

Spatializing Climate Risk Education in African Green Public Finance for Sustainable Public Sector Capacity Building, Climate Resilience, and Adaptive Governance

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ARTICLE DETAILS	ABSTRACT
History Received: May 10, 2026 Revised: June 15, 2026 Accepted: June 23, 2026 Published: June 30, 2026	Purpose This study addresses the critical research gap at the intersection of spatial literacy, climate education, and public financial management within emerging African economies. Methodology This study employs a Systematic Literature Review (SLR) methodology that strictly adheres to PRISMA protocols. Peer-reviewed literature spanning geography education, green finance, and adaptive governance was systematically screened, evaluated, and synthesized. Findings The synthesis reveals significant structural fragmentation within institutional PFM frameworks, widespread non-integration of Geographic Information Systems (GIS) into climate curricula, and weak Environmental, Social, and Governance (ESG) accountability mechanisms, collectively hindering public-sector capacity building and institutional transformation. Furthermore, existing green public finance instruments remain largely non-evident or inadequately operationalized, leading to a persistent misalignment between climate resilience investments and actual territorial vulnerabilities. Conclusion & Practical Implications To bridge these gaps, public-sector capacity plans must institutionalize GIS-embedded climate-risk orientations. Policymakers should formulate spatially responsive green finance policies and establish intra-sectoral public-private management mechanisms grounded in place-based climate accountability. By synthesizing spatial literacy with green public financial management, this research provides a novel conceptual linkage that directly advances institutional efficiency, accelerates digital transformation, and fosters inclusive governance and sustainability across emerging African economies.
Keywords Adaptive Governance Economic Geography GIS- Entrenched Climate Risk Education Green Public Finance Spatial Citizenship	
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1. Introduction

The amalgamation of climate change, Public Finance Management (PFM), and geospatial education is one of the most significant yet under-researched frontiers in economic development and scholarship. On the global stage, climate action has played catalytic roles in the masterminding of unprecedented institutional reforms, governance restructuring and financial innovations, particularly within the green public finance domain, which is a rapidly growing enterprise that encompasses climate-responsive budgeting, environmental fiscal instruments, green bonds, as well as within the frameworks of sustainability-linked public expenditure (Gopal & Pitts, 2025; Raihan, 2025). Despite this, the transformative potential of these instruments is largely inhibited as many public sector institutions are typified by under-resourced human capital, climate knowledge, and spatial literacy that are germane for designing, implementing, monitoring, and evaluating such frameworks with equity and territorial sensitivity (Jacob et al., 2021; Enaifoghe, 2025). Within emerging African economies, this challenge is predominantly evident. African governments are challenged by intensifying climate risks such as desertification, rising sea levels, flooding, protracted drought, and biodiversity losses, characterized by insufficiencies in institutional capacity, financial governance, and educational infrastructure (Steiner, 2019; Saber, 2025). These combined vulnerabilities render African public sectors specifically ill-equipped to deliver spatial, financial, and governance proficiencies for effective climate resilience. This culminates in a dangerous misalignment between green finance commitments and their institutional implementation; the misalignment undermines sustainable development and prolongs climate injustice, thereby eroding public trust in governance systems (Assibi, 2024; Das, 2025). This misalignment is fundamentally educational and epistemological. The lack of spatial climate risk education within African public sector capacity building programs means that the ministries of finance, environmental agencies, planning departments, and local municipalities continue to operate with limited understanding of the geographical distribution of climate risks, as well as how they are territorially differentiated and spatially compounded (Leal-Filho et al., 2018; Ziervogel et al., 2022). Hence, spatial illiteracy renders green PFM instruments inefficient and incapable of directing resources to the most severely vulnerable geographies or to the regions that will yield the greatest investment returns (Bruno & Cozzolino, 2023).

Green Public Finance is conceptualized as the integration of environmental sustainability goals, such as climate mitigation and adaptation objectives, into PFM systems, including budgeting, fiscal policy design, public investment frameworks, and intergovernmental fiscal transfers (Chugunov et al., 2019; Yilmaz & Zahir, 2020). Green Public Finance operates at the precipice of macroeconomic governance and environmentalism, demanding advanced institutional proficiencies that supersede traditional financial management. Climate Risk Education is theorized as the organized knowledge development, proficiencies, attitudes, and competencies that enable individuals and institutions to identify, communicate, assess, and respond to climate risks across local, regional, national, and global scales (Odiyo & Volenzo, 2019; Cvetković & Šišović, 2024). In the public sector, institutional responses to climate stressors, budgetary allocations, and the quality of policy decisions hinge on climate risk education. Spatialization, in relation to this study, is the integration of geospatial technologies (i.e., Geographic Information Systems (GIS), remote sensing, and spatial data analytics) and spatial thinking and place-based reasoning into educational frameworks, governance structures, and policy design processes (Morisson & Doussineau, 2019; Klepac et al., 2023). Spatializing climate risk education is therefore understood as the process of entrenching geographical intelligence in public sector professionals' understanding, mapping, communication, and response to climate vulnerabilities across different geographies. Adaptive governance is the institutional

arrangement epitomized by flexibility, participatory decision-making, multi-level coordination, and iterative learning that enable governance systems to adapt to evolving climatic, economic, and social conditions (Wang et al., 2018; Hakiman & Sheely, 2025). Adaptive governance is fundamental to climate resilience because it replaces static and linear planning paradigms with dynamic, spatially-responsive and knowledge-intensive institutional processes. Public Sector Capacity Building refers to the processes through which public establishments and public sector professionals develop and strengthen their capabilities to perform their core functions effectively, sustainably, and efficiently (Hamilton & Lubell, 2018; Rodriguez, 2025). These integrated constructs ensure that climate-educated public-sector professionals operate within adaptive governance frameworks to build and continuously renew institutional capacity for climate resilience.

