INTERNATIONAL JOURNAL OF RESEARCH AND SCIENTIFIC INNOVATION (IJRSI)
ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue VI June 2026

Bridging the Urban Climate Evidence-to-Action Gap: Introducing the Geospatial Urban Climate Adaptation and Resilience Decision-Support Framework (GUCAR-DSF)

***Garba T**

Department of Environmental Management Technology, Abubakar Tafawa Balewa University, Bauchi, Nigeria

***Corresponding Author**

DOI: https://doi.org/10.51244/IJRSI.2026.1306000513

Received: 05 July 2026; Accepted: 10 July 2026; Published: 21 July 2026

ABSTRACT

Rapid urbanisation, climate change, land-use transformation, ecosystem degradation, infrastructure deficits, and social inequality are intensifying complex and spatially uneven climate risks in cities. Although advances in remote sensing, Geographic Information Systems, Earth Observation, vulnerability assessment, resilience planning, and adaptive governance have improved the capacity to understand urban climate risk, these capabilities are often applied through fragmented analytical and institutional systems. As a result, hazard mapping may remain disconnected from vulnerability assessment, adaptation planning from implementation, governance from spatial evidence, and monitoring from future decision-making. This creates a persistent evidence-to-action gap in climate-resilient urban planning. This paper introduces the Geospatial Urban Climate Adaptation and Resilience Decision-Support Framework (GUCAR-DSF) as an integrative evidence-to-action framework for supporting climate-resilient urban planning. Developed through structured interdisciplinary evidence synthesis, the framework draws on resilience thinking, social-ecological systems, adaptive governance, geospatial intelligence, and multi-hazard risk perspectives. It connects eight interdependent functions: climate and environmental observation; geospatial intelligence and indicator generation; multi-hazard diagnostics; vulnerability and adaptive-capacity assessment; adaptation appraisal and prioritisation; governance, participation and implementation; monitoring, evaluation and adaptive learning; and decision-support communication and scaling. The central innovation of GUCAR-DSF lies in its continuous evidence-to-action cycle, in which implementation generates new knowledge and monitoring informs renewed observation, analysis, prioritisation, and institutional adjustment. The framework supports spatially targeted, socially differentiated, and continuously evaluated adaptation across risks such as urban heat, flooding, compound hazards, land-use change, ecosystem degradation, informal-settlement vulnerability, critical infrastructure exposure, and Nature-Based Solutions. Its modular design makes it relevant to both data-rich and resource-constrained contexts, particularly rapidly urbanising cities in the Global South. As a conceptual framework, GUCAR-DSF requires empirical validation, comparative testing, and longitudinal assessment. It therefore provides a foundation for future empirical testing, pilot implementation, and comparative urban resilience research.

Keywords: GUCAR-DSF; urban climate adaptation; geospatial intelligence; climate resilience; multi-hazard risk; vulnerability assessment; evidence-to-action; adaptive governance;

INTRODUCTION

Climate change is increasingly reshaping the conditions under which cities are planned, governed, serviced, and inhabited. Rising temperatures, shifting rainfall regimes, recurrent flooding, prolonged drought, ecosystem degradation, and more severe extreme events are placing growing pressure on urban infrastructure, public health, housing, mobility, water systems, ecosystems, and local economies. These pressures are especially acute in rapidly urbanising regions, where demographic growth, land conversion, infrastructure deficits, weak development control, and social inequality interact with climate hazards to produce complex and spatially differentiated patterns of vulnerability (Intergovernmental Panel on Climate Change [IPCC], 2023; Meerow et al., 2016). Urban climate adaptation has therefore become a central planning challenge, requiring cities not only to respond to hazards after they occur but also to anticipate changing risk conditions, reduce exposure, strengthen adaptive capacity, and guide development towards greater resilience.

The urban climate adaptation problem is fundamentally multidimensional. Climate hazards are shaped not only by atmospheric processes but also by the ways cities transform land, distribute infrastructure, manage ecosystems, and organise access to services. The conversion of vegetated and permeable surfaces into roads, buildings, and other impervious structures alters surface-energy balances, intensifies heat storage, reduces evapotranspiration, accelerates runoff, and increases pressure on drainage systems (Oke et al., 2017). At the same time, the degradation of wetlands, riparian corridors, urban forests, open spaces, and drainage buffers weakens ecological functions that regulate temperature, retain stormwater, support biodiversity, and improve environmental quality. These processes often intersect with poverty, inadequate housing, informal settlement expansion, and unequal access to services, creating neighbourhoods where climatic exposure and limited adaptive capacity reinforce one another (Folke et al., 2021; IPCC, 2023).

Urban heat and flooding illustrate this complexity clearly. Extreme heat is intensified by dense built form, limited vegetation, extensive impervious surfaces, and anthropogenic heat emissions. Flooding is shaped by rainfall variability, topography, drainage capacity, surface sealing, settlement location, and hydrological disruption. Although these hazards are often assessed separately, they may arise from common urban development processes. Impervious-surface expansion can increase thermal stress while accelerating runoff, while vegetation loss can reduce both evaporative cooling and rainfall interception. These relationships suggest that climate adaptation cannot be adequately addressed through isolated hazard-specific interventions. Instead, cities require planning approaches capable of identifying interactions among hazards, land-use change, ecosystem condition, infrastructure exposure, and social vulnerability.

A major limitation of contemporary urban adaptation practice is fragmentation. Hazard analysis, vulnerability assessment, land-use planning, infrastructure investment, disaster management, and environmental governance are frequently undertaken within separate analytical and institutional systems. Technical studies may produce heat maps, flood-susceptibility surfaces, or land-use classifications without being systematically connected to investment priorities or implementation mechanisms. Vulnerability assessments may identify exposed populations but remain disconnected from spatial development control. Urban plans may acknowledge climate risk without incorporating current geospatial evidence, while adaptation strategies may propose interventions without clear procedures for determining where they should be implemented, who should benefit, or how performance should be monitored over time.

This fragmentation is reinforced by institutional divisions. Responsibilities for drainage, land administration, environmental protection, disaster risk reduction, infrastructure, public health, and climate policy often lie across multiple agencies with different mandates, datasets, budgets, and planning horizons. Adaptive governance scholarship has long emphasised that complex environmental challenges require collaboration, learning, flexibility, and coordination across institutional boundaries (Folke et al., 2005; Tyler & Moench, 2012). Yet, in practice, urban climate planning frequently remains sectoral and project-driven. The result is a persistent disconnect between the integrated character of urban climate risk and the fragmented structures through which urban decisions are made.

At the same time, advances in geospatial technologies have substantially expanded the capacity to understand urban climate risk. Remote sensing, Geographic Information Systems (GIS), Earth Observation, cloud computing, machine learning, and spatial modelling can monitor land-use/land-cover change, vegetation decline, urban expansion, wetland encroachment, impervious-surface growth, land surface temperature, drainage conditions, terrain characteristics, flood susceptibility, and infrastructure exposure (Goodchild, 2020; Longley et al., 2021; Tamiminia et al., 2020). Open Earth Observation archives and cloud-based platforms have also made these capabilities more accessible, including in data-constrained contexts. Geospatial machine-learning techniques further offer opportunities to detect complex and non-linear relationships among environmental variables (Lary et al., 2016; Tamiminia et al., 2020).

However, greater analytical capacity does not automatically produce more effective adaptation. In many cases, geospatial outputs remain at the level of descriptive mapping. Risk maps may identify hotspots without indicating which adaptation options are most appropriate, which communities should be prioritised, how interventions should be sequenced, or how implementation outcomes should inform future decisions. The key challenge is therefore no longer only how to generate more spatial information, but how to transform that information into transparent, equitable, implementable, and adaptive planning decisions. A technically sophisticated map has limited policy value if it does not support a clear process for identifying priorities, comparing adaptation options, assigning responsibilities, mobilising resources, monitoring outcomes, and revising decisions as conditions change.

Existing approaches provide important but partial contributions to this challenge. GIS-based decision support can integrate indicators and reveal spatial patterns of risk; multi-criteria analysis can assist in comparing priorities; resilience frameworks strengthen systems thinking; adaptive governance emphasises participation and learning; and social-ecological perspectives highlight ecosystem feedbacks. Yet these approaches are often applied separately. What remains insufficiently developed is an integrated evidence-to-action framework that connects environmental observation, geospatial analytics, multi-hazard assessment, vulnerability analysis, adaptation prioritisation, governance, implementation, monitoring, and feedback within a continuous planning process.

This paper responds by introducing the Geospatial Urban Climate Adaptation and Resilience Decision-Support Framework (GUCAR-DSF) as an original evidence-to-action framework for climate-resilient urban planning. It integrates eight interconnected functions: climate and environmental observation; geospatial intelligence and indicator generation; multi-hazard diagnostics; vulnerability and adaptive-capacity assessment; adaptation appraisal and prioritisation; governance, participation and implementation; monitoring, evaluation and adaptive learning; and decision-support communication and scaling. Its central proposition is that climate adaptation should be treated as a continuous cycle in which evidence informs action, implementation generates new knowledge, and monitoring feeds back into renewed observation, assessment, prioritisation, and institutional learning. Conceived as flexible rather than prescriptive, GUCAR-DSF aims to strengthen the translation of climate knowledge into targeted, equitable, and continuously improving urban resilience action, particularly in rapidly urbanising and resource-constrained cities.

Conceptual And Methodological Basis Of The Gucar-Dsf

The Geospatial Urban Climate Adaptation and Resilience Decision-Support Framework (GUCAR-DSF) is grounded in a structured evidence-synthesis approach that integrates insights from climate adaptation, urban resilience, social-ecological systems, adaptive governance, geospatial science, and multi-hazard risk assessment. The purpose is not to conduct a formal meta-analysis or systematic review, but to synthesise conceptually and operationally relevant evidence from peer-reviewed scholarship, geospatial research, resilience theory, and authoritative policy literature. The synthesis prioritises studies that explain how climate hazards interact with land-use transformation, ecosystem degradation, infrastructure conditions, social vulnerability, and institutional capacity. It also identifies approaches that support the translation of spatial evidence into planning, implementation, monitoring, and adaptive decision-making.

