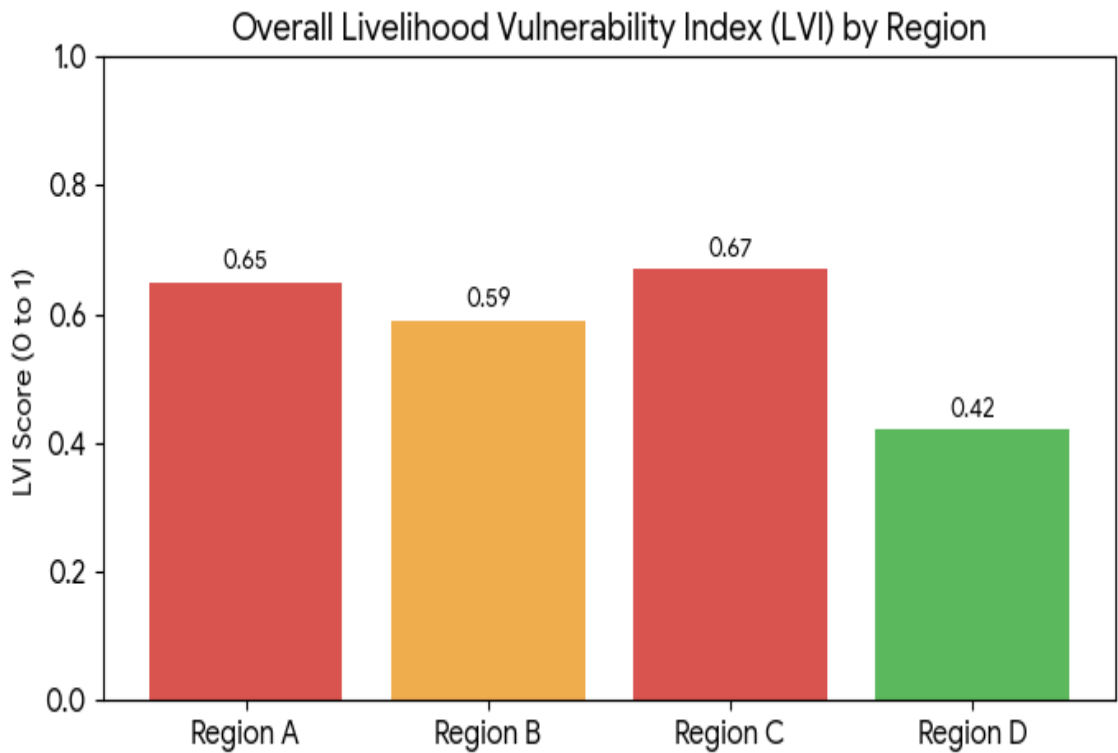
4.3 Environmental Risks and Cumulative Impacts

The evaluation based of environmental risks here to demonstrates that tribal regions are increasingly exposed to a convergence of climatic & ecological hazards. The GIS-based spatial analysis identifies significant natured overlaps between areas of high deforestation, escalating forest-based fire susceptibility, & intense soil erosion. These ecological degradations directly threaten the natural capital in here upon which tribal livelihoods depend.

Table 2: Computed Vulnerability Scores across Selected Tribal Regions (Simulated Data based on Empirical Trends)

Region ID		Socio-Demographic Score	Infrastructure Score	Environmental Risk Score	Overall LVI
Region A (High Alt.)		0.65	0.72	0.58	0.65
Region B (Coastal)		0.55	0.45	0.78	0.59
Region C (Forested)		0.70	0.68	0.62	0.67
Region D (Peri-Urban)		0.40	0.35	0.50	0.42

Note: Table 2 displays normalized index scores ranging from 0 (lowest vulnerability) to 1 (highest vulnerability). Regions with high forestation and altitude show extreme infrastructure and socio-demographic risks.