Some germane issues and intellectual arguments animate the scholarly domain of this study. First, the relationship between education and governance in climate action is debatable. While the literature supports the view that climate literacy enhances the quality of institutional decision-making (Raj & Amin, 2024; Yeh et al., 2025), critics argue that educational interventions are inadequate without corresponding structural reforms in fiscal governance, resource distribution, and political accountability (Smith & Benavot, 2019; Waddington et al., 2019). This study engages this argument by positing that spatialized climate education is an imperative prerequisite for expediting structural reform in public institutions. Second, green PFM as a field has been criticized for its technocratic alignment, which privileges financial instruments, market mechanisms, and taxonomies over the human capacities and territorial realities that determine whether such instruments succeed or fail in practice (Dziwok & Jäger, 2021; Bogner, 2024). Discussions on green finance are largely shaped by Northern institutional frameworks and multilateral development banks and have been slow to incorporate African institutions, spatial realities, and capacity challenges into their policy frameworks (Michaelowa et al., 2021; Güngen, 2023). It is on this premise that this study challenges this technocratic prejudice by foregrounding human capital, spatial literacy, and educational infrastructure as imperative to the effectiveness of green finance. Third, applications of GIS and geospatial technologies in public-sector governance and educational development are largely underdeveloped across African geographies. While GIS applications and utilization have expanded significantly in disaster risk reduction, natural resource management, and urban planning globally, their integration into PFM, climate governance education, and institutional capacity building across African public sectors remains fragmented, nascent, and under-theorized (Paientko, 2018; Attah et al., 2024). This represents a critical intellectual gap that this study directly addresses. Fourth, tensions exist between global climate finance frameworks such as the Sendai Framework for Disaster Risk Reduction, the Paris Agreement, and the Kunming-Montreal Global Biodiversity Frameworks, on the one hand, and the localized institutional realities of African governments, on the other (Streck, 2023; Boran & Pettorelli, 2024). African public institutions can hardly meet the technical and spatial capabilities associated with climate finance reporting standards, evaluation and monitoring requirements imposed by international frameworks, thereby culminating in the paradoxical diversion of scarce institutional capacity away from actual climate resilience building (Shakya et al., 2018; Angeles, 2021). This study investigates the structural tension and advocates for spatialized capacity building to reconcile global frameworks with African institutions.

Less than 4% of global greenhouse gas emissions originate in Africa, yet the continent bears an unequal burden of climate change impacts (Ashenafi, 2022; Fonjong, 2024). Africa's climate vulnerabilities are geographically heterogeneous, ranging from the advancing Sahara in North and West Africa, increased cyclone activity in Southern and

East Africa, a rise in sea levels that threatens coastal West African cities, as well as protracted drought undermining pastoral and agricultural productivity across the Sahel and Horn of Africa (N’gobi et al., 2022; Saber et al., 2025). This spatial heterogeneity calls for governance responses that are differentiated and territorially sensitive, but this becomes impossible without entrenching geospatial literacy within public sector institutions. The African Union's Agenda 2063 explicitly recognize the significance of climate resilience and environmental sustainability as foundational support for Africa's developmental vision (Royo et al., 2022). In the same vein, the African Development Bank's Climate Change Action Plan 2020–2025 is committed to mainstreaming climate risk across all public investment initiatives (Bazbauers, 2022). However, these continental commitments rarely translate into public-sector capacity-building programs that equip African finance and planning professionals with the spatial climate proficiencies needed to operationalize green finance commitments at the local and subnational levels, where climate impacts are most challenging. The COVID-19 pandemic further exposed and deepened these institutional capacity challenges, because commitments towards green PFM were frequently deprioritized, abandoned or deferred as African governments tried to re-channel public finance toward emergency responses, thus exposing the fragile nature of climate fiscal commitments when institutionalized, climate-literate governance cultures are absent (Ozili, 2022; Shipalana, 2022). It is germane to present a historical opportunity that the post-COVID pandemic offers for building more sustainable, digital, and climate-responsive public institutions, thereby creating the fiscal and political trajectory for transformative capacity building that this study endorses. Hence, this study is guided by the central research question: “How can spatialized climate risk education be strategically integrated into green public finance frameworks toward enhancing public sector capacity building, climate resilience, and adaptive governance within emerging African economies?”

2. Literature Review and Hypotheses Development

2.1. Theoretical Framework

Two complementary theoretical frameworks, namely the Spatial Citizenship and Adaptive Governance Theories, guide this investigation, and their integration generates imperative explanations and prescriptions for the study.

2.1.1. Spatial Citizenship Theory

This theory conceptualizes a deep understanding of geographic phenomena (such as space, place, scale, and power) to empower individuals to participate in societal decision-making actively. The theory provides the educational and epistemological perspective underpinning this study's inclination toward spatialized climate risk education. Spatial citizenship exemplifies how geospatial literacy (i.e., the capacity to read, produce, and operationalize spatial knowledge using GIS tools) establishes an imperative institutional proficiency that enables public-sector professionals to participate in spatially differentiated governance and make effective decisions. Figure 1 depicts the Spatial Citizenship Theory.

Figure 1 depicts the Spatial Citizenship Theory as elucidated by Jekel (2015), illustrating the competencies of individuals and institutions for developing the capacity to participate in spatially mediated governance and decision-making.