Resilience Thinking

Resilience thinking provides one of the central conceptual foundations of the framework. Urban resilience refers to the capacity of urban systems to absorb disturbances, maintain essential functions, recover from shocks, and adapt or transform under changing conditions (Meerow et al., 2016). This perspective is important because cities operate under uncertainty and cannot depend only on fixed responses to past hazards. Within GUCAR-DSF, resilience is therefore treated as a dynamic planning capability supported by continuous observation, assessment, implementation, monitoring, learning, and adjustment.

Social-Ecological Systems Thinking

The framework is also informed by social-ecological systems thinking, which views cities as interconnected systems where ecological processes, infrastructure, institutions, economic activities, and communities interact (Folke et al., 2021). Urban forests, wetlands, drainage corridors, soils, water bodies, and green spaces regulate temperature, runoff, biodiversity, public health, and environmental quality. Their degradation can intensify heat, flooding, and other climate risks, while their restoration can strengthen adaptive capacity. This perspective supports the framework's attention to land-use dynamics, ecosystem condition, and the integration of Nature-Based Solutions with infrastructure and spatial planning.

Adaptive Governance

Adaptive governance supplies the institutional foundation of the framework. Urban climate risks are dynamic, cross-sectoral, and uncertain, making rigid and fragmented governance systems inadequate for effective adaptation. Adaptive governance emphasises collaboration, participation, experimentation, knowledge sharing, and iterative learning across institutions and stakeholder groups (Folke et al., 2005; Tyler & Moench, 2012). In the GUCAR-DSF, this perspective justifies the inclusion of governance, stakeholder participation, implementation responsibility, monitoring, and feedback as core decision-support functions. The framework recognises that technically sound analysis has limited value unless institutions can coordinate action, mobilise resources, learn from outcomes, and revise decisions.

Geospatial Intelligence

Geospatial intelligence provides the analytical backbone of the GUCAR-DSF. It involves the integration of remote sensing, Geographic Information Systems, Earth Observation, climate datasets, spatial modelling, and related analytical methods to generate location-specific knowledge for decision-making. These tools allow changes in land use, vegetation, impervious surfaces, land surface temperature, drainage, terrain, settlement patterns, and infrastructure exposure to be analysed across space and time (Goodchild, 2020; Longley et al., 2021; Tamiminia et al., 2020). Within the framework, geospatial intelligence is not limited to hazard mapping; it connects spatial evidence with vulnerability assessment, adaptation prioritisation, implementation, and monitoring.

Multi-Hazard Risk Perspective

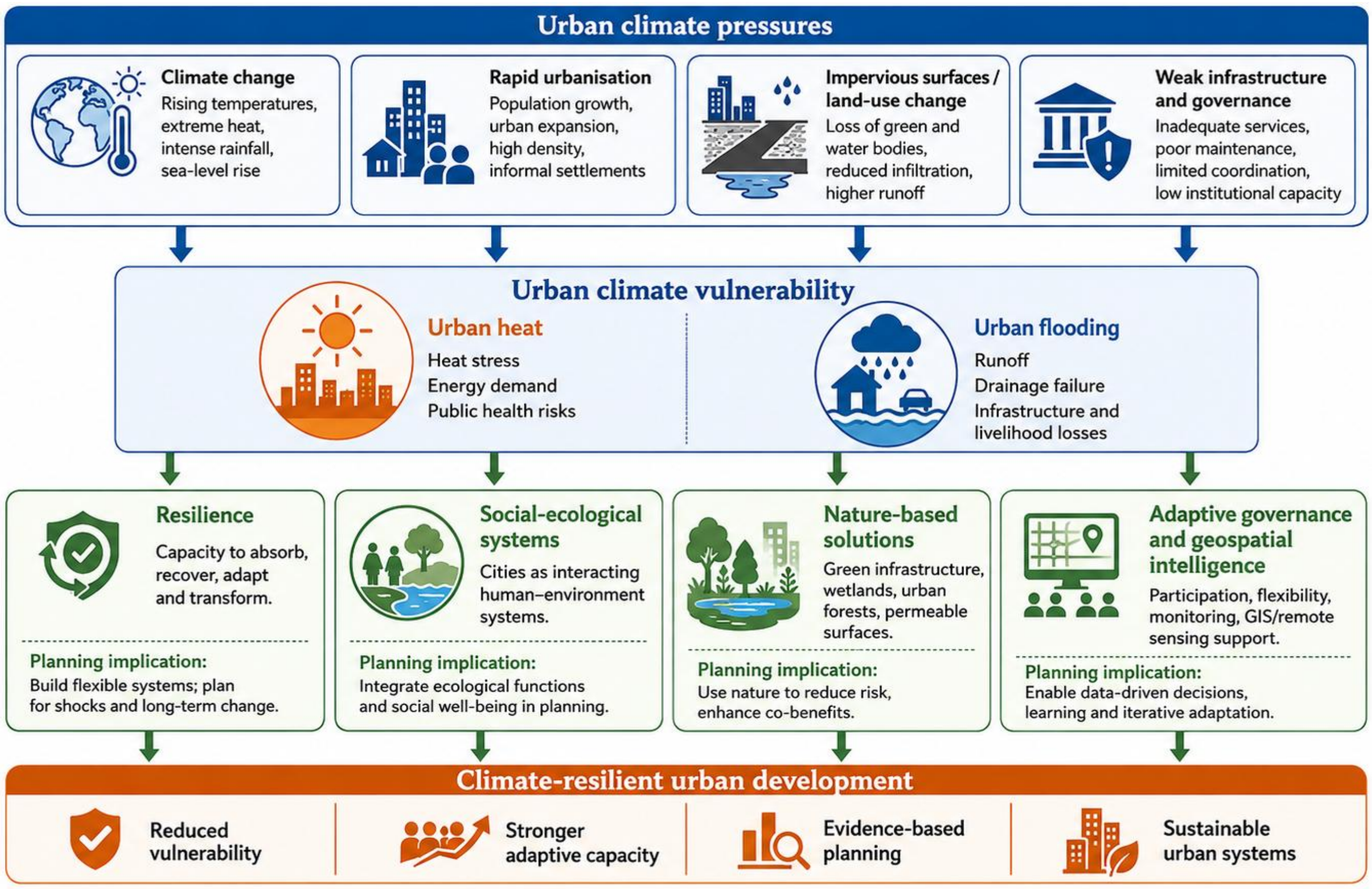
The framework further adopts a multi-hazard risk perspective because urban climate risks rarely occur in isolation. Heat, flooding, drought, ecosystem degradation, and infrastructure disruption may overlap, interact, or intensify one another through shared drivers and cascading processes. Multi-hazard thinking helps identify areas where risks converge, where exposure is compounded, and where one hazard may increase vulnerability to another. By combining hazard indicators with exposure, sensitivity, and adaptive-capacity information, GUCAR-DSF supports a more integrated understanding of where risks accumulate and which populations, assets, or ecosystems require priority attention.

Integrated Conceptual Logic

Taken together, these perspectives provide the foundation for the GUCAR-DSF. Structured evidence synthesis identifies relevant knowledge; resilience thinking emphasises adaptation, recovery, and transformation; social-ecological systems thinking reveals interactions among environmental and human systems; adaptive governance addresses coordination and learning; geospatial intelligence supplies spatially explicit evidence; and multi-hazard assessment captures interacting risks. Their integration enables GUCAR-DSF to function as an evidence-to-action framework for climate-resilient urban planning rather than as a stand-alone geospatial or analytical model.

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue VI June 2026

Figure 1. Conceptual Foundation of Urban Climate Adaptation



Source: Author's conceptualisation, informed by IPCC (2023), Meerow et al. (2016), Folke et al. (2021), and OECD (2023).

Figure 1, demonstrates that the GUCAR-DSF is not conceived merely as a geospatial technology framework. Its framework combines systems understanding, resilience, spatial intelligence, differentiated vulnerability, adaptive governance, and multi-hazard analysis within a common decision-support logic. The interaction among these foundations enables the framework to move from environmental observation towards prioritised intervention, implementation, monitoring, learning, and continuous institutional adjustment.

METHODOLOGICAL ORIENTATION

Research Design

This paper adopts a conceptual, interdisciplinary, and structured integrative evidence-synthesis approach to develop the Geospatial Urban Climate Adaptation and Resilience Decision-Support Framework (GUCAR-DSF). The study does not present primary field data, undertake a meta-analysis, or test the proposed framework within a single empirical case. Rather, it synthesises complementary bodies of scientific, methodological, policy, and practice-oriented knowledge to examine how urban climate observations can be translated into spatially differentiated and actionable adaptation decisions. This methodological orientation reflects the multidimensional character of urban climate risk, which emerges from interactions among climatic hazards, land-use transformation, ecosystem change, infrastructure conditions, socio-economic vulnerability, institutional capacity, and governance processes.

The synthesis was designed to move beyond a conventional narrative review by organising the evidence around predefined analytical domains directly related to the conceptual problem addressed by the paper. Particular attention was given to literature capable of explaining: (i) how urban environmental change generates or modifies climate risk; (ii) how geospatial technologies support risk detection and spatial diagnosis; (iii) how exposure, sensitivity, and adaptive capacity shape differentiated vulnerability; (iv) how adaptation options are prioritised and implemented; and (v) how monitoring, participation, governance, and institutional learning influence longer-term resilience. The resulting methodology therefore combines conceptual synthesis, geospatial reasoning, comparative interpretation, and framework construction within a unified evidence-to-action perspective.

The evidence base comprised peer-reviewed academic literature, authoritative institutional assessments, policy-oriented publications, methodological studies, and selected documented urban adaptation experiences. Institutional evidence was particularly relevant where global or regional syntheses were required, including assessments and policy materials produced by bodies such as the Intergovernmental Panel on Climate Change, UN-Habitat, the World Bank, the Organisation for Economic Co-operation and Development, and relevant United Nations agencies. Peer-reviewed studies were used to deepen the theoretical, analytical, and empirical foundations of the framework, particularly in relation to resilience, geospatial intelligence, urban heat, flooding, land-use change, vulnerability, multi-hazard risk, Nature-Based Solutions, and adaptive governance.

