



GEOARIA-AFRICA: A NOVEL INTEGRATIVE FRAMEWORK CROSSING GEOSPATIAL DATA, INFORMATION TECHNOLOGIES, ENVIRONMENT AND NATURE FOR THE ANALYSIS AND MANAGEMENT OF ENVIRONMENTAL RISKS ON THE AFRICAN CONTINENT

*GEOARIA-AFRICA: UMA ESTRUTURA INTEGRADORA INOVADORA
QUE CRUZA DADOS GEOESPACIAIS, TECNOLOGIAS DA
INFORMAÇÃO, MEIO AMBIENTE E NATUREZA PARA A ANÁLISE E
GESTÃO DE RISCOS AMBIENTAIS NO CONTINENTE AFRICANO*

DOI: 10.5281/zenodo.22821134



Pedro Silva¹

ABSTRACT

The African continent faces an unprecedented intensification of environmental risks — droughts, floods, erosion, wildfires, ecosystem degradation and technological accidents linked to extractive industries — amid institutional fragility, data scarcity and rapid digital transformation. African scientific literature has produced valuable yet fragmented studies: GIS applications to specific hazards, geospatially-enabled governance frameworks and reflections on information technologies, but no work has systematically and conceptually crossed the four domains — geospatial data, information technology, environment and nature, and environmental risk analysis — into a single continental-scale theoretical-operational framework. Authored at Universidade Gregório Semedo (Angola), this article presents GeoARIA-Africa, the first African conceptual framework to perform such integration. The methodology combines an exploratory-systematic literature review (corpus of 36 studies) with an original domain-convergence method, which confirmed the gap and grounded the framework's principles, its five-layer architecture and its mathematical formalization — including the Composite Geo-environmental Risk Index (ICRG). Prospective applications to Angolan scenarios (southern droughts, the Kwanza and Cuango basins, extractive industries) and continental scalability are discussed, aligned with the Sendai Framework, the Sustainable Development Goals and the African

1 Universidade Gregorio Semedo - Universidade Metodista de Angola. Lattes Curriculum: 0794001378193198. E-mail: pedro.silva@ugs.edu.ao. ORCID: 0009-0007-0301-5098.





Union's Agenda 2063; a step-by-step replication protocol and an illustrative ICRG calculation are provided. Contributions are theoretical (a novel interdisciplinary conceptual synthesis), methodological (a replicable domain-crossing protocol) and practical (an implementation roadmap for environmental risk governance in Africa).

Keywords: environmental risks; geospatial data; information technology; environment and nature; Africa; Angola; risk management; conceptual innovation.

RESUMO

O continente africano enfrenta uma intensificação sem precedentes de riscos ambientais — secas, inundações, erosão, incêndios florestais, degradação de ecossistemas e acidentes tecnológicos associados a indústrias extrativas — em um contexto de fragilidade institucional, escassez de dados e rápida transformação digital. A literatura científica africana produziu estudos valiosos, porém fragmentados: aplicações de SIG a perigos específicos, estruturas de governança com base geoespacial e reflexões sobre tecnologias da informação; contudo, nenhum trabalho integrou sistemática e conceitualmente os quatro domínios — dados geoespaciais, tecnologia da informação, meio ambiente e natureza, e análise de risco ambiental — em uma única estrutura teórico-operacional de escala continental. Desenvolvido na Universidade Gregório Semedo (Angola), este artigo apresenta o GeoARIA-Africa, a primeira estrutura conceitual africana a realizar tal integração. A metodologia combina uma revisão de literatura exploratória e sistemática (com um *corpus* de 36 estudos) com um método original de convergência de domínios, o qual confirmou a lacuna existente e fundamentou os princípios da estrutura, sua arquitetura de cinco camadas e sua formalização matemática — incluindo o Índice Composto de Risco Geoambiental (ICRG). Discutem-se aplicações prospectivas em cenários angolanos (secas no sul, bacias dos rios Kwanza e Cuango, indústrias extrativas) e a escalabilidade continental, em alinhamento com o Marco de Sendai, os Objetivos de Desenvolvimento Sustentável e a Agenda 2063 da União Africana; apresentam-se também um protocolo de replicação passo a passo e um exemplo ilustrativo de cálculo do ICRG. As contribuições são de natureza teórica (uma síntese conceitual interdisciplinar inédita), metodológica (um protocolo replicável de integração de domínios) e prática (um roteiro de implementação para a governança de riscos ambientais na África).

Palavras-chave: riscos ambientais; dados geoespaciais; tecnologia da informação; meio ambiente e natureza; África; Angola; gestão de riscos; inovação conceitual.

HIGHLIGHTS

- First African conceptual framework to integrate, in a single model, geospatial data, information technologies, environment and nature, and environmental risk analysis.
- Empirically confirmed gap: none of the 36 reviewed studies crosses the four domains simultaneously.





- Composite Geo-environmental Risk Index (ICRG): a spatially explicit metric, communicable in five levels and ready for public decision-making.
- Ten-step replication protocol, applicable by universities, public administrations and community organizations.
- Direct alignment with the Sendai Framework, SDGs 6/11/13/15 and the African Union's Agenda 2063.

LIST OF ACRONYMS AND ABBREVIATIONS

The acronyms used in the text are presented below and explained, in a footnote, at the first occurrence of each term, with the meaning of the cited source or concept.