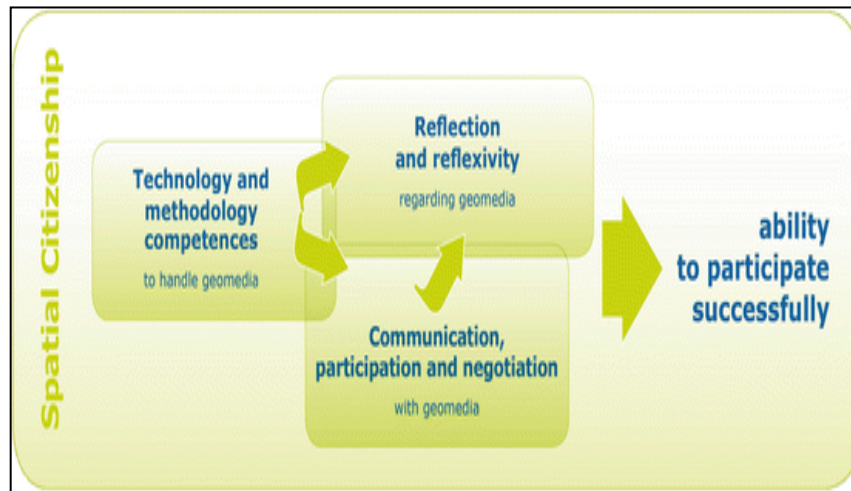


Figure.1.The Spatial Citizenship Theory (Jekel et al. 2015)
Source: Author's own elaboration

Figure 1 reveals three overlapping domains of competence: technology and methodology competences in handling geomeia; reflexivity and reflection concerning geomeia; and geomeia communication, participation, and negotiation, which collectively culminate in the ability to participate in spatially informed institutional, civic, and governance processes. As the bidirectional, cyclical arrows depict connections among these three domains, Spatial Citizenship is a reflexive, iterative learning process at each stage of competence. This has profound implications for the design, delivery and institutionalization of climate risk education within the frameworks of African public sector capacity building, and the theory is applied to the present study within this interpretive perspective.

2.1.2. Technology and Methodology Competences in the African Green Public Finance Context

The first competency domain (i.e., the technological and methodological competences for handling geomeia) forms the technical foundation of Spatial Citizenship. It is directly relevant to this study's inclination toward spatializing climate risk education within African green public finance systems. Geomeia incorporates the array of spatial digital technologies, tools and platforms for producing, visualizing and communicating geographic knowledge and includes Geographic Information Systems (GIS), remote sensing platforms, spatial databases, satellite imagery, digital climate risk mapping tools, and web-based geospatial platforms (Olszewski & Wendland, 2021; Anunti, 2023). In this study, technology and methodology competencies refer to the capacity of African public finance professionals, climate governance officials, environmental managers, and government administrators to use geospatial tools to identify, map, quantify, and communicate the spatial distribution of climate risks across heterogeneous African geographies. Applying this competency domain to this study is imperative regarding the continent's severe climate vulnerability and the spatial heterogeneity of climate risk across Africa. The continent's public sector professionals responsible for designing green finance instruments (such as climate-responsive budgets, environmental fiscal transfers, green bonds, and adaptation investment frameworks) require this spatial competence to ensure that financial resources are directed toward communities and ecosystems with severe climate vulnerability and toward areas where adaptive investments produce the highest returns. The absence of foundational geomeia competence will culminate in spatially challenged green public finance instruments and climate risk geographies. This study

therefore recognizes the development of geomedia technology and methodology competences as *sine qua non* for a successful African spatialized climate risk education program for public sector institutions, positing that frameworks for capacity building must incorporate remote sensing capabilities, spatial data interpretation skills and hands-on GIS training as major prerequisites for the professional development of PFM.

2.1.3. Reflection and Reflexivity Regarding Geomedia

The second competency domain, as depicted in Figure 1, concerns reflection and reflexivity regarding geomedia, which elevates Spatial Citizenship beyond mere technical competences into epistemological awareness, and it is in this realm that the theory makes its most intellectually distinctive contribution to this study. Reflection and reflexivity, as depicted in Figure 1, refer to the capacity to critically investigate geomedia techniques, spatial representations, and geographic narratives that produce, frame, and communicate climate risk knowledge, and the consequent institutionalization of that knowledge within public governance systems (Feindt & Weiland, 2018; Jack et al., 2020). In essence, GIS outputs, spatial models, maps, and climate risk visualizations represent reality and are socially constructed phenomena shaped by their manufacturers' values, assumptions, methodologies, and political economies. With reference to this study, the reflexivity dimension of Spatial Citizenship has implications for African public sector institutions engagement with internationally-generated climate risk information, and standardized indices of climate vulnerability as well as global green finance taxonomies, because climate risk frameworks which are generated by international financial organizations, multilateral institutions and environmental bodies of the Global North usually fail in capturing the spatial realities, indigenous territorial knowledge, and vulnerability configurations of African geographies (Radcliffe & Radhuber, 2020; Gillespie & Mitlin, 2023). Hence, the application of the reflexivity dimension of Spatial Citizenship in this study advocates that spatialized climate risk education in African public institutions must transcend GIS competencies and cultivate a critically reflective spatial consciousness that empowers public sector professionals to challenge dominant spatial narratives, apply African indigenous spatial knowledge within climate risk evaluations, and produce locally configured and reflexively generated green finance instruments. This reflexive dimension aligns holistically with the adaptive governance theoretical inclination, which equally accentuates knowledge co-production and iterative learning as fundamental institutional competencies for climate resilience.