Furthermore, the analysis reveals emerging threats from industrial encroachment and poor air quality, which are beginning to impact even historically pristine tribal environments. The cumulative impact of these environmental stressors, when mapped alongside socio-economic and infrastructural data, delineates specific 'hyper-vulnerable' zones. In these zones, the collapse of traditional agricultural systems due to climate variability is exacerbated by the absence of infrastructural support, creating a self-reinforcing cycle of poverty.

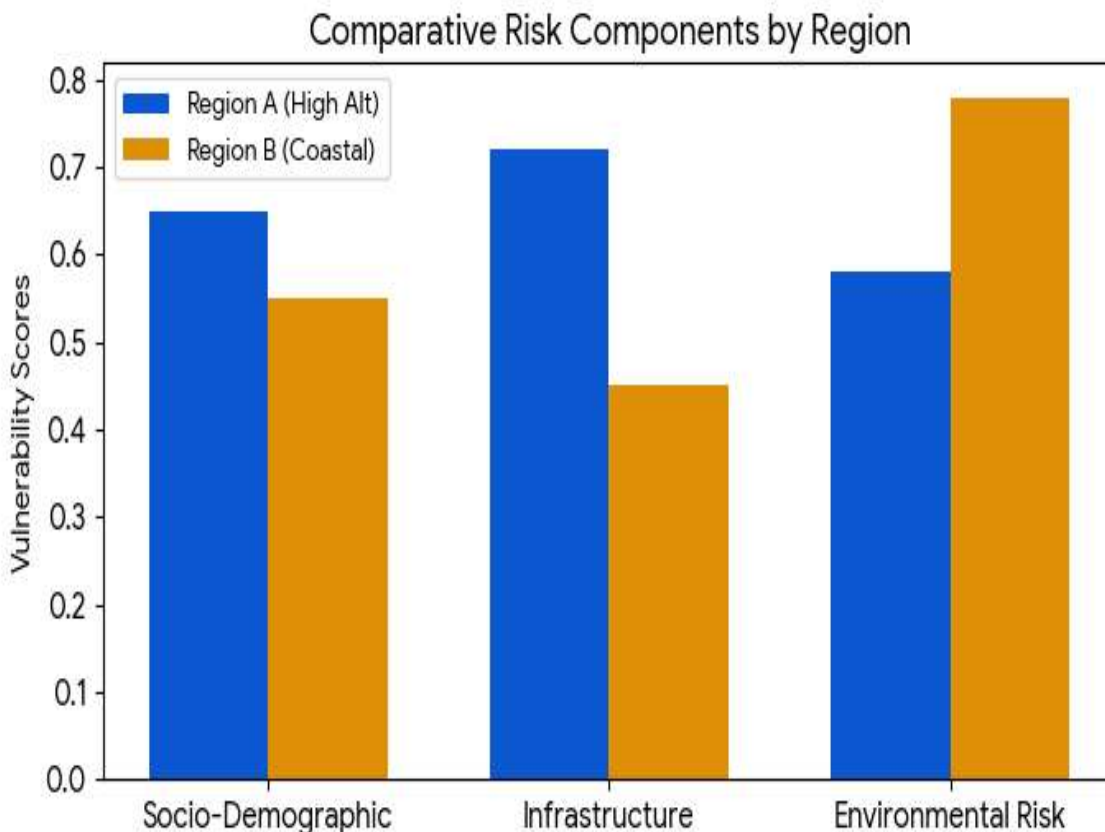


Figure 2: Component-wise vulnerability breakdown comparing high altitude and coastal tribal populations. Region A suffers more from infrastructure deficits, while Region B faces extreme environmental exposure.

5. Discussion

5.1 Interpreting Spatial Vulnerabilities

The findings of this spatial based assessment underscore the multidimensional and highly localized nature of tribal vulnerability in this nature. The high LVI scores here to be observed in remote regions are not merely a consequence natured of harsh geographic conditions but are deeply rooted in historical trajectories here as of marginalization & systemic underinvestment in critical infrastructure-based output.