Search Domains and Key Terms

Evidence identification was organised around interconnected thematic search domains rather than a single narrow disciplinary vocabulary. This was necessary because the proposed framework spans climate science, geography, environmental management, urban planning, remote sensing, disaster-risk reduction, governance, and sustainable development. The first domain addressed urban climate change and adaptation, using combinations of terms such as *urban climate adaptation*, *climate-resilient cities*, *urban resilience*, *climate vulnerability*, *adaptive capacity*, and *developing cities*. The second focused on geospatial intelligence and spatial decision support, including terms such as *GIS*, *remote sensing*, *Earth Observation*, *geospatial decision support*, *spatial modelling*, *WebGIS*, *climate-risk mapping*, and *geospatial intelligence*.

A third search domain examined land-use and environmental transformation, using terms including *land-use/land-cover change*, *urban expansion*, *impervious surfaces*, *vegetation dynamics*, *NDVI*, *land surface temperature*, *wetland degradation*, and *ecosystem change*. A fourth domain addressed urban heat and flood risk, with combinations such as *urban heat island*, *heat vulnerability*, *thermal hotspots*, *urban flooding*, *pluvial flooding*, *flood susceptibility*, *drainage vulnerability*, *compound risk*, and *multi-hazard assessment*. A fifth domain focused on social vulnerability, equity, and climate justice, using terms related to *exposure*, *sensitivity*, *adaptive capacity*, *informal settlements*, *social vulnerability mapping*, *climate justice*, and *spatial inequality*. The final domain covered adaptation implementation and governance, including *Nature-Based Solutions*, *ecosystem-based adaptation*, *resilient infrastructure*, *adaptive governance*, *stakeholder participation*, *adaptation prioritisation*, *monitoring and evaluation*, *institutional learning*, and *climate decision support*.

Search concepts were combined iteratively to identify literature at the intersections of these domains. Particular emphasis was placed on studies linking more than one analytical dimension—for example, land-use change with heat or flood risk; geospatial analysis with vulnerability assessment; multi-hazard diagnostics with adaptation planning; or monitoring with adaptive governance. This intersectional strategy was essential because the central methodological purpose of the paper was not simply to catalogue isolated approaches, but to identify the relationships required for an integrated decision-support framework .

Evidence Selection and Eligibility

Evidence was selected on the basis of relevance, conceptual contribution, methodological applicability, source credibility, and transferability to urban climate adaptation. Eligible sources were those that made a substantive contribution to at least one component of the analytical framework , including climate and environmental observation, geospatial indicator generation, urban heat or flood assessment, multi-hazard analysis, vulnerability assessment, adaptation prioritisation, implementation, governance, participation, monitoring, or adaptive learning. Priority was given to peer-reviewed studies and authoritative institutional publications with clear analytical, methodological, policy, or planning relevance.

Sources were also considered eligible where they provided transferable insights from different geographical contexts, including both developed and developing cities. Comparative evidence was not treated as universally applicable; rather, it was examined for principles that could be adapted to rapidly urbanising and resource-constrained settings. Particular interpretive weight was therefore given to studies addressing data limitations, informal urbanisation, infrastructure deficits, weak institutional coordination, socio-economic inequality, and constrained municipal capacity.

Evidence was excluded from substantive synthesis where it was only tangentially related to urban climate adaptation, focused exclusively on climate mitigation without adaptation relevance, treated hazards without a meaningful connection to urban systems or planning, or lacked sufficient conceptual or methodological clarity. Purely descriptive mapping studies were considered of limited value unless they contributed to the broader progression from environmental observation to risk diagnosis, vulnerability interpretation, intervention targeting, or decision support. Duplicate conceptual arguments were consolidated during synthesis to reduce overrepresentation of frequently repeated themes. Selection was therefore guided by conceptual saturation and analytical relevance rather than by the accumulation of the largest possible number of publications.

Analytical Synthesis and Framework Construction

The selected evidence was synthesised through a thematic and relational analytical process. First, evidence was grouped into major conceptual and operational categories: climate and environmental observation; geospatial processing and indicator generation; land-use and ecosystem dynamics; heat and flood diagnostics; exposure and vulnerability; adaptation options; governance and participation; implementation; and monitoring and learning. Second, relationships among these categories were examined to identify recurring causal pathways, methodological complementarities, and institutional disconnects. Particular attention was given to points at which existing approaches appeared fragmented—for example, where hazard mapping was disconnected from social vulnerability, vulnerability assessment from intervention prioritisation, adaptation planning from implementation responsibility, or monitoring from subsequent decision revision.

Third, the synthesis examined the shared drivers of urban heat and flood vulnerability, including impervious-surface expansion, vegetation loss, wetland degradation, hydrological alteration, infrastructure deficits, and uneven adaptive capacity. This relational interpretation provided the basis for treating climate risk as a multi-hazard and socially differentiated planning problem rather than as a collection of isolated environmental threats. Fourth, evidence on adaptation practice was analysed to identify complementary intervention families, including Nature-Based Solutions, resilient infrastructure, climate-sensitive land-use planning, digital decision support, early warning, community participation, and adaptive governance.

The GUCAR-DSF was constructed from this synthesis through progressive integration of these analytical categories into an iterative evidence-to-action framework . The resulting framework comprises eight interconnected components: (1) climate and environmental observation; (2) geospatial intelligence and indicator generation; (3) multi-hazard diagnostics; (4) vulnerability and adaptive-capacity assessment; (5) adaptation option appraisal and prioritisation; (6) governance, participation, and implementation; (7) monitoring, evaluation, and adaptive learning; and (8) decision-support communication and scaling. These components were organised not as a rigid linear sequence but as a feedback-driven cycle in which monitoring outcomes, stakeholder experience, institutional learning, and new environmental observations can revise subsequent diagnosis and adaptation priorities.

Accordingly, the framework represents a conceptually derived and analytically integrated planning framework , rather than an empirically validated predictive model. Its contribution lies in making explicit the relationships among data acquisition, geospatial analysis, risk interpretation, socially differentiated vulnerability, intervention choice, implementation, and adaptive learning. The framework therefore requires future testing, calibration, and refinement through application in specific urban contexts, including comparative pilot studies capable of assessing its operational feasibility, institutional requirements, sensitivity to data quality, and transferability across different climatic and governance settings.

The synthesis therefore examined not only how climate risks are observed and mapped, but also how vulnerability is differentiated, adaptation options are prioritised, governance arrangements influence implementation, and monitoring outcomes inform subsequent decisions. Table 1 summarises the principal evidence domains, analytical questions, and contributions through which the interdisciplinary synthesis informed framework development.

Table 1. Methodological Components, Knowledge Inputs and Contributions

Methodological component	Knowledge inputs	Purpose	Typical content/variables	Contribution to the framework
1. Conceptual and interdisciplinary synthesis	Climate science, urban planning, environmental management, geography, governance, disaster risk reduction (DRR), and sustainable development	Build a broad conceptual foundation	Adaptation concepts, resilience, vulnerability, and planning perspectives	Ensures an integrative understanding of urban climate adaptation
2. Structured integrative evidence synthesis	Peer-reviewed journal articles and authoritative reports	Identify consistent themes and current evidence	Climate risks, adaptation strategies, and resilience pathways	Grounds the chapter in contemporary scholarship
3. Policy and institutional review	IPCC, UN-Habitat, World Bank, OECD, and United Nations reports	Capture governance and policy dimensions	Adaptation governance, planning frameworks, and institutional capacity	Links scientific knowledge to policy and planning practice
4. Geospatial planning perspective	GIS, remote sensing, Earth observation, and climate datasets	Support spatial understanding of climate exposure	LULC change, NDVI, LST, rainfall variability, and flood susceptibility	Provides evidence for vulnerability mapping and adaptation prioritisation
5. Comparative analysis	Selected urban case examples from developed and developing countries	Extract transferable principles and lessons	Adaptation practices, planning innovations, ecosystem-based interventions, and digital tools	Broadens applicability to cities of the Global South
6. Framework development	Synthesised evidence from all preceding components	Produce a unified planning model	Climate observation, geospatial analysis, vulnerability assessment, adaptation prioritisation, governance, and monitoring	Yields a flexible decision-support framework

Source: Compiled by the author from IPCC (2023); UN-Habitat (2024); World Bank (2023); OECD (2023); ESA (2024); NASA (2024).

Table 1 shows that framework development involved the integration of complementary knowledge domains rather than the adoption of any single established model. The methodological significance of this approach lies in identifying functional connections among observation, analysis, vulnerability assessment, decision-making, governance, implementation, and adaptive learning. These connections subsequently provide the basis for the framework developed in Section 7.

The Gucar-Dsf Evidence-To-Action Framework

Contemporary urban climate adaptation benefits from increasingly sophisticated methods for hazard assessment, vulnerability analysis, spatial planning, and resilience governance. However, these approaches are frequently developed and applied as separate analytical or institutional exercises. The central limitation is therefore not the absence of knowledge or technology, but the weak integration of existing capabilities into a continuous decision process. Hazard maps may identify where climatic threats are concentrated, vulnerability assessments may reveal who is most at risk, adaptation plans may propose interventions, governance systems may assign institutional responsibilities, and monitoring mechanisms may track selected outcomes. Yet these functions are often disconnected in practice. The result is a fragmented adaptation landscape in which evidence is generated without being consistently translated into prioritised, implementable, and revisable action.

Hazard mapping illustrates this limitation clearly. Advances in remote sensing, Geographic Information Systems, Earth Observation, and spatial modelling have greatly improved the capacity to map urban heat, flood susceptibility, drought exposure, land degradation, and related environmental pressures (Goodchild, 2020; Longley et al., 2021; Tamiminia et al., 2020). These outputs are valuable because they reveal spatial patterns that conventional statistics or citywide averages may conceal. However, hazard maps commonly remain descriptive. They show where risk-related conditions occur but do not necessarily explain which populations are least able to cope, which interventions are most appropriate, how scarce resources should be allocated, or how institutional responsibilities should be organised. A technically accurate heat or flood map is therefore not equivalent to an adaptation decision.