2.1.4. Communication, Participation and Negotiation with Geomedia

The third competency domain depicted in Figure 1 (i.e. participation, communication, and negotiation with geomedia) speaks to the social, collaborative, and deliberative aspects of spatial citizenship, which recognizes the collective, participatory governance of spatial resources, risks, and responsibilities as the overarching reason for geomedia competences (Berniker & Humphreys, 2024; Fast et al., 2024). This domain involves the use of geomedia tools and spatial representations to communicate with and engage stakeholders, as collaborative decision-making and multi-level negotiations are integral to transforming GIS visualizations and spatial data into shared platforms for inclusive governance. Applying this domain to this study, from an African green public finance perspective, the capabilities to communicate and negotiate with geomedia are imperative for successful governance processes. First, it empowers local and subnational government professionals to communicate spatially differentiated climate-risk realities to national finance and planning institutions in visually compelling, territorially specific, and empirically credible ways, thereby strengthening the case for spatially targeted green finance allocations. Second, it advances the participation of vulnerable rural agricultural communities,

informal urban settlements, and pastoralist societies in developing climate adaptation investment frameworks by using spatial representations of how climate risks affect their communities. Third, it enhances intergovernmental coordination and cooperation in allocating climate finance across competing territories, thus enabling spatially informed fiscal decision-making. Also, this domain affirms the study's emphasis on Public-Private Partnerships (PPP) and collaborative governance mechanisms as germane institutional prerequisites for sustainable green finance.

2.1.5. Adaptive Governance Theory

This is an institutional theory designed to manage complex, ill-defined, and rapidly metamorphosing socio-ecological systems. The theory advocates a "learning by doing" paradigm, decentralized decision-making, and collaboration across multiple societal hierarchies toward building resilience during unforeseen crises. The theory provides an institutional perspective on how public sector systems are structured to be iterative and flexible in response to unprecedented climate challenges. The theory advocates polycentric institutional provisions, knowledge co-production, and social-ecological learning as resilience-building principles for climate literacy in public finance governance. Figure 2 depicts the operationalization of the Adaptive Governance Theory.

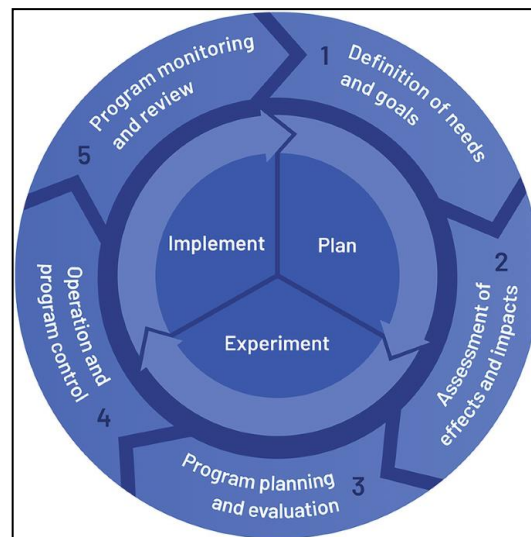


Figure.2.Operationalization of the Adaptive Governance Theory (Simon, 2024)

Source: Author's own elaboration

Figure 2 elucidates the dynamism, as well as the iterative and cyclical disposition of the Adaptive Governance Theory through a five-stage cycle of governance and encompasses the defining goals, needs as well as the evaluations of effects and impacts, the planning and assessment of programs, operation in addition to program reviews, monitoring and control, all grounded in experimentation, planning and implementation for the continuous propelling of systemic adaptation and institutional learning. Applied to the present study, this theory provides an understanding of how African public sector institutions can entrench spatialized climate risk education within their green finance governance systems in iterative, adaptively responsive, and evidence-driven ways in response to evolving climate realities. The subsequent assessment of effects and impacts stage empowers institutions to assess the effectiveness of spatialized climate education interventions in enhancing the quality of green finance decisions and to utilize spatial data analytics to

measure capacity-building investments in climate resilience outcomes across various African geographies. The operation and program control stage expedites these spatialized capacity-building frameworks within the green public finance governance systems by entrenching climate risk communication competences, GIS proficiencies, and reflexive spatial thinking into the institutional practices of financial establishments, environmental/planning agencies, and local council administrative units. The program monitoring/review stage continuously assesses whether spatialized climate education is generating the intended governance outcomes of new spatial knowledge for redefining institutional objectives and needs, thereby sustaining the iterative, learning-dynamic disposition of adaptive governance theory. The inner triad emphasizing the plan, implement, and experiment requirements at the heart of Figure-02 affirms the execution of green finance plans that African public sector institutions must boldly experiment with, reflexively learn from spatial evidence, and adapt to in response to the complex, uncertain, and dynamic climate vulnerabilities they challenge. Hence, integrating these two theories generates theoretical novelty of Spatially-Adaptive Climate Governance (SACG), which is proposed in this study as contributing to the management science palace. SACG postulates that climate resilience in African public institutions necessitates spatial citizenship competencies and adaptive governance structures, expedited through institutional and geographical frameworks of green public finance, thus positioning this study within inclusive governance, institutional effectiveness, sustainability, and digital transformation and knowledge economies for emerging African economies.