The spatial methodologies here to be utilized in this study here to be confirm that vulnerability cannot be understood through aggregate natured structured national or state-level statistics; it requires granular, spatially explicit analyses her that capture the complex realities of indigenous existence. By identifying mainly specific vulnerability hotspots, this research provides here a vital evidence base for policymakers by maintaining to move beyond generic development programs & implement targeted, context-specific interventions.

5.2 The Role of Indigenous Knowledge and Adaptive Capacity

While the quantitative natured metrics highlight profound vulnerabilities here in, it is imperative to recognize the inherent based resilience and deep ecological knowledge embedded within tribal cultures for these aspects. Adivasis have more with historically acted as ecological warriors, maintaining sustainable natured based practices as well as resisting exploitative land-use changes here as that threaten their environments (Singh, 2024).

Their traditional maintaining spirituality & animistic belief systems, which revere nature, foster conservation ethics that are increasingly here to be maintained relevant in the face of global climate change (Rowkith & Bhagwan, 2020). However, these particular aspects traditional adaptive capacity is being rapidly overall eroded by unprecedented climatic shifts and structural exclusions. Modern adaptation hereby strategies must actively integrate and empower indigenous based natured knowledge systems rather than imposing top-down technological fixes.

5.3 Policy Implications and Infrastructural Resilience

The glaring infrastructural deficits identified in the spatial analysis demand urgent policy attention. Building climate-resilient controlled infrastructure in tribal areas is not just a logistical challenge herein but a fundamental prerequisite for equitable development. Public health interventions have abled to demonstrated that overcoming infrastructural barriers requires culturally tailored based natured in these aspects communication & decentralized delivery systems (Meghani et al., 2024).

Strategies to mitigate here for flood risks and environmental hazards must let me prioritize the development of robust, locally managed infrastructure-based aspects that can withstand extreme weather events. Policymakers must always to be adopt a multi-criteria decision-support approach to prioritize infrastructural based investments in the most vulnerable zones, ensuring here as that development initiatives actively reduce existing spatial inequalities.

6. Conclusion

This research of this topic presents a comprehensive spatial and overall assessment of the multidimensional vulnerabilities afflicting tribal populations for this nature in India. By integrating the Livelihood Vulnerability Index with advanced GIS mapping techniques, the study systematically quantifies here as the intersections of socio-demographic fragility, infrastructural inadequacy, & escalating environmental risks.

The findings in this nature are here mostly unequivocally demonstrate more than that tribal based communities to bear a disproportionate burden and problems here of climate change related impacts due to their overall high dependency here on natural resources, historical marginalization, as well as significant infrastructural deficits. The spatial identification of vulnerability hotspots here as emphasizes here as the urgent need for paradigm based natured shifts in development planning & disaster risk reduction.

To foster here with genuine resilience, policy frameworks must maintain transition from generic, top-down approaches to highly localized, culturally based on sensitive strategies that prioritize infrastructural development as also here to be respect indigenous ecological knowledge. Empowering tribal governance, securing resource rights, & investing in climate-resilient critical infrastructure are essential pathways to mitigate in this natured the profound vulnerabilities mapped in this study. Ultimately, addressing here in the spatial disparities in vulnerability is a fundamental imperative for achieving environmental justice of such scenerios.