Acronym	Meaning
AHP	Analytic Hierarchy Process (multi-criteria weighting method)
PHA	Preliminary Hazard Analysis
FTA	Fault Tree Analysis
FMEA	Failure Mode and Effects Analysis
ICRG	Composite Geo-environmental Risk Index (proposed in this article)
IoT	Internet of Things
MCDA	Multi-Criteria Decision Analysis
MODIS	Moderate Resolution Imaging Spectroradiometer (Terra/Aqua satellites sensor)
NDVI	Normalized Difference Vegetation Index
SDGs	Sustainable Development Goals (UN 2030 Agenda)
OGC	Open Geospatial Consortium
SAR	Synthetic Aperture Radar
NbS	Nature-based Solutions





Acronym	Meaning
GIS	Geographic Information System(s)
SMS / USSD	Short Message Service / interactive code-based service on mobile networks
UN-GGIM	UN Committee of Experts on Global Geospatial Information Management
Source: prepared by the author (2026).	

1. INTRODUCTION

1.1 Context and problem

Environmental risk analysis is a well-established scientific field, with quantitative foundations laid since the 1980s (KAPLAN; GARRICK, 1981; COVELLO; MUMPOWER, 1985) and applications ranging from reliability engineering (HENLEY; KUMAMOTO, 1981) to natural disaster management (SMITH, 2013). However, its application to the African continent remains marked by a structural asymmetry: the territories most exposed to hydroclimatic and technological hazards are, as a rule, those with the lowest data density, the least installed analytical capacity and the most fragile information infrastructures (WISNER et al., 2004; OUEDRAOGO et al., 2019). Angola exemplifies this asymmetry: the country lives with recurring droughts in the south, floods and erosion in the Kwanza and Cuango basins, technological risks associated with the oil and mining industries, and health vulnerabilities linked to water and soil quality (COSTA et al., 2018; GAIVÃO et al., 2017).

In parallel, a dual revolution is unfolding that African environmental governance has yet to properly harness. On the one hand, the explosive availability of geospatial data — Earth observation satellite constellations, programmes such as GMES & Africa² and Digital Earth Africa³, and open cloud-processing platforms — has made it possible to observe African

2 GMES & AFRICA - a cooperation programme between the African Union and the European Union (Global Monitoring for Environment and Security) that provides satellite environmental monitoring services to African institutions.

3 DIGITAL EARTH AFRICA - an open-access continental platform that provides analysis-ready Earth observation data and products, making it possible to track the evolution of African territory in time series.





territory at a spatial and temporal resolution unthinkable two decades ago. On the other hand, the accelerated penetration of information technologies – mobile telephony, the Internet of Things (IoT)⁴, cloud computing, big data and artificial intelligence – has created a distributed cognitive infrastructure that includes the citizen themselves as a sensor⁵ (GOODCHILD, 2007).

The scientific problem this article addresses is precisely the absence of synthesis: the four domains – geospatial data, information technologies, environment and nature, and environmental risk analysis – have been treated in Africa as separate disciplinary and institutional silos. African studies apply GIS to isolated hazards (floods, droughts, wildfires, diseases); reflections on digital governance ignore the biophysical dimension of ecosystems; and the environmental risk literature rarely incorporates the technological layer as a structuring variable. As the review presented in Section 4 demonstrates, none of the 36 studies in the analyzed corpus integrates the four domains simultaneously. The research question guiding this work is therefore: how to conceive, ground and operationalize a conceptual framework that crosses, for the first time in the African context, geospatial data, information technologies, environment and nature, and risk analysis, so as to generate geo-environmental intelligence useful to public decision-making?

1.2 Rationale and novelty

The rationale is threefold. Scientifically, domain crossing is a recognized driver of conceptual innovation: the great syntheses of environmental science – from systems ecology to socio-ecological resilience (FOLKE et al., 2010) – were born of disciplinary intersections. Socially, Africa concentrates some of the planet's populations most vulnerable to environmental hazards, and the Sendai Framework for Disaster Risk Reduction 2015–2030⁶ (UNITED NATIONS, 2015) explicitly demands the strengthening of the availability of, and

4 IoT - Internet of Things: a network of physical devices – sensors, meters and low-cost stations – that collect and transmit environmental data in near real time.

5 Citizen as sensor - a concept formulated by Goodchild (2007): the citizen, equipped with mobile devices, functions as a distributed sensor, producing volunteered geographic information (VGI) useful for environmental monitoring.





access to, spatially disaggregated risk data. Institutionally, the African Union's Agenda 2063 and the Sustainable Development Goals (SDGs⁷ 6, 11, 13 and 15) presuppose environmental monitoring capabilities that African states do not yet possess in an integrated manner⁸.

As for novelty, the in-depth bibliographic research carried out detailed in Sections 3 and 4 confirmed that, as of this writing, there is no proposal in the indexed literature for a conceptual framework, model or architecture integrating the four aforementioned domains with a focus on the African continent. Relevant sectoral applications exist (e.g., remote sensing for oil spills in Angola, LUPEDIA et al., 2023; GIS mapping of gullies in Huambo, QUISSINDO et al., 2021; spatial drought assessment in Cape Town, ORIMOLOYE et al., 2019) and geospatial governance frameworks (IBRAHIM et al., 2024), but none crosses the four domains in a unified model. GeoARIA-Africa is, in this sense, the first of its kind on the continent.

1.3 Objectives

General objective: to conceive, theoretically ground and formalize an integrative framework designated GeoARIA-Africa that crosses geospatial data, information technologies, environment and nature, and environmental risk analysis, proposing an operational architecture applicable to Angola and scalable to the African continent.

Specific objectives:

- to systematize the African state of the art in each of the four domains and to confirm, with bibliographic evidence, the absence of prior integration;

6 SENDAI FRAMEWORK - Sendai Framework for Disaster Risk Reduction 2015–2030: a United Nations agreement adopted in Sendai (Japan), which sets four priorities understanding risk, strengthening risk governance, investing in resilience and improving preparedness for response.

7 SDGs - Sustainable Development Goals of the UN 2030 Agenda (2015); particularly relevant to this article are SDG 6 (water and sanitation), SDG 11 (sustainable cities and communities), SDG 13 (climate action) and SDG 15 (life on land).