Vulnerability assessment addresses part of this gap by incorporating exposure, sensitivity, and adaptive capacity. Such analyses can reveal how poverty, age, housing quality, infrastructure access, health conditions, informality, and service deficits shape differentiated climate impacts. This is especially important because comparable hazard intensity can produce very different consequences across neighbourhoods (Meerow et al., 2016; IPCC, 2023). Nevertheless, vulnerability studies are often conducted independently of operational planning. Composite vulnerability indices may identify priority populations but remain disconnected from land-use regulation, infrastructure budgeting, emergency preparedness, or project implementation. In addition, different weighting methods and indicator choices can produce divergent results, making transparency and validation essential.

Adaptation planning constitutes another partially disconnected domain. Urban resilience strategies increasingly promote Nature-Based Solutions, resilient infrastructure, heat action plans, early warning systems, sustainable drainage, ecosystem restoration, settlement upgrading, and climate-sensitive zoning. Yet intervention lists are often prepared without a sufficiently explicit spatial logic for deciding where particular measures should be located, combined, sequenced, or monitored. This can lead to generic adaptation portfolios that acknowledge climate risk but do not fully connect proposed actions with specific hazard patterns, vulnerable groups, ecosystem conditions, or infrastructure deficits. Tyler and Moench (2012) emphasise that urban climate resilience requires flexible systems and capacities rather than isolated projects, yet implementation frequently remains programme-specific and sectoral.

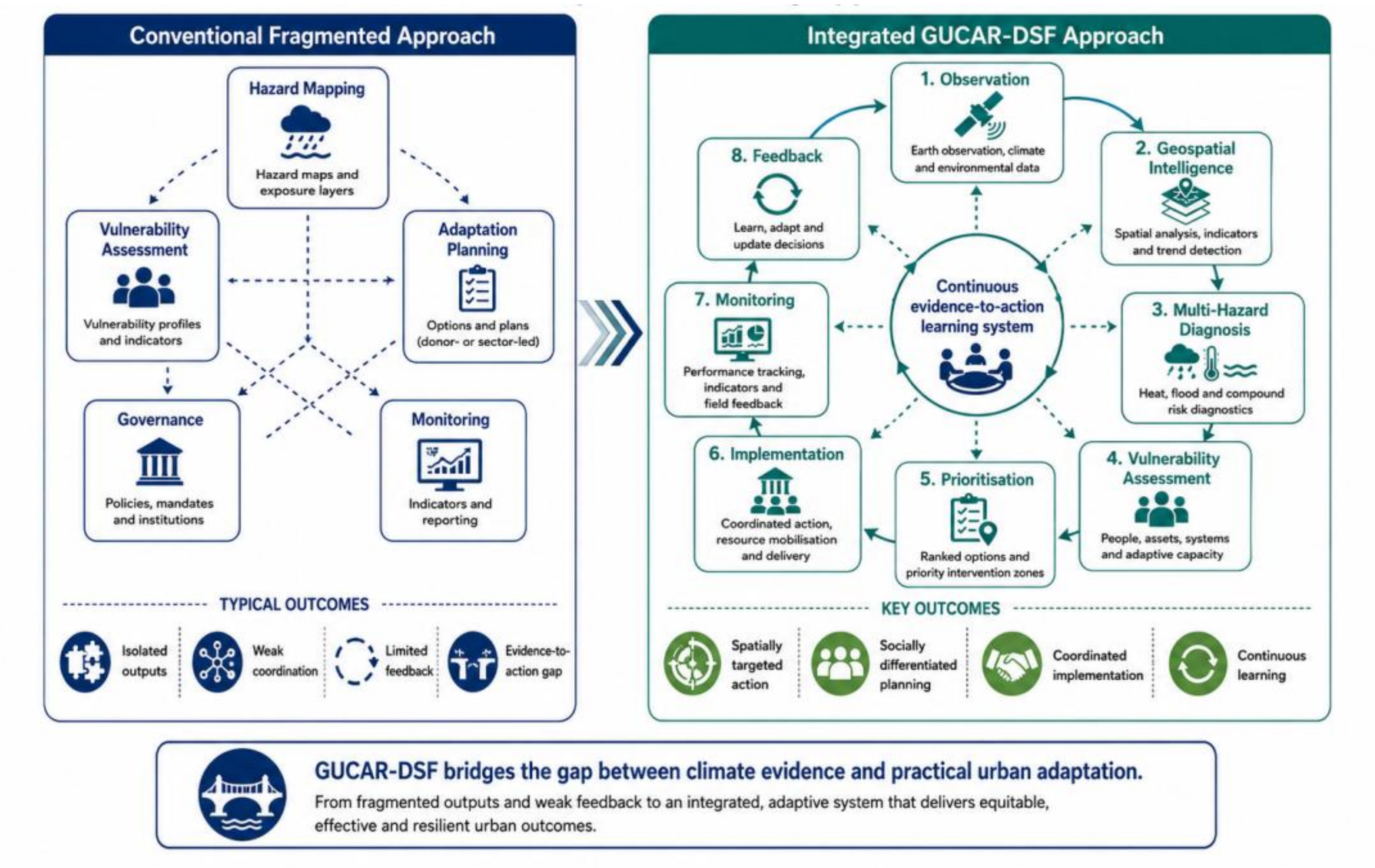
Governance fragmentation further constrains integration. Urban climate risk crosses the mandates of planning authorities, environmental agencies, disaster-management institutions, water utilities, health departments, infrastructure providers, meteorological services, and local communities. Adaptive governance scholarship stresses the importance of collaboration, participation, learning, and cross-scale coordination in addressing complex environmental problems (Folke et al., 2005). In practice, however, institutions often operate with different datasets, mandates, budgets, and planning horizons. One agency may produce flood information, another regulate land use, another maintain drainage, and another manage emergencies, without a shared decision framework linking these functions. As a result, technically sound recommendations may be delayed, duplicated, or implemented inconsistently.

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue VI June 2026

Monitoring and evaluation are equally problematic. Many adaptation initiatives are assessed primarily through project-completion indicators, such as the number of drains constructed, trees planted, or plans prepared. These indicators may be useful for accountability but do not necessarily reveal whether climate vulnerability has actually declined. Long-term monitoring of thermal conditions, flood frequency, ecosystem recovery, service continuity, or changes in adaptive capacity is often weak. Even where monitoring data exist, they may not feed back into future planning. This creates a linear model in which assessment is followed by intervention, but implementation experience does not systematically revise hazard analysis, vulnerability assumptions, or investment priorities.

The combined effect of these limitations is an evidence-to-action gap. Existing approaches often generate valuable but isolated outputs: hazard maps without social prioritisation, vulnerability indices without implementation pathways, adaptation plans without spatial targeting, governance arrangements without shared analytical systems, and monitoring processes without feedback. The problem is therefore one of connection rather than complete absence. Each domain contributes essential knowledge, but their separation limits the capacity of cities to respond to dynamic, compound, and socially differentiated climate risks. The limitations discussed above arise not because existing hazard, vulnerability, adaptation, governance, and monitoring approaches lack value, but because they are frequently applied through weakly connected analytical and institutional arrangements. Figure 2 contrasts this fragmented configuration with the integrated logic proposed by the GUCAR-DSF, highlighting the transition from isolated outputs and limited feedback towards a continuous evidence-to-action system.

Figure 2. Positioning of GUCAR-DSF Relative to Conventional Hazard-Mapping and Adaptation-Planning Approaches



Source: Original GUCAR-DSF conceptualisation by Tijjani Garba (2026), informed by relevant literature on urban resilience, adaptive governance, geospatial decision support, and climate adaptation.

As illustrated in Figure 2, the distinctive contribution of GUCAR-DSF lies in connecting functions that are commonly treated as separate. Hazard information, vulnerability analysis, adaptation prioritisation, implementation, monitoring, and feedback are organised within a continuous decision process, thereby reducing the risk that technically robust evidence remains disconnected from practical urban action.

This fragmentation is especially consequential in developing cities, where financial resources are constrained and adaptation investments must achieve multiple benefits. Under such conditions, poorly coordinated interventions can duplicate effort, overlook vulnerable communities, or shift risk from one location to another. A drainage project may reduce flooding locally while increasing downstream runoff; a greening initiative may improve thermal conditions but fail if maintenance capacity is weak; or a technically advanced warning system may have limited effect if vulnerable groups are excluded from communication channels. These examples demonstrate that adaptation effectiveness depends on interactions among evidence, institutions, implementation, and learning.

The need for the Geospatial Urban Climate Adaptation and Resilience Decision-Support Framework (GUCAR-DSF) arises directly from this fragmentation. GUCAR-DSF is designed to connect functions that are commonly separated by linking climate and environmental observation, geospatial intelligence, multi-hazard diagnostics, vulnerability and adaptive-capacity assessment, adaptation option appraisal, governance and implementation, monitoring, and iterative feedback within a single framework . Its purpose is not to replace hazard mapping, vulnerability assessment, adaptation planning, or governance systems, but to organise their relationships so that outputs from one stage become usable inputs for the next.

The framework therefore shifts attention from isolated analytical products to a continuous decision process. Hazard evidence identifies where pressures are concentrated; vulnerability analysis reveals who and what are most at risk; adaptation appraisal matches interventions to spatial and social conditions; governance arrangements translate priorities into action; and monitoring results feed back into subsequent observation and reassessment. In this way, GUCAR-DSF addresses the core weakness of existing approaches by establishing an integrated evidence-to-action pathway for climate-resilient urban planning.

The development of the GUCAR-DSF required the integration of evidence from multiple disciplinary and applied domains that are often treated independently in urban climate research.