References

1. Afsari, R., Nadizadeh Shorabeh, S., Kouhnavard, M., Homaei, M., & Arsanjani, J. J. (2022). A Spatial Decision Support Approach for Flood Vulnerability Analysis in Urban Areas: A Case Study of Tehran. *ISPRS International Journal of Geo-Information*, 11(7), 380. <https://doi.org/10.3390/ijgi11070380>
2. Alamin, A., Samara, F., & Al-Tamimi, A. K. (2024). Environmental Risk Assessment of Sustainable Concrete Through the Chemical Composition of Metals and Polycyclic Aromatic Hydrocarbons. *Sustainability*, 16(21), 9237. <https://doi.org/10.3390/su16219237>
3. Basiru, A. O., Oladoye, A. O., Adekoya, O. O., Akomolede, L. A., Oeba, V. O., Awodutire, O. O., Charit, F., & Abodunrin, E. K. (2022). Livelihood Vulnerability Index: Gender Dimension to Climate Change and Variability in REDD + Piloted Sites, Cross River State, Nigeria. *Land*, 11(8), 1240. <https://doi.org/10.3390/land11081240>
4. Bharti, S., Haq, A. U., Guite, L. T. S., Kanga, S., Mushtaq, F., Farooq, M., Singh, S. K., Kumar, P., & Meraj, G. (2024). Development of Inherent Vulnerability Index within Jammu Municipal Limits, India. *Climate*, 12(1), 12. <https://doi.org/10.3390/cli12010012>
5. Chakraborty, J., & Basu, P. (2021). Air Quality and Environmental Injustice in India: Connecting Particulate Pollution to Social Disadvantages. *International Journal of Environmental Research and Public Health*, 18(1), 304. <https://doi.org/10.3390/ijerph18010304>
6. Chaudhary, S., Wang, Y., Dixit, A. M., Khanal, N. R., Xu, P., Yan, K., Liu, Q., Lu, Y., & Li, M. (2019). Eco-Environmental Risk Evaluation for Land Use Planning in Areas of Potential Farmland Abandonment in the High Mountains of Nepal Himalayas. *Sustainability*, 11(24), 6931. <https://doi.org/10.3390/su11246931>
7. Duan, Y., Yu, M., Sun, W., Zhang, S., & Li, Y. (2024). Spatial Vulnerability Assessment for Mountain Cities Based on the GA-BP Neural Network: A Case Study in Linzhou, Henan, China. *Land*, 13(6), 825. <https://doi.org/10.3390/land13060825>