3. Methodology

The primary research methodology adopted for this study is the Systematic Literature Review (SLR) due to the interdisciplinary, empirically heterogeneous, and conceptually complex nature of the research problem. The SLR navigates transdisciplinary fields of geography education, climate governance, green public finance, GIS and geospatial education, adaptive governance theory, and African development. Given that no single study has integrated these domains into a coherent study, the SLR methodology expedites the productive function of knowledge cartography by mapping the discourse and conceptualizing insights germane to the novel Spatially-Adaptive Climate Governance (SACG) construct proposed in this research. The SLR for this study is anchored by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol for reporting of systematic reviews in various scientific disciplines (Wang et al. 2019; O'Dea et al. 2021) and was expedited through four stages, namely the Identification, Screening, Eligibility, and Inclusion stages.

3.1. Database Selection and Search Strategy

This is the first stage of the PRISMA protocol, which identified relevant literature through a comprehensive, multi-database search strategy for maximizing interdisciplinary literature relevant to the study's research question. The key academic databases were chosen for their wide disciplinary coverage, international relevance, and alignment with the study's thematic structure, including Scopus, Google Scholar, Web of Science, ScienceDirect, EBSCOhost, JSTOR, and the African Journals Online (AJOL) databases. AJOL was deliberately incorporated to adequately represent African-situated studies, given the continent's underrepresentation in Global North-dominated databases and its relevance to this study's focus on African emerging economies (Tuyishime et al. 2022; Alonso-Álvarez, 2024). The search strategy was constructed around a structured Boolean search which combined thematic clusters of keywords derived from the study's conceptual architecture. The first cluster addressed spatialized climate education and GIS competence, adopting the terms "climate risk education", "GIS education", "climate literacy", "spatial

literacy", "geospatial competence", "geography education", and "geomedia". "Green public finance", "climate finance governance", ESG Africa" and "climate-responsive budgeting", " climate governance, "environmental fiscal policy", sustainable public finance and "green bonds Africa" formed the second cluster. In contrast, the third cluster incorporated "public sector capacity building", "public financial management", "institutional effectiveness", "climate governance, "human capital development Africa"; and "adaptive management". Also, "adaptive governance", "polycentric governance", "institutional resilience", "climate resilience", "climate adaptation governance" and "social-ecological systems" dominated the fourth cluster and all clusters were combined with the utilization of Boolean operators such as “OR” for expanding coverage within clusters, as well as “AND” for connecting clusters thereby producing a comprehensive search string that incorporated the full trans disciplinarily of the research question.

3.2. Screening

This stage involved the importation of 847 records into Rayyan (which is an AI-assisted systematic review platform that facilitates transparency and efficiency in the records screening processes (Blaizot et al. 2022). Firstly, 203 duplicate records that overlapped across the 7 databases were removed, thereby generating 644 deduplicated records. The inclusion and exclusion stage followed, which ensured the alignment of the records with at least one of the study's major thematic areas of spatialized climate education/GIS literacy; public sector capacity building in emerging economies, green public finance or climate-responsive fiscal governance, climate resilience or adaptive governance, and their relationships to African geographies. Hence, 387 unrelated records were expunged at this stage, yielding a corpus of 257 full-text records for eligibility evaluation.

3.3. Eligibility

The 257 retained records were retrieved for full-text evaluation, and their eligibility was assessed using a quality appraisal protocol. Each full-text was evaluated through a comprehensive review of its theoretical contribution, relevance, contextual applicability, and methodological rigor in relation to the study's research question.

3.4. Exclusion criteria

At this stage, records that did not substantively engage with the study's thematic areas and did not provide insights for the study were excluded, as were methodologically limited records. The Mixed Methods Appraisal Tool (MMAT) was adopted as the quality appraisal tool because of its capacity to assess diverse methodologies across qualitative, quantitative, conceptual, and mixed-methods studies, thereby accommodating the interdisciplinary corpus and methodological heterogeneity of the selected studies (Hong et al. 2018). Each record was evaluated based on the conceptual objective; appropriateness of the theories; methodological/conceptual transparency; coherence/credibility of the findings; and their relevance to the study. Records that met fewer than 3 of 5 quality criteria were excluded from the final corpus, resulting in the exclusion of 161 records and yielding a corpus of 96 peer-reviewed research articles for data extraction.

3.5. Inclusion Criteria

At this final stage the 96 articles were extracted using a standardized data extraction template that captured the following information categories for each included study, namely bibliographic details (such as author, year, journal, and publication type; geographical information); theoretical/conceptual orientation; research methodology and sources of data; key findings relevant to the study; major constructs/ analytical framework

relevant to the study's; and contributions on spatialized climate education, public sector capacity building, green public finance governance, or adaptive governance in African economies.