8 AGENDA 2063 - the African Union's long-term strategic plan, “The Africa We Want”, which defines aspirations for sustainable development, climate resilience and digital transformation of the continent.





- to propose a replicable method of conceptual domain convergence, applicable to other interdisciplinary problems;
- to define the principles, layered architecture and mathematical formalization of GeoARIA-Africa, including the Composite Geo-environmental Risk Index (ICRG);
- to demonstrate the framework's prospective applicability to real Angolan and African scenarios, with an illustrative calculation example;
- to outline contributions to public policies, implementation challenges and a future research agenda.

1.4 Article structure

Section 2 presents the theoretical-conceptual framework of the four domains and their partial intersections. Section 3 describes the methodology. Section 4 presents the state of the art and the empirical confirmation of the gap. Section 5 constitutes the core of the article, with the detailed presentation of GeoARIA-Africa, including the replication protocol. Section 6 explores prospective applications and an illustrative numerical example. Section 7 discusses contributions, challenges and future agenda, and Section 8 concludes.

2. THEORETICAL-CONCEPTUAL FRAMEWORK

2.1 Environmental risk analysis: foundations and evolution

Environmental risk analysis rests on a canonical conceptual triad: hazard, understood as a phenomenon, substance or activity with the potential to cause harm; exposure, as the presence of people, ecosystems or assets in susceptible areas; and vulnerability, as the propensity of exposed systems to suffer harm, determined by physical, social, economic and institutional factors (SMITH, 2013; WISNER et al., 2004). Risk results from the combination of these elements. In the classic quantitative formulation of Kaplan and Garrick (1981)⁹, risk is defined by the triple (scenario, probability, consequence), operationalized in probability ×

⁹ The (scenario; probability; consequence) triple of Kaplan and Garrick (1981) is the canonical quantitative definition of risk and the foundation of the probability × impact matrix (Table 2).





impact matrices, preliminary hazard analyses (PHA), fault tree analyses (FTA) and failure mode and effects analyses (FMEA)¹⁰ (HENLEY; KUMAMOTO, 1981; MARCHETTI, 2015).

The evolution of the field brought two shifts relevant to this article. The first is the passage from risk as a technical property to risk as a socio-ecological construction: disasters are not purely natural events, but revealers of socially produced vulnerabilities (WISNER et al., 2004; FREITAS; MACHADO, 2002). The second is the centrality of resilience — the capacity of a socio-ecological system to absorb disturbances, adapt and transform (FOLKE et al., 2010; MANYENA, 2006) which shifted the focus from response to anticipation. Both shifts demand spatially explicit data and participation mechanisms, which naturally connects this domain to the two that follow.

2.2 Geospatial data and Earth observation in Africa

Geospatial data satellite imagery, digital terrain models, thematic cartography, georeferenced sensor data are today the backbone of environmental monitoring. In Africa, their scientific application has grown remarkably: drought assessment with GIS and remote sensing data in South Africa (ORIMOLOYE et al., 2019), flood susceptibility modelling with multi-criteria approaches, gully mapping on the central Angolan plateau (QUISSINDO et al., 2021), oil spill detection with synthetic aperture radar (SAR) imagery¹¹ off Angola (LUPEDIA et al., 2023) and extraction of vegetation indices and land surface temperature for health studies in northern Angola (TEODORO et al., 2018). Continental initiatives GMES & Africa, Digital Earth Africa, the UN-GGIM Integrated Geospatial Information Framework¹² seek to structure this data supply into decision services.

10 PHA - Preliminary Hazard Analysis; FTA - Fault Tree Analysis; FMEA - Failure Mode and Effects Analysis: classic risk engineering instruments that GeoARIA-Africa spatializes.

11 SAR - Synthetic Aperture Radar: a satellite imaging sensor that operates regardless of cloud cover or solar illumination, widely used in detecting oil spills and floods.

12 UN-GGIM - United Nations Committee of Experts on Global Geospatial Information Management, responsible for the Integrated Geospatial Information Framework (IGIF) adopted by Member States.





Documented limitations nevertheless persist: biases and coverage gaps in global datasets over African territory (GEVAERT et al., 2024), scarcity of in situ monitoring stations for validation, and weak integration of georeferenced local knowledge. The African literature uses geospatial data predominantly as a diagnostic tool for isolated hazards, rarely as a layer of a continuous, multi-domain risk intelligence system.

2.3 Information technologies and environmental digital transformation

The third domain covers the computational infrastructure that enables the capture, storage, processing and dissemination of environmental information: cloud computing, big data, machine learning, IoT with low-cost sensors, mobile applications and citizen science platforms. Africa presents a virtuous paradox here: the penetration rate of mobile telephony far exceeds that of classic scientific infrastructures, enabling leapfrogging¹³ communities without weather stations can nonetheless report floods via SMS or mobile applications. Recent works explore mobile citizen science for environmental justice, spatio-temporal big data for climate-adapted urban green infrastructure, and the integration of geospatial intelligence into e-governance systems. The theory of “citizens as sensors” (GOODCHILD, 2007) provides the epistemological foundation: georeferenced voluntary observation is a legitimate data source, provided it is subject to quality controls.

What the African literature has not yet done is to treat these technologies as the substrate of environmental risk analysis itself that is, as the structuring layer of a system that transforms observation (geospatial) and ecosystems (environment and nature) into risk assessment and governance.