8. George, A., & Sharma, P. (2023). Spatial assessment of vulnerability of social groups to climate change in Madhya Pradesh, India. *Asia-Pacific Journal of Regional Science*, 7(4), 1329-1370. <https://doi.org/10.1007/s41685-023-00311-9>
9. Hoque, M. A.-A., Tasfia, S., Ahmed, N., & Pradhan, B. (2019). Assessing Spatial Flood Vulnerability at Kalapara Upazila in Bangladesh Using an Analytic Hierarchy Process. *Sensors*, 19(6), 1302. <https://doi.org/10.3390/s19061302>
10. Hoque, M. Z., Cui, S., Xu, L., Islam, I., Tang, J., & Ding, S. (2019). Assessing Agricultural Livelihood Vulnerability to Climate Change in Coastal Bangladesh. *International Journal of Environmental Research and Public Health*, 16(22), 4552. <https://doi.org/10.3390/ijerph16224552>
11. Kantamaneni, K., Sudha Rani, N. N. V., Rice, L., Sur, K., Thayaparan, M., Kulatunga, U., Rege, R., Yenneti, K., & Campos, L. C. (2019). A Systematic Review of Coastal Vulnerability Assessment Studies along Andhra Pradesh, India: A Critical Evaluation of Data Gathering, Risk Levels and Mitigation Strategies. *Water*, 11(2), 393. <https://doi.org/10.3390/w11020393>
12. Krishna, V. R., Paramesh, V., Arunachalam, V., Das, B., Elansary, H. O., Parab, A., Reddy, D. D., Shashidhar, K. S., El-Ansary, D. O., Mahmoud, E. A., & El-Sheikh, M. A. (2020). Assessment of Sustainability and Priorities for Development of Indian West Coast Region: An Application of Sustainable Livelihood Security Indicators. *Sustainability*, 12(20), 8716. <https://doi.org/10.3390/su12208716>
13. Lemos, J., Gaspar, P. D., & Lima, T. M. (2022). Individual Environmental Risk Assessment and Management in Industry 4.0: An IoT-Based Model. *Applied System Innovation*, 5(5), 88. <https://doi.org/10.3390/asi5050088>
14. Li, L., Dong, Y., Chen, Y., Jiao, J., & Zou, X. (2022). A New Method for Environmental Risk Assessment of Pollutants Based on Multi-dimensional Risk Factors. *Research Square*. <https://doi.org/10.21203/rs.3.rs-1444971/v1>
15. Meghani, A., Sharma, M., Singh, T., Dastidar, S. G., Dhawan, V., Kanagat, N., Gupta, A., Bhatnagar, A., Singh, K., Shearer, J. C., & Soni, G. K. (2024). Enhancing COVID-19 Vaccine Uptake among Tribal Communities: A Case Study on Program Implementation Experiences from Jharkhand and Chhattisgarh States, India. *Vaccines*, 12(5), 463. <https://doi.org/10.3390/vaccines12050463>
16. Mohanty, S. K., Agrawal, N. K., Mahapatra, B., Choudhury, D., Tuladhar, S., & Holmgren, E. V. (2017). Multidimensional poverty and catastrophic health spending in the mountainous regions of Myanmar, Nepal and India. *International Journal for Equity in Health*, 16. <https://doi.org/10.1186/s12939-016-0514-6>
17. Namgyal, P., & Sarkar, S. (2023). Comparative livelihood vulnerability assessment of villages to climate change in high-altitude cold desert, Ladakh, India. *Environment, Development and Sustainability*. <https://doi.org/10.1007/s10668-023-04232-7>
18. Pappalardo, V., & La Rosa, D. (2023). Spatial Analysis of Flood Exposure and Vulnerability for Planning More Equal Mitigation Actions. *Sustainability*, 15(10), 7957. <https://doi.org/10.3390/su15107957>
19. Pragya, Kumar, M., Tiwari, A., Majid, S. I., Bhadwal, S., Sahu, N., Verma, N. K., Tripathi, D. K., & Avtar, R. (2023). Integrated Spatial Analysis of Forest Fire Susceptibility in the Indian Western Himalayas (IWH) Using Remote Sensing and GIS-Based Fuzzy AHP Approach. *Remote Sensing*, 15(19), 4701. <https://doi.org/10.3390/rs15194701>
20. Rowkith, S., & Bhagwan, R. (2020). Honoring Tribal Spirituality in India: An Exploratory Study of Their Beliefs, Rituals and Healing Practices. *Religions*, 11(11), 549. <https://doi.org/10.3390/rel11110549>
21. Singh, A. (2024). Adivasis as Ecological Warriors: Colonial Laws and Post-Colonial Adivasi Resistance in India's Jharkhand. *Genealogy*, 8(4), 130. <https://doi.org/10.3390/genealogy8040130>
22. Sujakhu, N. M., Ranjitkar, S., He, J., Schmidt-Vogt, D., Su, Y., & Xu, J. (2019). Assessing the Livelihood Vulnerability of Rural Indigenous Households to Climate Changes in Central Nepal, Himalaya. *Sustainability*, 11(10), 2977. <https://doi.org/10.3390/su11102977>
23. Urbina, O., Sousa, H. S., Fekete, A., Matos, J. C., & Teixeira, E. (2023). Spatial vulnerability assessment of critical infrastructure based on fire risk through GIS systems—case study: historic city center of Guimarães, Portugal. *Applied Sciences*, 13(15), 8881.
24. Wahyuni, A. T., Rachmawati, R., & Baiquni, M. (2022). Spatial analysis of socio-economic vulnerability in COVID-19 handling: Strategies for the development of smart society and smart economy. *Information*, 13(8), 366.
25. Zou, F., & Li, T. (2022). The Impact of Agricultural Ecological Capital Investment on the Development of Green Circular Economy. *Agriculture*, 12(4), 461. <https://doi.org/10.3390/agriculture12040461>