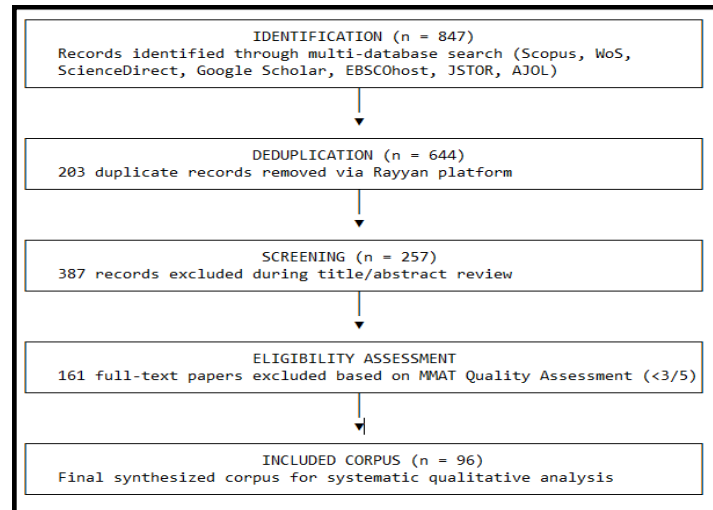


Figure.3.Inclusion Criteria
Source: Author's own elaboration

4. Findings and Discussion

4.1. Institutional Fragmentation of Climate Risk Education in African Public Finance Governance

Studies such as Clark et al. (2018), Savvidou et al. (2021), and Ziervogel et al. (2022) elucidated significant disconnections between climate education, PFM systems, and institutional capacity-building programs in African public sectors such as government establishments and across inter-governmental fiscal relationships, and between subnational implementation realities and national governance frameworks. Also, findings indicate that governance systems facing complex environmental challenges are strained when institutional learning, knowledge production, and decision-making are carried out within rigid, bureaucratic structures, as is the case across African public finance institutions in the literature. With reference to the inner triad of the Adaptive Governance framework on experimentation, planning, and implementation, it requires a reflexive and continuous institutional learning cycle with shared, cross-institutional knowledge platforms for the free flow of climate risk information across government establishments. In essence, the documented institutional fragmentation in this study constitutes a significant barrier to adaptive learning, thereby affirming that the demands of knowledge-intensive, iterative, effective green finance governance challenge African PFM institutions. This finding compares with Heikkila et al. (2018) and Schröder's (2018) studies on polycentric governance, which posited that resilient environmental governance systems are characterized by overlapping, self-organizing governance networks capable of concurrently producing, sharing, and operationalizing spatially differentiated environmental knowledge across multiple institutional scales. The findings from the African PFM systems present a contrasting scenario of this polycentric ideal, as climate risk education departments are usually domiciled within ministries of environment and disconnected from finance ministries (Dunz & Power, 2021), while geospatial information and GIS competencies are concentrated within departments of urban planning, with no linkage to public investment frameworks.

Furthermore, findings reveal that decisions on adaptation finance are expedited at the national level without input from subnational institutions closest to the communities experiencing the realities of climate change (Attah et al., 2024; Li et al., 2024). From the foregoing, this institutional fragmentation is not merely an organizational challenge, but epistemological, because it is a historical formation of African public service professionals, who are trained within narrow public administration, economics, or PFM paradigms which exclude spatial literacy, geographical thinking, and environmentalism from their professional knowledge structures (Walkington et al., 2018; August et al., 2022). This further implies that even where green finance instruments or climate-responsive budgeting frameworks are introduced through institutional reform efforts, their operationalization has been undermined by the lack of geospatial and climate intelligence essential to utilize these instruments in territorial realities optimally. The Spatial Citizenship framework precisely identifies this challenge; hence, without the technological proficiencies to handle geomedial, African PFM professionals lack the fundamental spatial acumen through which climate risk knowledge is generated, communicated, and institutionalized for efficient governance. This culminates in spatial blindness, i.e., a situation in which governance institutions are incapable of conceptualizing and responding to the geographical challenges posed by the climate risks they are authorized to govern (Parthasarathy, 2018; Birchall & Kehler, 2023). In essence, this finding significantly advances existing scholarship because previous studies have only documented the general capacity deficits of African public institutions in climate governance (Leal-Filho et al. 2018) as well as the mainstreaming challenges of climate into public finance (Clark et al. 2018; de Mello & Martinez-Vazquez, 2022), but none has specifically exemplified the spatial fragmentation of public sector climate education as the major reason for the failure of green finance governance. Hence, one of the novel contributions of this study is the integration of Adaptive Governance Theory into institutional learning and the articulation of Spatial Citizenship Theory on geomedial competence as a governance requirement, which identifies the spatialization of climate risk education as the fundamental and non-negotiable requirement for capacity building.

4.2. Spatial Blindness of Green Public Finance Instruments and Its Challenges on Governance

The second major finding reveals that existing green PFM instruments positioned across African emerging economies are characterized by substantial spatial blindness, as previously reported in this study. Spatial blindness is evident in several ways and undermines the transformative potential of green finance as a vehicle for building Africa's climate resilience. First, the findings indicate that African climate-responsive budget frameworks aggregate climate vulnerability evaluations at national or regional scales, without incorporating the localized and subnational heterogeneity of climate risk that determines where adaptive investments are critically needed and will produce the greatest returns (Sethamo & Harder, 2021; Hansen et al., 2022). In the same vein, African governments and regional authorities issue green bonds that lack spatial intelligence, with proceeds usually allocated to broad sectors for the provision of sustainable agriculture, water infrastructure, and renewable energy, without the GIS-informed analysis required for identifying specific geographic locations that these investments will most effectively and efficiently address severe climate vulnerabilities (Bensadi, 2025; Kochanek et al., 2025). For instance, this finding is particularly evident in Mozambique and Madagascar's ever-increasing cyclone exposure, coastal inundation vulnerability in Lagos, Dakar, and Alexandria, and advanced desertification in the Sahel, among others, each of which demands spatially specific governance responses that spatially blind green finance instruments cannot provide. This spatial blindness of green finance instruments has

implications for effective governance, particularly regarding democratic legitimacy and institutional accountability. As positioned by the Adaptive Governance theory, when green finance instruments lack spatial targeting, assessing their impacts and effects becomes impossible, because institutions cannot assess whether climate finance has reached the most vulnerable geographies if they have no spatial framework that defines, measures, or monitors territorial vulnerability in the first place (Bracking & Leffel, 2021; Lai et al., 2025), hence culminating in a vicious cycle of accountability deficiency whereby spatially-blind investments produce spatially-indeterminate consequences and outputs, thus generating spatially-unintelligible assessments, which in turn disseminates spatial blindness of successive investment cycles, which is in contrast to the adaptive governance cycle as elucidated in this study.