2.4 Environment and nature: the socio-ecological approach and ecosystem services

The fourth domain anchors the framework in biophysical reality: African ecosystems savannas, the Congo and Miombo forests, coastal wetlands, watersheds provide provisioning,

13 LEAPFROGGING - a technological “stage jump”: the direct adoption of advanced solutions without going through the intermediate stages of classic infrastructures (e.g., mobile telephony in regions that never had a fixed network).





regulating, supporting and cultural ecosystem services whose degradation is, in itself, a risk factor (MILLENNIUM ECOSYSTEM ASSESSMENT, 2005). The loss of vegetation cover amplifies erosion and floods; wetland degradation reduces water regulation; biodiversity loss erodes the resilience of rural production systems. The socio-ecological approach (FOLKE et al., 2010) refuses the separation between social and ecological systems: environmental risk emerges from their co-production. This implies that nature is not merely an “exposed object” to risk, but an active variable in its genesis and mitigation a premise that GeoARIA-Africa incorporates into its intelligence layer by treating ecological state indicators (NDVI¹⁴, forest cover, water quality) as inputs to the risk engine.

2.5 Partial intersections and the missing synthesis

Partial intersections between domains exist and are productive: geospatial × risk (hazard mapping), technology × governance (e-gov, national geospatial frameworks), environment × technology (Earth observation decision-support systems). But the quaternary intersection geospatial × information technologies × environment and nature × risk remains empty in the African literature. It is this intersection that this article occupies. The proposed synthesis is not a juxtaposition of disciplines, but a convergence founded on three axioms: (i) all environmental risk is spatially explicit and therefore georeferenceable; (ii) all contemporary risk assessment is computationally mediated; (iii) all environmental risk is, ultimately, an emergent property of socio-ecological systems. From these axioms derive the principles of GeoARIA-Africa (Section 5).

3. METHODOLOGY

3.1 Research design

The research follows a conceptual-analytical design in two phases, typical of theory-proposition articles. Phase 1 consists of an exploratory-systematic literature review, aimed at

14 NDVI - Normalized Difference Vegetation Index: an indicator of vegetation vigor and density derived from satellite imagery, used in this framework as a proxy for ecological state.

Revista *OWL Journal*, Campina Grande - PB, v. 4 n. 9 (2026) - ISSN 2965-2634

A Revista *OWL Journal* está licenciada com uma Licença Creative Commons Atribuição (CC BY)





confirming or refuting the gap hypothesis (the inexistence of quaternary integration). Phase 2 applies an original method of conceptual domain convergence, developed by the author, which transforms the confirmed gap into a theoretical construction: the axioms of Section 2.5 are combined with the foundations of each domain to derive, by qualitative deduction, the principles, components, architecture and mathematical formalization of the new framework.

3.2 Corpus, sources and selection criteria

The corpus was assembled through searches in an open-access academic bibliographic database (a multidisciplinary scientific literature indexer), with three complementary search strings: (a) “geospatial data environmental risk assessment Africa”; (b) “GIS ICT environmental risk Angola”; (c) “integrated framework geospatial information technology environmental governance Africa”. The inclusion criteria were: African geographic focus or applicability to Africa; relevance to at least one of the four domains; publication in a journal, academic publisher or indexed conference; and availability of complete metadata. After deduplication, 36 unique studies were obtained, covering the period 2006–2026, which constitute the empirical basis of the gap analysis in Section 4. To this corpus were added canonical sources from each domain (foundations of risk, resilience, ecosystem services, volunteered geography) and international normative frameworks (Sendai Framework, SDGs, Agenda 2063).

3.3 Gap analysis procedure

Each study in the corpus was classified according to the combination of domains it covers: G (geospatial data), T (information technologies), A (environment and nature) and R (environmental risk analysis). The classification was dichotomous per domain (present/absent), based on the title, abstract and description of the study object. The resulting distribution makes it possible to visualize the occupation of the intersections and to confirm the emptiness of the quaternary intersection ($G \times T \times A \times R$). It is acknowledged that this classification, performed by the author, entails a margin of judgment; to mitigate this risk,





strict rules were adopted: a domain was only marked as present when it constituted the central object, and not a mere backdrop, of the study.

3.4 Conceptual domain convergence method

The method proposed in Phase 2 unfolds in five replicable steps: (1) delimitation of the domains and their core concepts; (2) formulation of compatibility axioms that make the domains commensurable; (3) derivation of guiding principles from the conjunction of the axioms; (4) architecturing organizing the components into functional layers with explicit information flows; and (5) formalization translating the key concepts into testable mathematical expressions. This protocol, applied here for the first time, is itself a methodological contribution, insofar as it disciplines the “crossing of ideas” that interdisciplinary practice often leaves to chance.

3.5 Methodological limitations

Three limitations must be declared. First: the review covered literature indexed predominantly in English and Portuguese; national grey literature (technical reports from ministries and NGOs) may escape the corpus, although it would hardly alter the conclusion about the gap, given its non-conceptual nature. Second: GeoARIA-Africa is a conceptual and formal proposal; its full empirical validation will require subsequent pilot studies, which Section 7 frames as a future agenda. Third: the applications in Section 6 are prospective and illustrative, based on secondary evidence and on duly flagged hypothetical values, not on primary data collected by the author.

4. STATE OF THE ART AND CONFIRMATION OF THE GAP

4.1 Distribution of African scientific output by domain combination

The classification of the 36 studies in the corpus according to the domains G (geospatial), T (information technologies), A (environment and nature) and R (environmental