Table 2. Comparative Positioning of Existing Urban Climate Adaptation Approaches and GUCAR-DSF

Existing approach	**Main contribution**	**Common limitation**	**GUCAR-DSF advancement**
Hazard mapping	Identifies spatial hazard zones	Often weak on social vulnerability	Integrates hazard with exposure, sensitivity and adaptive capacity
Vulnerability assessment	Identifies vulnerable groups and places	Often weak on implementation	Links vulnerability to adaptation appraisal and prioritisation
Adaptation planning	Lists interventions	Often lacks spatial targeting	Matches interventions to risk hotspots and local conditions
Adaptive governance	Supports coordination and learning	Often weak on spatial analytics	Connects governance to geospatial evidence and monitoring
Monitoring and evaluation	Tracks project outputs	Often weak on feedback	Reintegrates monitoring into renewed observation and prioritisation
GUCAR-DSF	Connects evidence, action and learning	Requires empirical validation	Provides integrated evidence-to-action framework

The Gucar-Dsf Framework

The Geospatial Urban Climate Adaptation and Resilience Decision-Support Framework (GUCAR-DSF) is proposed as an integrated framework for translating climate and environmental evidence into prioritised, implementable, and continuously improving urban adaptation decisions. It responds to the fragmentation of existing approaches in which hazard mapping, vulnerability assessment, adaptation planning, governance, implementation, and monitoring often operate as separate analytical or institutional domains. The framework does not replace these approaches; rather, it organises them within a connected decision process where evidence generated at one stage informs subsequent analysis, planning, implementation, monitoring, and learning.

The central proposition of GUCAR-DSF is that climate-resilient urban planning requires a continuous relationship among observation, analysis, diagnosis, prioritisation, action, monitoring, and revision. Urban climate risk is dynamic because climatic conditions, land-use patterns, ecosystem states, infrastructure systems, population distribution, and institutional capacities change over time. A one-time risk assessment may quickly become outdated as cities expand, new vulnerabilities emerge, or interventions alter environmental and social conditions. GUCAR-DSF addresses this challenge through eight interconnected components: climate and environmental observation; geospatial intelligence and indicator generation; multi-hazard diagnostics; vulnerability and adaptive-capacity assessment; adaptation option appraisal and prioritisation; governance, participation and implementation; monitoring, evaluation and adaptive learning; and decision-support communication and scaling. Although presented sequentially, these components are not linear. Feedback occurs across stages, making the framework a recursive decision-support system.

Climate and Environmental Observation

The first component establishes the empirical foundation of the framework through systematic observation of climatic, environmental, hydrological, ecological, and urban conditions. Relevant inputs include satellite imagery, meteorological records, rainfall and temperature data, climate reanalysis products, Digital Elevation Models, land-use data, soil moisture, surface-water information, infrastructure records, and community-based observations. The purpose is to establish baselines, detect trends, identify anomalies, and monitor emerging pressures such as built-up expansion, vegetation decline, wetland encroachment, increasing thermal stress, or recurrent flood patterns. Observation is therefore continuous rather than preliminary, supporting periodic reassessment of risks and interventions in line with resilience thinking, which emphasises learning and adjustment under uncertainty (Meerow et al., 2016; Tyler & Moench, 2012).

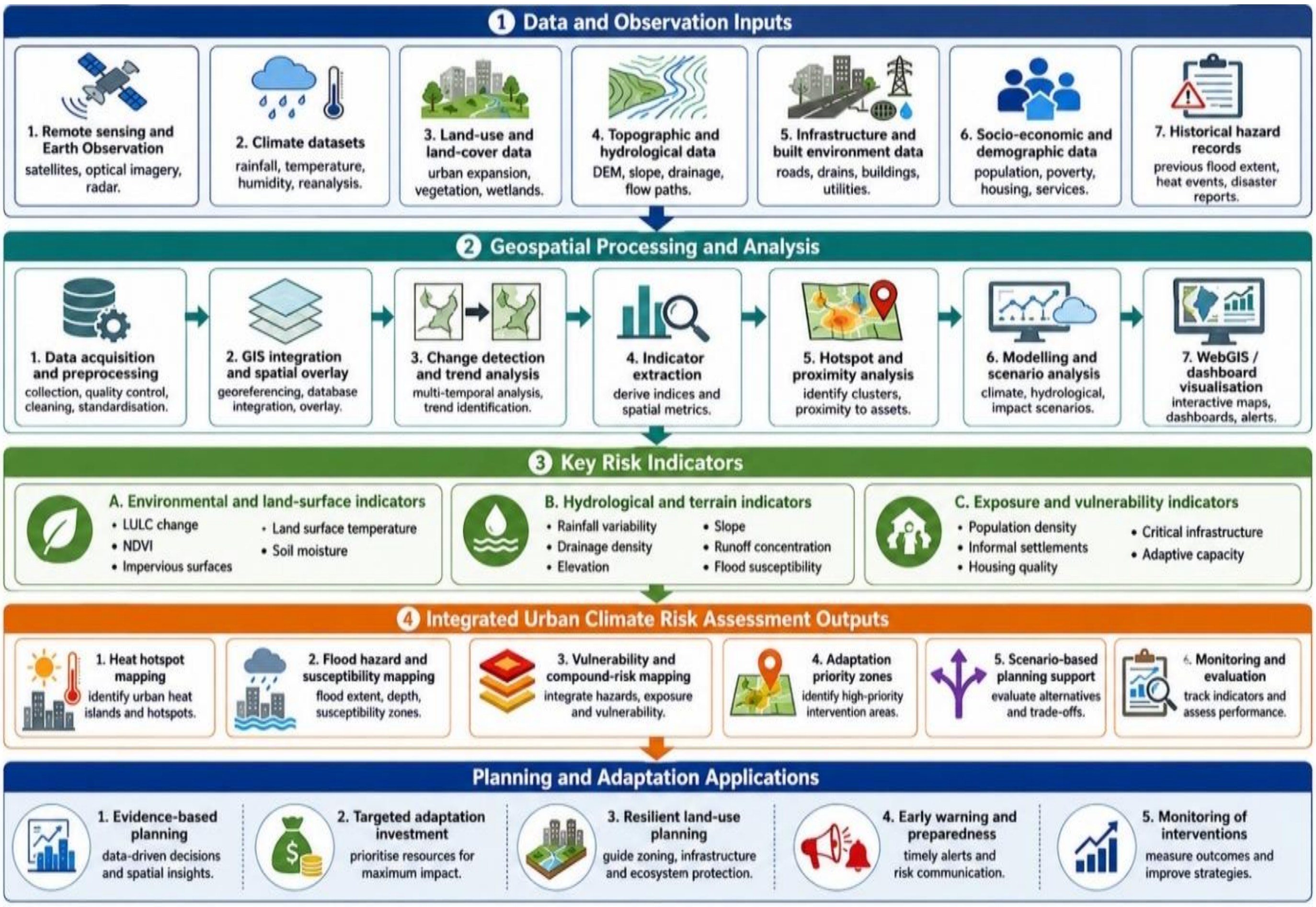
Geospatial Intelligence and Indicator Generation

The second component transforms diverse observations into spatially interpretable indicators. Geospatial intelligence forms the analytical backbone of GUCAR-DSF because climate risk is spatially uneven and cannot be adequately understood through citywide averages alone. Remote sensing, Geographic Information Systems, Earth Observation, spatial modelling, and related methods enable environmental and social data to be integrated within a common spatial framework (Goodchild, 2020; Longley et al., 2021). Relevant indicators include land-use/land-cover change, NDVI, built-up indices, land surface temperature, impervious-surface concentration, rainfall variability, elevation, slope, drainage density, flood extent, infrastructure accessibility, population density, and settlement characteristics.

By combining these indicators, geospatial intelligence reveals how urban development, ecosystem change, and climatic pressures shape risk. Declining vegetation, increasing built-up density, and rising land surface temperature may indicate emerging thermal vulnerability, while low elevation, high imperviousness, poor drainage, and recurrent inundation may indicate flood susceptibility. Thus, geospatial intelligence converts fragmented datasets into decision-relevant spatial evidence.

Their planning value increases when these capabilities are integrated within a coherent workflow that transforms raw observations into indicators, diagnostic products, vulnerability information, and decision-relevant outputs. Figure 3. presents this progression from multi-source environmental data to spatially explicit adaptation intelligence.

Figure 3. Integrated Geospatial Intelligence Framework for Urban Climate Risk Assessment



Source: Author's conceptualisation, informed by IPCC (2023); Goodchild (2020); Longley et al. (2021); Tamiminia et al. (2020).

As shown in Figure 3, geospatial intelligence functions as a translation mechanism between environmental observation and planning action. Satellite imagery, climate records, terrain information, infrastructure data, and socio-economic evidence are processed through change detection, spatial modelling, indicator generation, overlay analysis, hotspot identification, and scenario assessment. The resulting products help identify where risks are emerging, which populations and systems are most vulnerable, and where adaptation interventions should be prioritised.

Multi-Hazard Diagnostics

The third component assesses the spatial distribution and interaction of climatic and environmental hazards. Instead of examining heat, flooding, drought, or ecosystem degradation separately, GUCAR-DSF adopts a multi-hazard perspective because urban risks may overlap, interact, or share common drivers. For example, impervious-surface expansion may intensify heat storage while reducing infiltration and accelerating runoff. Vegetation loss may reduce both evaporative cooling and rainfall interception, while wetland degradation may remove flood-storage capacity and weaken ecological regulation. Multi-hazard diagnostics therefore identify areas of convergence and compound vulnerability, producing outputs such as heat-risk maps, flood-susceptibility maps, compound-risk surfaces, hotspot zones, and scenario outputs. This supports anticipatory planning by showing how future urban expansion, vegetation loss, rainfall change, or infrastructure development may alter risk patterns.

Vulnerability and Adaptive-Capacity Assessment

The fourth component integrates hazard information with exposure, sensitivity, and adaptive capacity. Hazard intensity alone does not determine climate impact; similar levels of heat or flooding may produce different consequences depending on population characteristics, housing quality, income, infrastructure, service access, health conditions, and institutional support. Potential indicators include population density, poverty, age structure, informal settlement distribution, housing quality, access to health services, green-space availability, mobility constraints, critical infrastructure, livelihood dependence, and institutional capacity. This component strengthens the equity orientation of the framework by identifying not only where hazards occur, but where their consequences are likely to be most severe. Participatory knowledge can further improve interpretation by revealing local flood pathways, heat-stress locations, drainage failures, and social constraints not captured in formal datasets.