4.3. Structural Barriers to GIS Integration in African Public Sector Capacity Building

The third finding epitomizes an amalgamation of structural, financial, institutional, and epistemological barriers that jointly hinder the integration of GIS and geospatial intelligence into African public-sector capacity-building frameworks. As identified in this study, these barriers should be removed as a prerequisite for the spatialization of climate risk education within green PFM systems. These barriers operate concurrently across multiple levels of governance, resulting in complex obstacles that hinder reform strategies and require multi-level institutional transformation, as prescribed by Adaptive Governance Theory. It was discovered from the literature that at the infrastructural level, there exists inadequate digital infrastructure such as high-speed Internet connectivity, reliable electricity supply, and availability of hardware, evidenced across African public sector institutions at regional and local government levels where climate vulnerability is most severe and where spatially-informed governance is most urgently required (Robin, 2022). This infrastructural challenge results in a fundamental paradox: the geographies most challenged by climate risks are often the least digitally connected, rendering the operationalization of GIS-based climate risk education a herculean task where it is most needed. This finding is in tandem with the position that infrastructure development and socio-economic transformation are fundamental prerequisites for digital innovation and institutional effectiveness in African economic geographies.

With reference to human capital development, there are inadequate GIS professionals at institutional levels within African Higher Education Institutions (HEIs), in professional development programs and in training institutions (Sumari et al. 2019; Mzuza & Van der Westhuizen, 2020), and this inadequacy is exacerbated by the “geospatial brain drain phenomenon,” which is referred to as the migration of African GIS professionals to the private sector, multilateral organizations and international NGOs that offer more career development opportunities and higher remuneration when compared to those that public sector institutions offer (Woldai, 2020), therefore culminating in the lack the internal geospatial expertise in public institutions and perpetuating institutional spatial blindness. With reference to the Spatial Citizenship Theory, this human capital deficit signifies a systemic failure in the institutional development of technology for handling geomedial. This confirms the position that the barriers to spatialized climate governance are inherently structurally rooted in the African public sector’s political economy, thus hindering employment and professional development. In terms of curriculum development, findings reveal that professional training and capacity building programs in the African public sector tilt towards traditional public administration, PFM, and economic planning paradigms, thereby marginalizing spatial science, geography, environmental studies and GIS literacy from professional development curricula (Hammond et al. 2018; González et

al. 2020; Lauermann, 2022). This curricular marginalization is also evident within African HEIs and public-sector training institutions, with the erroneous belief that quantitative economics and legal-administrative knowledge should be favored as more important governance competences. In contrast, spatial and environmental knowledge are downgraded to secondary competences. In reference to the reflection and reflexivity dimension of the Spatial Citizenship Theory, this epistemological hierarchy is epitomized as a critical barrier to spatialized governance. When public service professionals are not trained in spatial intelligence dimensions of governance, they cannot deliver knowledge and competence in geospatial intelligence required to address those dimensions effectively.

4.4. The Spatially-Adaptive Climate Governance Framework as an Institutional Transformation Pathway

The most theoretically generated finding for this study concerns the Spatially-Adaptive Climate Governance (SACG) framework. This novel conceptual contribution proposes it as a pathway for institutional transformation to entrench spatialized climate risk education within African green PFM systems. This framework emerges as a grounded finding integrated through the Adaptive Governance and Spatial Citizenship Theories into a feasible, coherent, and operational architecture for effective governance. The success of the SACG framework is hinged on three institutional transformation requirements that align with the three competency domains of the Spatial Citizenship framework. The first requirement is the spatialized generation of climate knowledge, which requires African public institutions to develop the geomedia technology competences needed to produce, manage, and interpret spatial climate risk data within green PFM processes. Hence, the institutionalization of GIS-based climate vulnerability mapping is germane to defining the needs and effects evaluation stages of the adaptive governance cycle and ensures that spatially informed territorial vulnerability evaluations precede every green finance allocation decision to achieve targeted, effective and equitable investments. This position is supported in the literature (Feyissa et al., 201; Schaefer et al., 2020; Nwogu et al., 2025).

The second requirement relates to reflexive institutional spatial learning, which involves incorporating critical geomedia reflexivity into the program evaluation, planning, and monitoring stages of adaptive governance, and concerns reflexive institutional spatial learning, which entails incorporating critical geomedia reflexivity into the program evaluation, planning, and monitoring stages of adaptive governance, and cultivating institutional cultures in which public professionals investigate the cultivating institutional cultures in which public professionals investigate spatial assumptions, epistemological limitations, and territorial biases of the green PFM frameworks within which they operate. This requirement addresses spatial blindness, positing that technical GIS competence alone is not sufficient without the reflexive critical consciousness that enables public service professionals to recognize when their spatial frameworks are inadequate, or when indigenous or community-generated spatial knowledge offers superior territorial intelligence, as well as when internationally imposed green finance taxonomies do not capture the climate risk realities of the African continent. This finding reveals that institutions exhibit this reflexive spatial learning culture in successful climate adaptation governance in Ethiopia, Rwanda and Kenya (Brisebois et al. 2022; Gebremedhin et al. 2025), because they exhibit greater adaptive capacity and green PFM effectiveness than those operating within unreflective paradigms of spatial governance. This finding advances adaptive governance by recognizing reflexive spatial learning as a measurable dimension of institutional adaptive capacity, thereby affirming Novy's (2022) and Shi & Ling's (2025) general theory of social-ecological learning within the domain of spatialized public finance governance.