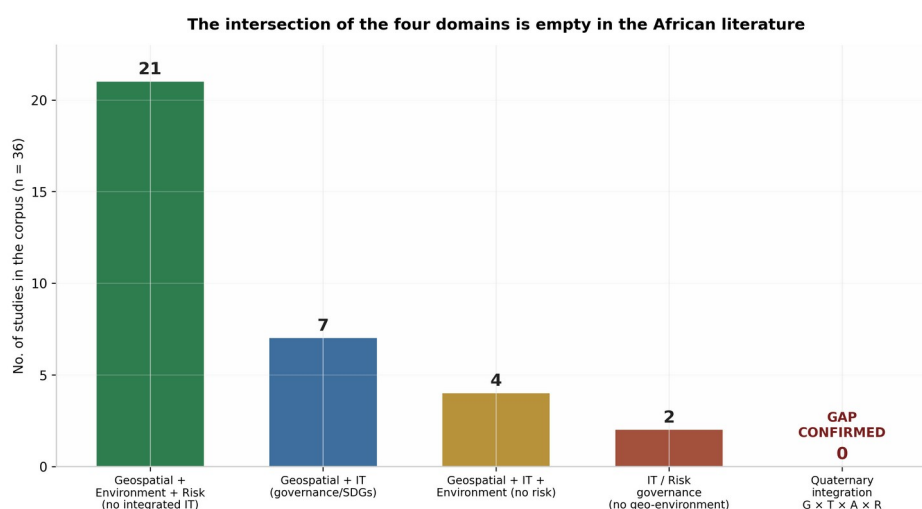
risk) produced the distribution shown in Table 1 and Figure 1. The pattern is unequivocal: the overwhelming majority of output (21 studies, 58%) concentrates on the geospatial-environment-risk triad, typically as an application of GIS and remote sensing to a single hazard; a second group (7 studies) articulates geospatial data and information technologies, but in the service of governance and the SDGs, without a risk analysis engine; four studies integrate Earth observation, technology and environment without formalizing risk; and two address risk governance without a geo-environmental layer. The quaternary integration cell is empty.

Table 1 – Classification of the corpus (n = 36) by domain combination

Domain combination	No. of studies	Representative examples from the corpus	Dominant focus
G + A + R (no integrated T)	21	Orimoloye et al. (2019) - drought, South Africa; Lupedia et al. (2023) - oil spills, Angola; Quissindo et al. (2021) - gullies, Huambo; Redshaw et al. (2017) - landslides, sub-Saharan Africa	Sectoral hazards
G + T (no integrated R/A)	7	Ibrahim et al. (2024) - geoinformatics and SDGs; national geospatial framework for the SDGs (2020); geospatial intelligence in e-governance (2023)	Governance and data
G + T + A (no R)	4	Earth observation decision-support system, Lake Nokoué (2021); big data and urban green infrastructure (2025); mobile citizen science and environmental justice (2026)	Environmental decision
T / risk governance (no G-A)	2	Okunola (2025) - multilevel disaster risk governance post-Sendai; Gevaert et al. (2024) - geospatial data biases	Institutions
G + T + A + R (quaternary integration)	0	No study identified in the indexed literature	GAP
Source: prepared by the author (2026), based on the review described in Section 3.			



Figure 1 – Domain coverage in the reviewed corpus: no African study integrates the four domains simultaneously



Source: prepared by the author (2026), based on the corpus of Section 3.

4.2 Critical synthesis: what has already been done

Among geospatial applications to risk, Angolan works stand out: Lupedia et al. (2023) demonstrated the feasibility of oil spill detection with SAR imagery feeding a web-GIS platform; Quissindo et al. (2021) mapped gullies in the peripheral zones of Huambo; Teodoro et al. (2018) developed an open-source GIS application for extracting NDVI and land surface temperature from MODIS data¹⁵; and Matos et al. (2021) applied multi-criteria analysis with QGIS to coastal sanitation in northern Angola. At the continental level, the spatial assessments of drought (ORIMOLOYE et al., 2019), landslides (REDSHAW et al., 2017) and floods deserve mention, as do the reviews on joint applications of remote sensing and GIS to disaster management (AMATEBELLE et al., 2025). In governance, strategic geospatial frameworks (IBRAHIM et al., 2024) and the reflection on institutional silos in disaster risk governance (OKUNOLA, 2025) approach the problem, but remain at the institutional level, without a technical integration architecture.

15 MODIS - Moderate Resolution Imaging Spectroradiometer: a sensor aboard NASA's Terra and Aqua satellites, with near-daily observation of vegetation, land surface temperature and fire hotspots.



4.3 The confirmed gap and its opportunity

The evidence allows us to state with confidence that, as of this research, there is no conceptual framework, model or architecture in the indexed scientific literature that simultaneously crosses geospatial data, information technologies, environment and nature, and environmental risk analysis with a focus on the African continent. The gap is not only quantitative (number of studies) but structural: the domains evolve at different paces and in different languages, and no work has proposed the compatibility axioms that would allow their convergence. It is this task that Section 5 performs, making this article, as far as the review could ascertain, the first of its kind at the continental level.

5. THE GEOARIA-AFRICA FRAMEWORK: A NOVEL CONCEPTUAL PROPOSAL

5.1 Genesis, designation and guiding principles

The framework proposed here is designated GeoARIA-Africa, an acronym that condenses its constituents: Geo (geospatial data), A (environment and nature), R (environmental risk), I (information/information technologies) and A (Africa). The designation also evokes the idea of an “aria” a composition in which a singular voice emerges from an orchestra — a metaphor for the risk intelligence that emerges from the orchestration of the four domains. The framework arises from applying the conceptual convergence method (Section 3.4) to the axioms formulated in Section 2.5, from which five guiding principles derive:

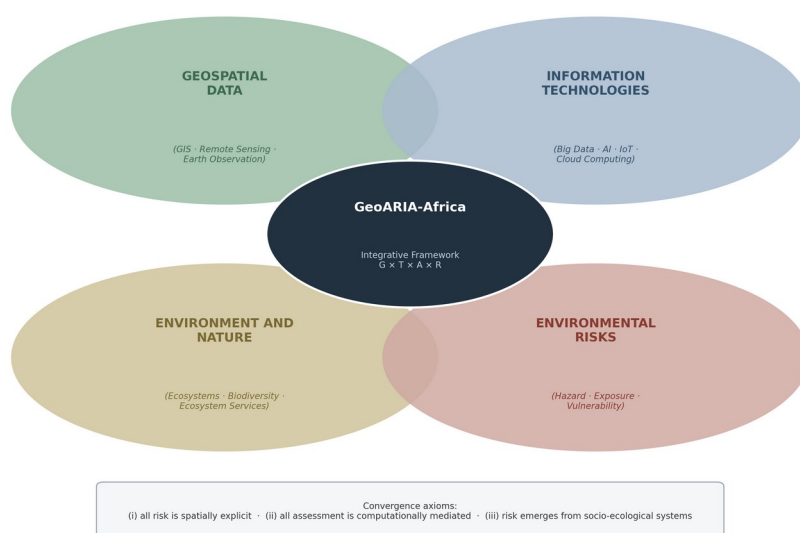
- **P1 - Integral spatiality:** every element of the system (hazard, exposure, vulnerability, ecological state, governance action) is represented as a georeferenced object, with declared spatial resolution;
- **P2 - Computational mediation:** no risk assessment exists outside an auditable, reproducible and preferably open-source data processing chain;





- **P3 - Nature as an active variable:** ecosystems integrate the risk engine both as exposed assets and as natural mitigation infrastructure, through nature-based solutions (NbS)¹⁶;
- **P4 - Citizen as sensor:** georeferenced community observation is a legitimate data source, subject to quality controls and ethical protocols;
- **P5 - Data sovereignty and equity:** the infrastructure must respect African sovereignty over its data and correct rather than amplify the coverage biases documented in the literature (GEVAERT et al., 2024).

Figure 2 - Conceptual crossing of the four domains that give rise to GeoARIA-Africa
From disciplinary silo to quaternary convergence: the genesis of GeoARIA-Africa



Source: prepared by the author (2026).

5.2 Five-layer architecture

The GeoARIA-Africa architecture is organized into five functional layers with an upward flow of evidence and a downward flow of decision feedback (Figure 3; Table 2). Layer 1 ensures observation: satellite data from open missions, in situ network data and 16 NbS - Nature-based Solutions: interventions that mobilize ecosystems — mangrove restoration, wetlands and vegetation cover to reduce risks such as floods, erosion and droughts.

Revista *OWL Journal*, Campina Grande - PB, v. 4 n. 9 (2026) - ISSN 2965-2634

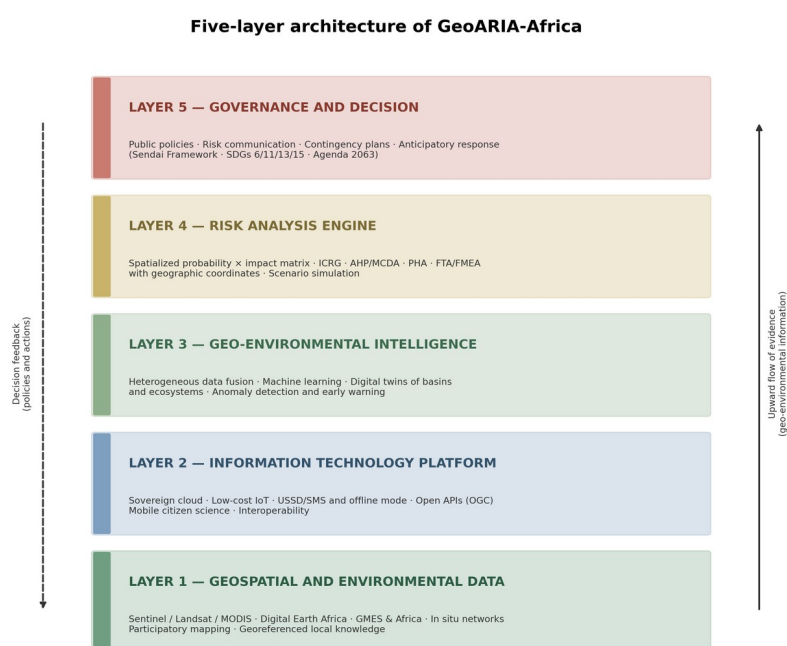
A Revista *OWL Journal* está licenciada com uma Licença *Creative Commons Atribuição (CC BY)*





participatory mapping. Layer 2 provides the technological substrate: ingestion, cloud storage, interoperability through open standards and citizen science channels adapted to the African connectivity context (USSD/SMS¹⁷, offline mode). Layer 3 is the cognitive core: fusion of heterogeneous data, machine learning for anomaly and trend detection, and simplified digital twins¹⁸ of critical socio-ecological systems (watersheds, biodiversity corridors, coastal zones). Layer 4 performs the risk analysis proper, spatializing the classic instruments (probability × impact matrix, PHA, FTA, FMEA) and computing the ICRG (Section 5.3). Layer 5 converts intelligence into action: dashboards for decision-makers, culturally appropriate risk communication protocols, contingency plans and articulation with international normative instruments.

Figure 3 – Five-layer architecture of GeoARIA-Africa, with upward (evidence) and downward (feedback) flows



Source: prepared by the author (2026).

17 USSD - Unstructured Supplementary Service Data: a mobile network protocol that enables interactive services through simple codes (e.g., *123#), without the need for internet; SMS is the short message service. Both are channels suited to low-connectivity rural areas.

18 DIGITAL TWIN - a dynamic virtual replica of a real system (watershed, ecosystem or city), fed by data, that allows scenarios to be simulated before any intervention in the territory.