Adaptation Appraisal, Governance and Implementation

The fifth and sixth components connect diagnosis to action. Adaptation appraisal translates spatial evidence into intervention choices such as urban greening, wetland restoration, sustainable drainage, infrastructure upgrading, land-use zoning, early warning systems, settlement upgrading, social protection, and public-health measures. Appraisal considers expected risk reduction, feasibility, cost, co-benefits, equity, institutional responsibility, maintenance requirements, and stakeholder acceptance. Prioritisation is spatially explicit, ensuring that interventions are matched to local conditions rather than applied generically.

Implementation then depends on governance, finance, legal authority, coordination, participation, and long-term maintenance. Relevant actors may include planning authorities, environmental agencies, disaster-management institutions, water utilities, health departments, infrastructure providers, universities, civil society organisations, private-sector actors, and local communities. Adaptive governance is essential because complex environmental challenges require collaboration, learning, participation, and institutional adjustment (Folke et al., 2005). Community participation should inform problem definition, indicator interpretation, intervention design, and monitoring.

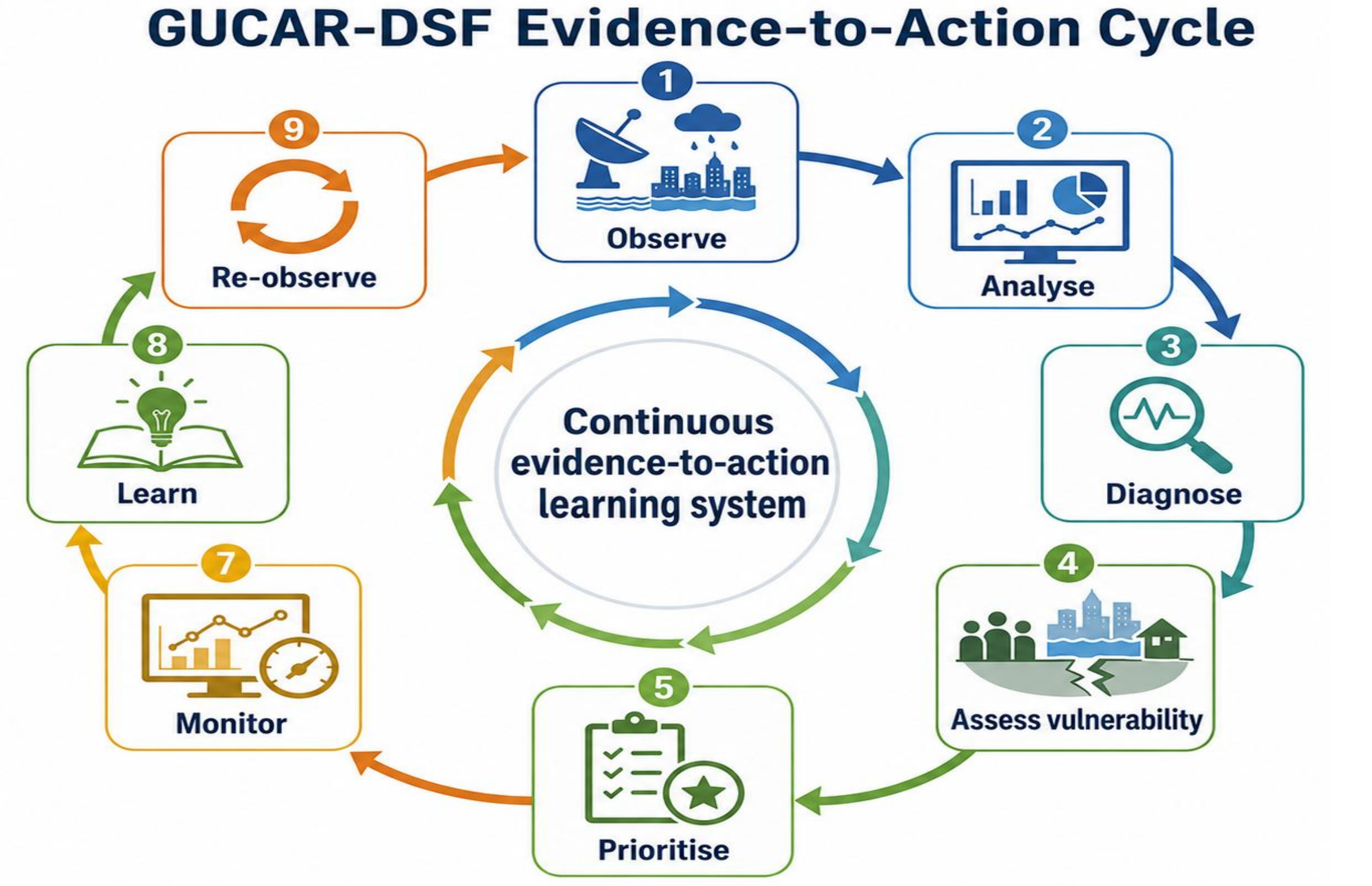
Monitoring, Learning, Communication and Scaling

The final components provide the feedback and communication mechanisms of GUCAR-DSF. Monitoring determines whether interventions have reduced risk, reached intended populations, and avoided unintended consequences. Evidence may include updated satellite imagery, environmental measurements, flood records, thermal indicators, ecosystem condition, infrastructure performance, project data, and community feedback. Results then feed back into earlier stages, supporting indicator revision, new observation, revised prioritisation, institutional adjustment, or scaling of successful interventions.

Decision-support communication translates analytical and implementation evidence into usable formats such as dashboards, WebGIS platforms, risk maps, scenario tools, planning briefs, investment priorities, policy guidance, and open-data platforms. The framework can operate at neighbourhood, municipal, metropolitan, and regional scales, depending on data availability and institutional capacity. Taken together, the eight components establish GUCAR-DSF as an integrated evidence-to-action framework . Its originality lies not in claiming that each component is entirely new, but in connecting them within a unified, iterative, and feedback-oriented framework for climate-resilient urban planning.

Evidence-to-Action and Adaptive Feedback Logic

The defining feature of the Geospatial Urban Climate Adaptation and Resilience Decision-Support Framework (GUCAR-DSF) is its emphasis on a continuous evidence-to-action process rather than a one-directional sequence from assessment to intervention. Urban climate adaptation frequently follows a linear pattern in which data are collected, hazards are mapped, plans are prepared, and projects are implemented with limited systematic reassessment. Such an approach is increasingly inadequate because climate conditions, land-use patterns, infrastructure systems, ecosystem states, and social vulnerabilities change over time. GUCAR-DSF therefore adopts an iterative logic in which evidence informs action, implementation generates new information, and monitoring results reshape subsequent observation, analysis, and prioritisation.



The core cycle can be expressed as:

This sequence provides the organising logic of the framework, but it should not be interpreted as a rigid chain. Each stage may generate information that alters earlier assumptions or requires additional analysis. The framework therefore combines sequential progression with feedback, allowing decision-making to adjust as knowledge and conditions evolve.

The cycle begins with observation, through which climate, environmental, land-use, infrastructural, and social conditions are documented. Satellite imagery, climate records, Earth Observation products, local monitoring, infrastructure inventories, and community knowledge provide the empirical basis for identifying changes and emerging pressures. The importance of this stage lies not only in describing current conditions but also in establishing baselines against which future change can be assessed. In rapidly urbanising environments, repeated observation may reveal expanding impervious surfaces, vegetation decline, wetland encroachment, recurrent inundation, or intensifying thermal hotspots. Such evidence provides the foundation for subsequent analysis.

The second stage is analysis, in which raw observations are transformed into interpretable indicators and spatial intelligence. Remote sensing, Geographic Information Systems, spatial modelling, and related techniques can generate indicators of land-use change, vegetation condition, land surface temperature, rainfall variability, terrain, drainage, imperviousness, infrastructure accessibility, and settlement patterns (Goodchild, 2020; Longley et al., 2021). The purpose is to identify spatial relationships that may not be visible in isolated datasets. Analysis therefore moves the framework from data accumulation towards explanation.

The third stage, diagnosis, assesses the distribution and interaction of climate-related hazards. Rather than treating heat, flooding, ecosystem degradation, or infrastructure stress as entirely separate problems, GUCAR-DSF examines where hazards overlap, share common drivers, or generate cascading effects. A neighbourhood characterised by low vegetation, high land surface temperature, extensive imperviousness, inadequate drainage, and recurrent inundation may represent a compound-risk hotspot. Diagnosis therefore seeks to answer not only where hazards occur but also how they interact and which underlying processes sustain them.

The fourth stage is vulnerability and adaptive-capacity assessment. Hazard evidence is interpreted in relation to exposure, sensitivity, and the capacity of populations and institutions to respond. This is essential because high hazard intensity does not automatically translate into the highest social risk. Housing quality, poverty, age structure, service access, health conditions, mobility constraints, infrastructure reliability, and institutional support can substantially alter outcomes. The framework therefore incorporates differentiated vulnerability and recognises that climate risk is socially and spatially uneven (Meerow et al., 2016; IPCC, 2023).

The fifth stage is adaptation prioritisation, where analytical evidence is translated into intervention choices. This is the critical point at which the framework moves from understanding risk to deciding what should be done, where, and for whom. Potential measures may include Nature-Based Solutions, sustainable drainage, urban greening, infrastructure upgrading, land-use regulation, heat-action planning, early warning systems, settlement upgrading, and targeted social support. Prioritisation considers spatial need, expected risk reduction, feasibility, cost, co-benefits, equity, institutional responsibility, and stakeholder preferences. The objective is not merely to rank projects, but to match interventions with the specific environmental and social conditions of different locations.

The sixth stage is implementation, where prioritised options are translated into programmes, investments, regulations, and coordinated institutional action. At this point, governance becomes central. Responsibilities must be assigned, finance mobilised, stakeholders engaged, timelines defined, and maintenance arrangements established. Adaptive governance scholarship emphasises that complex environmental challenges require collaboration, participation, and learning rather than rigid sectoral action (Folke et al., 2005; Tyler & Moench, 2012). GUCAR-DSF therefore treats implementation as an institutional process rather than the automatic consequence of technical analysis.