The third requirement concerns participatory spatial governance, which entails institutionalizing geospatial participation, communication, and negotiation processes across the stages of program control and operation in adaptive governance, and transforming spatially produced climate risk knowledge into inclusive, multi-stakeholder governance processes for green PFM. This requirement responds directly to the climate justice dimensions of spatial blindness. This assertion is supported by West African programs on community-based adaptation (Gryl & Jekel, 2018; Fast et al., 2024), East African initiatives on climate finance governance (Kweyu et al., 2023), and Southern African programs on green infrastructure (Cilliers, 2019; Pauleit et al., 2021) which demonstrate that participatory spatial governance generates more durable, community-supported climate adaptation results than top-down, technocratic green PFM interventions. Hence, the holistic consideration of the SACG framework is a theoretically grounded, practically operational, and empirically validated pathway for the transformation of African green PFM from an institutionally fragmented, spatially blind, and capacity-deficient governance system into a spatially intelligent, adaptively governed, and institutionally coherent intervention for building a formidable African climate resilience that is urgently required to ameliorate climate vulnerability. This proposed framework is a primary theoretical contribution to the management science literature and positions this study within theoretically grounded, empirically relevant scholarship for Africa's sustainable governance, institutional effectiveness and inclusive economic transformation. In essence, the SACG framework demonstrates that these dimensions are neither sequential nor parallel governance goals but rather interdependent and mutually institutional requirements. Hence, digital GIS innovation is inevitable in actualizing institutional effectiveness in African green PFM governance. Digital GIS innovation requires spatialized educational transformation, while spatialized educational transformation requires inclusive participatory governance. Further, inclusive participatory governance requires institutional adaptive capabilities for continuous learning, evolving and experimenting in response to the territorial climate realities that only spatial governance systems observe, epitomize, and effectively ameliorate. It is on this premise that it is expedient to document the integrated and theoretical understanding of the conditions for Africa's sustainable green PFM governance that constitutes the most prolific contribution of this study to the academic palace.

5. Conclusion

This study examined the strategic integration of spatialized climate risk education into green Public Financial Management (PFM) frameworks to strengthen public-sector capacity, climate resilience, and adaptive governance in emerging African economies. Employing a systematic literature review (SLR) methodology guided by PRISMA protocols and grounded in Adaptive Governance and Spatial Citizenship Theories, the research demonstrates that the deficit in Africa's green PFM governance is fundamentally educational and epistemological. This deficit arises from the exclusion of geographic intelligence, spatial literacy, and place-based climate risk knowledge among African public service professionals and the institutions they manage. Four analytical themes emerged from the SLR: spatial blindness of green PFM instruments, institutional fragmentation of climate risk education, structural barriers to integrating Geographic Information Systems (GIS) into public-sector capacity building, and the Spatially-Adaptive Climate Governance (SACG) framework. Together, these themes provide a coherent and empirically grounded account of the origins and interrelations of these epistemological deficits across governance scales. The SACG framework offers a pathway to develop institutionally resilient, spatially intelligent, and adaptively governed African green PFM systems in response to climate vulnerability. Application of Spatial Citizenship Theory revealed

deficiencies in three domains of geomedia competencies within African public institutions: technological competence, participatory communicative capacity, and reflexive critical awareness. These deficiencies result in spatial blindness, which hampers the effectiveness of green PFM instruments despite financial and policy support. The Adaptive Governance framework further highlights that insufficient spatialized climate knowledge undermines all stages of the institutional governance cycle, from needs assessment and impact evaluation to program planning, operational control, and monitoring. This exacerbates accountability gaps, misdirects climate finance, and undermines institutional credibility, thereby impeding Africa's climate resilience agenda as outlined in the 2063 AU Agenda and the African Development Bank's Climate Change Action Plan. The proposed SACG framework, which integrates spatialized climate knowledge generation, participatory spatial governance, and reflexive institutional spatial learning within adaptive governance, represents a novel theoretical contribution to green PFM governance, management science, and geography education. This framework provides a comprehensive pathway for transforming African public finance institutions from epistemologically fragmented and spatially blind entities into adaptively governed, spatially literate, and reflexively informed organizations capable of supporting climate resilience. Ultimately, the long-term effectiveness of Africa's green PFM depends on the spatial intelligence and adaptive reflexivity of institutional competencies responsible for conceptualizing, implementing, monitoring, and renewing these frameworks in response to Africa's diverse and evolving climate challenges. The spatialization of climate risk education within green PFM is therefore identified as a critical imperative for institutional transformation in Africa's development agenda.

Author Contributions

The authors are: Lead/1st Author – Dr. Tolulope Ayodeji OLATOYE (TAO); 2nd Author- Prof. Raymond Nkwenti FRU (RNF). 3rd Author- Prof. Anathi MAGADLELA (AM). Conceptualization (TAO); Literature Review (TAO); Methodology (TAO); Data Presentation (TAO); Software (TAO); Validation (TAO); Formal Analysis (TAO); Investigation (TAO); Data Curation (TAO); Visualization (TAO); Drafting & Preparation (TAO); Writing- Original Draft (TAO) Writing - Review & Editing (TAO); Supervision (TAO, RNF & AM); Project Administration (TAO, RNF & AM); Funding Acquisition (TAO, RNF & AM); Resources (TAO, RNF & AM). The authors are responsible for this article's results, findings and content.

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Conflicts of Interest

The authors have no conflict of interest either before, during or after the submission of this manuscript.

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