Revista *OWL Journal*, Campina Grande - PB, v. 4 n. 9 (2026) - ISSN 2965-2634

A Revista *OWL Journal* está licenciada com uma Licença Creative Commons Atribuição (CC BY)





Table 2 - Components, data sources and functions of the GeoARIA-Africa layers

Component	African data sources	Function in GeoARIA-Africa
Layer 1 - Geospatial and environmental data	Sentinel/Landsat/MODIS; Digital Earth Africa; GMES & Africa; national hydrometeorological networks; community participatory mapping	Continuous observation of the territory; georeferencing of hazards, exposure and ecological state
Layer 2 - IT platform	Public/sovereign cloud; low-cost IoT sensors; USSD/SMS and mobile applications; open APIs (OGC standards)	Data ingestion, storage, interoperability and access, including citizen science
Layer 3 - Geo-environmental intelligence	Machine learning models; data fusion; time series; digital twins of basins and ecosystems	Transformation of data into hazard, vulnerability and trend indicators; early warning
Layer 4 - Risk analysis engine	Spatialized probability × impact matrices; AHP/MCDA; ICRG; scenario simulation	Quantification, classification and spatial prioritization of environmental risks
Layer 5 - Governance and decision	Decision dashboards; risk communication protocols; contingency plans; articulation with Sendai/SDGs/Agenda 2063	Conversion of intelligence into public policies, emergency response and community participation
<i>Source: prepared by the author (2026).</i>		

5.3 Formalization: from classic risk to the Composite Geo-environmental Risk Index

The classic quantitative definition of risk (KAPLAN; GARRICK, 1981) relates the probability of occurrence of a scenario to the magnitude of its consequences, operationalized in the risk matrix (Table 3):

$$R = P \times I$$

where R is the risk level, P the probability of the hazardous event and I the expected impact on people, ecosystems and assets. GeoARIA-Africa spatializes and enriches this formulation, proposing the Composite Geo-environmental Risk Index (ICRG) for each territorial unit *i* (grid cell, sub-basin or municipality):

Revista *OWL Journal*, Campina Grande - PB, v. 4 n. 9 (2026) - ISSN 2965-2634

A Revista *OWL Journal* está licenciada com uma Licença Creative Commons Atribuição (CC BY)





$$ICRG_i = V_i \cdot E_i \cdot (w_1H_{1i} + w_2H_{2i} + \dots + w_kH_{ki})$$

where $V(i)$ is the socio-ecological vulnerability index of territorial unit i (social, economic, institutional and ecological dimensions, aggregated by multi-criteria analysis), $E(i)$ is the exposure index (population, infrastructure, agricultural areas and ecosystems in the affectable zone), the $H(k,i)$ are the spatialized intensities of the k hazards considered (drought, flood, erosion, wildfire, technological contamination, among others), estimated from the geospatial layers of Layer 1, and the $w(k)$ are weights calibrated by the analytic hierarchy process (AHP)¹⁹ with validation by experts and communities. The ICRG varies on a normalized scale $[0, 1]$ and is classified into five levels consistent with the classic risk matrix (0.00–0.20: very low; 0.21–0.40: low; 0.41–0.60: moderate; 0.61–0.80: high; 0.81–1.00: very high), allowing direct reading by non-specialist managers. The formal innovation lies in the triple origin of the inputs: the $H(k,i)$ come from geospatial data processed by the IT infrastructure; $V(i)$ explicitly incorporates the state of nature (ecological indicators); and the final aggregation is computationally mediated the three signatures of the quaternary crossing.

Table 3 - Probability × impact risk matrix, spatialized in GeoARIA-Africa per territorial unit

Probability × Impact	I1 - Insignificant	I2 - Minor	I3 - Moderate	I4 - Major	I5 - Catastrophic
P5 - Almost certain	High	High	Very high	Very high	Very high
P4 - Likely	Moderate	High	High	Very high	Very high
P3 - Possible	Low	Moderate	High	High	Very high
P2 - Unlikely	Low	Low	Moderate	High	High
P1 - Rare	Very low	Low	Moderate	High	High

Source: prepared by the author (2026), adapted from Smith (2013) and Henley and Kumamoto (1981).

19 AHP - Analytic Hierarchy Process: a multi-criteria analysis method (MCDA) that derives weights from pairwise comparisons by experts; in GeoARIA-Africa it calibrates the hazard weights $w(k)$.

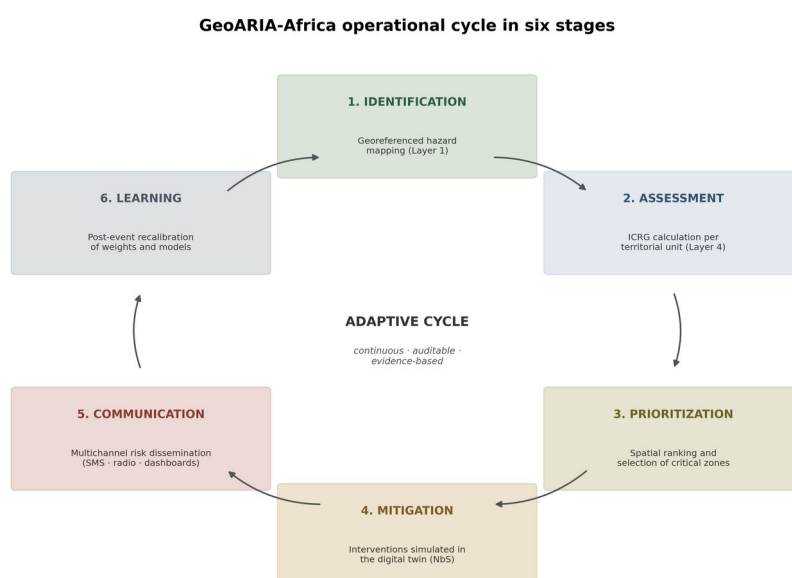




5.4 Operational cycle

Operationally, GeoARIA-Africa runs in a continuous six-stage cycle (Figure 4): (1) identification georeferencing of hazards from the data layers; (2) assessment calculation of the ICRG per territorial unit and classification by the matrix; (3) prioritization spatial ranking of risks and selection of critical units; (4) mitigation design of interventions, including nature-based solutions, simulated in the digital twin before execution; (5) communication multichannel dissemination of risk to populations and decision-makers; and (6) learning feeding post-event observations back to recalibrate weights and models, closing the adaptive cycle. The cycle incorporates the classic instruments of the risk analysis module (PHA, FTA, FMEA) in their spatialized version: every failure mode, every branch of the fault tree, gains geographic coordinates.