The seventh stage is monitoring, through which the actual effects of interventions are assessed. Monitoring may combine updated satellite observations, environmental indicators, infrastructure records, project data, and community feedback. The central question is whether vulnerability has genuinely declined. For example, a completed drainage project should not be evaluated only by whether construction has finished, but by whether recurrent inundation has decreased. Likewise, urban greening should be assessed not solely by the number of trees planted, but by survival, canopy development, thermal effect, spatial distribution, and benefits to vulnerable populations.

The eighth stage is learning, where monitoring results are interpreted and fed back into the framework. Successful interventions may be expanded or adapted to other locations. Poorly performing measures may require redesign. Emerging risks may alter priorities. Community experience may reveal previously overlooked constraints. This stage is fundamental because adaptation unfolds under uncertainty and cannot depend on the assumption that initial decisions will remain optimal indefinitely. Resilience thinking therefore emphasises the ability to learn, adjust, and where necessary transform in response to changing conditions (Meerow et al., 2016).

The adaptive feedback mechanism distinguishes GUCAR-DSF from static planning approaches. Monitoring can trigger renewed observation; new observations can require revised indicators; changing vulnerability can modify intervention priorities; and implementation experience can reshape governance arrangements. Feedback may therefore occur across multiple stages rather than only at the end of the cycle. This creates a recursive system in which urban climate planning is continually updated.

Such logic is particularly important in developing cities, where data gaps, institutional limitations, financial constraints, and rapid urban change make perfect information impossible. Rather than delaying action until complete knowledge is available, GUCAR-DSF supports phased decisions that can be revised as new evidence emerges. This creates an approach that is simultaneously evidence-based and adaptive.

The broader significance of the evidence-to-action cycle lies in its ability to bridge the persistent gap between technical knowledge and practical planning. Geospatial evidence identifies changing conditions; diagnosis reveals interacting risks; vulnerability assessment identifies unequal burdens; prioritisation converts knowledge into choices; implementation mobilises institutions; monitoring evaluates outcomes; and learning updates future decisions. The framework therefore treats adaptation not as a finished plan but as a continuously evolving process of informed action and institutional learning.

Application to Climate-Resilient Urban Planning

The practical relevance of the Geospatial Urban Climate Adaptation and Resilience Decision-Support Framework (GUCAR-DSF) lies in its capacity to connect spatial evidence with concrete urban planning decisions. Climate-resilient planning requires more than identifying areas exposed to hazards; it requires understanding how environmental change, land-use dynamics, infrastructure, social vulnerability, and institutional capacity interact, and then translating that understanding into targeted interventions. GUCAR-DSF provides a structured pathway for this translation by linking observation, geospatial analysis, multi-hazard diagnostics, vulnerability assessment, adaptation prioritisation, implementation, monitoring, and learning.

One important area of application is urban heat adaptation. Rapid expansion of built-up areas, declining vegetation, dense development, and increasing imperviousness can intensify local thermal stress. Through the integration of land surface temperature, vegetation indices, built-up indicators, population density, housing characteristics, and access to services, GUCAR-DSF can identify neighbourhoods where environmental exposure and social vulnerability converge. This allows planners to move beyond citywide heat averages towards spatially differentiated intervention. Priority responses may include urban tree-canopy expansion, cooling corridors, shaded public spaces, reflective materials, heat-sensitive building design, public-health preparedness, and targeted support for highly exposed populations. The framework can also monitor whether interventions produce measurable changes in vegetation cover, thermal conditions, or access to cooling benefits.

A second major application concerns urban flooding and stormwater management. Flood vulnerability is shaped by the interaction of rainfall, topography, impervious surfaces, drainage capacity, land-use change, settlement location, and infrastructure condition. GUCAR-DSF can integrate these variables to identify low-lying zones, runoff concentration areas, recurrent inundation pathways, drainage deficits, and populations with limited recovery capacity. This supports more strategic decisions about sustainable drainage, retention and detention systems, wetland protection, floodplain management, drainage upgrading, land-use control, and early warning. Rather than treating flooding solely as an engineering problem, the framework encourages the combination of infrastructural, ecological, regulatory, and social measures.

The framework is particularly useful for analysing the heat–flood nexus because both hazards may be intensified by common development processes. Expansion of impervious surfaces increases heat storage while reducing infiltration, and vegetation loss weakens both evaporative cooling and rainfall interception. In such settings, single-purpose interventions may be inefficient. GUCAR-DSF can identify compound-risk hotspots and support multi-benefit responses such as blue-green infrastructure, urban forests, permeable landscapes, wetland restoration, and integrated neighbourhood upgrading. The objective is to select adaptation portfolios capable of addressing interacting risks rather than treating each hazard independently.

A further application lies in risk-informed land-use planning. Urban development decisions can lock vulnerability into the built environment for decades. Expansion into wetlands, floodplains, riparian corridors, steep terrain, or environmentally sensitive areas may increase long-term exposure while degrading natural resilience functions. Through scenario analysis and change detection, GUCAR-DSF can reveal where urban growth is occurring, where ecological buffers are being lost, and how alternative development pathways may influence future risk. This evidence can support zoning, development control, conservation planning, strategic densification, infrastructure sequencing, and the identification of areas where expansion should be restricted or redirected.

The framework can also strengthen the planning of Nature-Based Solutions and ecosystem restoration. Urban forests, wetlands, riparian buffers, green corridors, bioswales, and permeable surfaces can provide cooling, stormwater retention, biodiversity, and public-space benefits. However, their effectiveness depends on location, ecological suitability, maintenance, and connectivity. GUCAR-DSF can help identify where ecosystem-based interventions are likely to generate the greatest resilience value by integrating heat exposure, flood susceptibility, vegetation deficits, ecosystem condition, population density, and social vulnerability. This supports more strategic placement of Nature-Based Solutions and reduces the risk of symbolic or poorly targeted greening.

Another important area is informal settlements and socially differentiated vulnerability. In many developing cities, high-risk populations live in areas characterised by insecure tenure, inadequate drainage, poor housing quality, limited green space, and restricted access to services. Conventional hazard mapping may identify environmental exposure without fully capturing these social conditions. GUCAR-DSF incorporates vulnerability and adaptive capacity so that planning priorities reflect not only where hazards are severe but also where people have the least capacity to cope. This can support settlement upgrading, targeted infrastructure, emergency access, social protection, health interventions, and participatory adaptation planning.

The framework is also relevant to critical infrastructure and service continuity. Climate hazards can disrupt transport, electricity, water supply, health facilities, schools, communications, and emergency services. By integrating hazard surfaces with infrastructure networks and service dependencies, GUCAR-DSF can identify assets whose failure may generate wider cascading consequences. This supports resilience investment, redundancy planning, maintenance prioritisation, emergency access, and protection of essential services.

At the institutional level, GUCAR-DSF can support investment prioritisation and interagency coordination. Because adaptation resources are often limited, decision-makers need transparent ways to compare locations and intervention options. Spatial evidence can help identify where risk concentration, vulnerability, ecosystem loss, and infrastructure deficits justify urgent investment. The framework can also provide a shared evidence base for planning authorities, environmental agencies, disaster managers, utilities, health institutions, researchers, and communities. Such integration is particularly valuable where responsibilities are fragmented across organisations.

The modular character of GUCAR-DSF makes it relevant to cities with different levels of data availability and institutional capacity. Data-rich metropolitan areas may integrate high-resolution imagery, sensor networks, detailed infrastructure inventories, and advanced modelling. Resource-constrained cities may rely on open satellite data, freely available climate products, participatory mapping, and open-source GIS. The framework therefore does not prescribe a single technological standard. Its value lies in maintaining the logic of evidence-to-action integration even where the sophistication of individual tools differs.

Ultimately, the application of GUCAR-DSF to climate-resilient urban planning is based on a shift from generic adaptation to spatially targeted, socially differentiated, and continuously evaluated action. It helps planners ask not only what climate risks exist, but where they are intensifying, who is most vulnerable, which interventions are most appropriate, how implementation should be coordinated, and whether outcomes are improving over time. In this way, the framework provides a practical basis for linking geospatial intelligence with planning, governance, and adaptive learning.

Transferability, Limitations and Validation Agenda

The Geospatial Urban Climate Adaptation and Resilience Decision-Support Framework (GUCAR-DSF) is designed as a flexible and transferable framework rather than a universally standardised model. Its eight components provide a common decision logic, but their operationalisation should vary according to climatic conditions, urban form, data availability, institutional capacity, socio-economic characteristics, and planning priorities. This flexibility is important because climate risks differ substantially across cities. Coastal settlements may prioritise sea-level rise, storm surge, and drainage failure; dryland cities may focus on extreme heat, drought, water insecurity, and land degradation; while rapidly expanding inland cities may confront compound heat, flooding, infrastructure deficits, and ecosystem loss. The framework therefore maintains a stable evidence-to-action structure while allowing indicators, analytical methods, governance arrangements, and adaptation options to be locally configured.

Transferability is also supported by the modular character of GUCAR-DSF. Cities with advanced data infrastructures may integrate high-resolution satellite imagery, sensor networks, detailed cadastral information, real-time climate observations, and sophisticated scenario modelling. Resource-constrained municipalities may rely on open Landsat and Sentinel data, freely available climate products, participatory mapping, administrative records, and open-source GIS. The framework does not require every component to be technologically complex from the outset. Instead, it allows progressive adoption in which analytical capability can expand as data systems, institutional coordination, and technical expertise improve. This is particularly relevant to developing cities, where adaptation planning often proceeds under conditions of incomplete information.

Despite this potential, several limitations must be acknowledged. First, GUCAR-DSF is presently a conceptual decision-support framework and has not yet been empirically validated through full-scale implementation in a specific city. Its analytical coherence does not automatically demonstrate operational effectiveness. Future application is therefore required to determine whether the framework improves risk identification, intervention targeting, institutional coordination, investment prioritisation, and adaptation outcomes in practice.

Second, the quality of framework outputs depends partly on the quality of underlying data. Satellite imagery, climate datasets, infrastructure inventories, demographic records, and socio-economic indicators may differ in spatial resolution, temporal consistency, completeness, and reliability. Informal settlements and marginalised populations are frequently underrepresented in official databases, while local drainage conditions, infrastructure failures, or recurrent exposure pathways may not be visible in remotely sensed data alone. GUCAR-DSF therefore requires triangulation among geospatial evidence, field observations, institutional records, and participatory knowledge.

Third, methodological uncertainty is unavoidable. Hazard models, vulnerability indices, indicator weighting, Multi-Criteria Decision Analysis, and scenario assumptions can produce different results depending on variable selection, data processing, thresholds, and analytical design. Spatial precision should therefore not be confused with certainty. Transparent documentation, sensitivity analysis, uncertainty communication, stakeholder review, and empirical validation are necessary to prevent decision-support tools from presenting contestable assumptions as objective conclusions.

A fourth limitation concerns institutional and political feasibility. Integrated analysis may identify technically appropriate adaptation priorities, yet implementation can be constrained by fragmented mandates, limited finance, weak enforcement, land-tenure disputes, political interests, or insufficient maintenance capacity. Adaptive governance literature emphasises the importance of coordination, participation, and learning, but these capacities cannot be assumed to exist simply because a framework recommends them (Folke et al., 2005; Tyler & Moench, 2012). GUCAR-DSF must therefore be understood as supporting decision processes rather than eliminating political and institutional constraints.

A further concern relates to the risk of technological overreach. Increasing use of artificial intelligence, machine learning, cloud computing, automated classification, and real-time monitoring may enhance analytical capability, but complex technology can also reduce transparency or create dependence on expertise and infrastructure that local institutions cannot sustain. The framework should therefore favour technological appropriateness, interpretability, affordability, and long-term usability rather than analytical sophistication for its own sake.

The validation agenda for GUCAR-DSF should proceed in stages. The first stage should involve retrospective validation, in which the framework is applied to cities with documented historical heat, flood, land-use, or infrastructure impacts. This would test whether the analytical sequence identifies known hotspots and vulnerable populations. The second stage should involve comparative pilot application across contrasting urban contexts, such as a rapidly growing inland city, a dryland city, and a flood-prone metropolitan area. Comparative testing would help distinguish transferable components from those requiring local adaptation.

A third stage should focus on decision-process validation. This would examine whether GUCAR-DSF improves planning discussions, interagency coordination, transparency, and stakeholder participation compared with conventional approaches. Evaluation should therefore assess not only predictive accuracy but also institutional usability. A fourth stage should involve longitudinal monitoring, testing whether interventions prioritised through the framework produce measurable reductions in exposure or vulnerability over time.

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XIII Issue VI June 2026

Validation should also include explicit comparison with alternative decision-support approaches. The framework has not yet been formally benchmarked against other integrated urban resilience, spatial decision-support, or climate-adaptation models. Future research should therefore compare GUCAR-DSF with existing approaches using common criteria such as analytical integration, transparency, usability, equity, adaptability, implementation relevance, and monitoring capacity. This would provide a stronger basis for determining its distinctive contribution.

Ultimately, the transferability of GUCAR-DSF should not be judged by whether identical indicators or technologies can be reproduced everywhere. Its deeper transferability lies in the decision logic connecting observation, geospatial intelligence, multi-hazard diagnosis, vulnerability, prioritisation, implementation, monitoring, and learning. The framework should therefore evolve through empirical testing, local adaptation, comparative evaluation, and iterative refinement. Such an approach is consistent with the framework's own philosophy: GUCAR-DSF should itself remain adaptive, evidence-responsive, and open to improvement as new knowledge and practical experience emerge.

CONCLUSION

Urban climate adaptation now demands planning approaches capable of responding to risks that are dynamic, spatially uneven, socially differentiated, and mutually reinforcing. Rapid urbanisation, land-use transformation, ecosystem degradation, infrastructure deficits, and social inequality interact with climatic pressures to produce complex patterns of vulnerability that cannot be adequately addressed through isolated hazard mapping, stand-alone vulnerability assessment, or fragmented adaptation projects. The critical challenge is therefore no longer only the production of more climate data, but the creation of decision-support mechanisms that can translate evidence into coordinated, prioritised, equitable, and continuously improving urban action.

This paper has introduced the Geospatial Urban Climate Adaptation and Resilience Decision-Support Framework (GUCAR-DSF) as an original evidence-to-action framework for climate-resilient urban planning. The framework connects eight interdependent functions: climate and environmental observation; geospatial intelligence and indicator generation; multi-hazard diagnostics; vulnerability and adaptive-capacity assessment; adaptation option appraisal and prioritisation; governance, participation and implementation; monitoring, evaluation and adaptive learning; and decision-support communication and scaling. Its main contribution lies not in treating these functions as separate technical or institutional activities, but in organising them into a unified and iterative decision process.

The GUCAR-DSF advances the argument that effective urban adaptation must move beyond descriptive mapping towards integrated and adaptive decision-making. Hazard information must be linked to vulnerability; vulnerability assessment must inform intervention choices; adaptation priorities must be spatially targeted; governance must support coordinated implementation; and monitoring must feed back into future decisions. In this sense, the framework directly addresses the evidence-to-action gap that continues to limit the practical value of many climate-risk assessments and adaptation plans.

A key strength of the framework is its adaptive feedback logic. Implementation is not treated as the endpoint of planning. Instead, monitoring outcomes generate new evidence, reveal changing vulnerabilities, expose implementation constraints, identify unintended consequences, and inform renewed observation, diagnosis, prioritisation, and institutional adjustment. This recursive logic is especially important under conditions of uncertainty, where climate hazards, land-use patterns, ecosystem conditions, infrastructure systems, and governance capacities continue to evolve.

The framework is intentionally flexible rather than universally prescriptive. Its indicators, analytical tools, governance arrangements, and adaptation options can be configured according to local environmental conditions, data availability, institutional capacity, and planning priorities. This makes it relevant to both data-rich metropolitan regions and resource-constrained developing cities, provided that geospatial and digital tools are matched with transparency, participation, institutional usability, affordability, and long-term maintenance.

At the same time, GUCAR-DSF should be understood as a conceptual framework that requires empirical validation and refinement. Future studies should test its application across diverse urban contexts, assess its usefulness in improving decision quality and interagency coordination, and evaluate whether interventions prioritised through the framework produce measurable reductions in exposure, sensitivity, and vulnerability. Such validation is necessary to establish its practical effectiveness and operational limits.

Ultimately, the significance of GUCAR-DSF lies in its capacity to bridge the persistent gap between climate knowledge and practical urban action. By linking geospatial intelligence with multi-hazard analysis, differentiated vulnerability, adaptation prioritisation, governance, implementation, monitoring, and continuous learning, the framework provides a structured basis for moving from fragmented risk assessment towards proactive, equitable, and adaptive climate-resilient planning. GUCAR-DSF therefore provides a foundation for future empirical testing, pilot implementation and comparative urban resilience research.

REFERENCES

1. Folke, C., Hahn, T., Olsson, P., & Norberg, J. (2005). Adaptive governance of social-ecological systems. Annual Review of Environment and Resources, 30, 441–473. https://doi.org/10.1146/annurev.energy.30.050504.144511
2. Folke, C., Polasky, S., Rockström, J., Galaz, V., Westley, F., Lamont, M., Scheffer, M., Österblom, H., Carpenter, S. R., Chapin, F. S., III, Seto, K. C., Weber, E. U., Crona, B. I., Daily, G. C., Dasgupta, P., Gaffney, O., Gordon, L. J., Hoff, H., Levin, S. A., ... Walker, B. H. (2021). Our future in the Anthropocene biosphere. *Ambio, 50*(4), 834–869. https://doi.org/10.1007/s13280-021-01544-8
3. Goodchild, M. F. (2020). GIS and spatial analysis in the era of big data. International Journal of Geographical Information Science, 34(9), 1741–1745. https://doi.org/10.1080/13658816.2020.1745504
4. Intergovernmental Panel on Climate Change. (2023). Climate change 2023: Synthesis report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC. https://doi.org/10.59327/IPCC/AR6-9789291691647
5. Lary, D. J., Alavi, A. H., Gandomi, A. H., & Walker, A. L. (2016). Machine learning in geosciences and remote sensing. Geoscience Frontiers, 7(1), 3–10. https://doi.org/10.1016/j.gsf.2015.07.003
6. Longley, P. A., Goodchild, M. F., Maguire, D. J., & Rhind, D. W. (2021). Geographic information systems and science (5th ed.). Wiley.
7. Malczewski, J. (2006). GIS-based multicriteria decision analysis: A survey of the literature. International Journal of Geographical Information Science, 20(7), 703–726.
8. Meerow, S., Newell, J. P., & Stults, M. (2016). Defining urban resilience: A review. Landscape and Urban Planning, 147, 38–49. https://doi.org/10.1016/j.landurbplan.2015.11.011
9. Oke, T. R., Mills, G., Christen, A., & Voogt, J. A. (2017). Urban climates. Cambridge University Press.
10. Organisation for Economic Co-operation and Development. (2023). Building systemic climate resilience in cities. OECD Publishing.
11. Tamiminia, H., Salehi, B., Mahdianpari, M., Quackenbush, L., Adeli, S., & Brisco, B. (2020). Google Earth Engine for geo-big data applications: A meta-analysis and systematic review. *ISPRS Journal of Photogrammetry and Remote Sensing, 164*, 152–170. https://doi.org/10.1016/j.isprsjprs.2020.04.001
12. Tyler, S., & Moench, M. (2012). A framework for urban climate resilience. Climate and Development, 4(4), 311–326. https://doi.org/10.1080/17565529.2012.745389
13. United Nations Human Settlements Programme. (2024). World Cities Report 2024: Cities and climate action. UN-Habitat.
14. United Nations Office for Disaster Risk Reduction. (2022). Global assessment report on disaster risk reduction 2022: Our world at risk—Transforming governance for a resilient future. UNDRR.
15. World Bank. (2023). Thriving: Making cities green, resilient, and inclusive in a changing climate. World Bank.