Figure 4 – GeoARIA-Africa operational cycle in six stages



Source: prepared by the author (2026).



5.5 Data governance, ethics and equity

Principle P5 imposes a data governance sub-framework: (i) data generated on African territory must have a sovereign replica on continental or national infrastructure; (ii) citizen science requires informed consent, anonymization and return of value to the communities that produce the data; (iii) machine learning models must be audited for coverage biases, given that global datasets under-represent African territory (GEVAERT et al., 2024); and (iv) open data must be the rule FAIR and OGC standards²⁰ with exceptions only for security-sensitive data or the location of endangered species.

5.6 GeoARIA-Africa replication protocol

To make the framework effectively applicable and replicable by other teams and institutions, its adoption process is systematized into ten operational steps, designed for resource-limited contexts and executable with open-source tools (QGIS, free-access Earth observation platforms and spreadsheets):

- **Step 1 - Territorial delimitation:** define the analysis unit (municipality, sub-basin or regular grid) and the working spatial resolution, declaring it explicitly (P1).
- **Step 2 - Hazard inventory:** survey the relevant hazards (drought, flood, erosion, wildfire, contamination) and the data sources available in Layer 1, including georeferenced local knowledge.
- **Step 3 - Data normalization:** convert each layer to the [0, 1] scale and to the common territorial unit, documenting the processing chain (P2).
- **Step 4 - Calculation of hazard intensities $H(k,i)$:** derive the spatialized intensity of each hazard from satellite indices, models and historical records.

20 OGC - Open Geospatial Consortium: an international consortium that defines open geospatial interoperability standards; FAIR - data management principles: Findable, Accessible, Interoperable and Reusable.





- **Step 5 - Vulnerability index $V(i)$:** aggregate social, economic, institutional and ecological indicators by multi-criteria analysis, incorporating the state of nature (P3).
- **Step 6 - Exposure index $E(i)$:** quantify population, infrastructure, agricultural areas and ecosystems in the affectable zone.
- **Step 7 - Participatory AHP weighting:** calibrate the weights $w(k)$ with experts and community representatives, recording the judgments for audit (P4).
- **Step 8 - ICRG calculation and classification:** apply the formula of Section 5.3, classify the territorial units into the five levels and produce the risk map.
- **Step 9 - Translation into decision:** convert the results into budgeting, licensing, anticipatory response and risk communication priorities (Layer 5).
- **Step 10 - Monitoring and recalibration:** compare forecasts with observed events, recalibrate weights and models, and publish the data under open standards (P5), restarting the cycle.

This protocol can be executed by a multidisciplinary team of three to five members (geographer/GIS specialist, IT technician, environmental specialist and community agents) in a pilot cycle of six to twelve months, with low marginal costs when open data and software are used an essential condition for its adoption by African universities and public administrations.

6. PROSPECTIVE APPLICATION TO AFRICAN AND ANGOLAN SCENARIOS

To demonstrate the conceptual operability of GeoARIA-Africa, four prospective applications are presented formulated as implementation scenarios and not as empirical results, since field validation constitutes a subsequent stage of the research together with an illustrative ICRG calculation with hypotheticalal values.





6.1 Recurring droughts in southern Angola

In the provinces of Cunene, Namibe and Huíla, hydroclimatic variability has produced severe droughts with documented humanitarian impacts (COSTA et al., 2018; GAIVÃO et al., 2017). In GeoARIA-Africa, Layer 1 would provide satellite-derived vegetation index series and precipitation anomalies; Layer 2 would integrate community reports via SMS on the state of boreholes and pastures; Layer 3 would detect trends and issue early warnings three to six months in advance; Layer 4 would calculate the ICRG per municipality, crossing drought intensity with agro-pastoral exposure and food vulnerability; and Layer 5 would activate anticipatory response protocols (distribution of resilient seeds, reinforcement of water points) before the peak of the crisis realizing the paradigm shift from reaction to anticipation advocated by the Sendai Framework (UNITED NATIONS, 2015).

6.2 The Kwanza and Cuango watersheds

The Kwanza and Cuango basins concentrate seasonal floods, accelerated erosion and pressures on water quality, downstream of urban centers and diamond mining. Applying the framework would make it possible to build simplified digital twins of the sub-basins, simulating extreme rainfall scenarios and mining tailings dam failures; the spatialized risk matrix (Table 3) would identify riverbank stretches with critical ICRG, guiding land-use planning and the definition of protection strips. Participatory mapping would incorporate riverside communities' knowledge of historical flood levels data absent from the country's short instrumental series.

6.3 Technological risks of the extractive industry

The offshore oil industry and mining impose low-frequency, high-impact technological risks. The feasibility of spill detection with SAR imagery has already been demonstrated for Angola (LUPEDIA et al., 2023); GeoARIA-Africa generalizes this logic: SAR and optical sensors (Layer 1) feed plume drift models (Layer 3), whose output enters the risk engine as a technological hazard $H(k,i)$, combined with the exposure of sensitive coastal ecosystems





mangroves, artisanal fishing zones and with the socio-economic vulnerability of dependent communities. Layer 5 would link the alerts to national contingency plans and environmental accountability mechanisms.

6.4 Continental scalability

The architecture is deliberately continental: the data sources (Digital Earth Africa, GMES & Africa) cover the entire territory; the interoperability standards are international; and the ICRG formalization is independent of administrative scale. A national pilot in Angola could be replicated, with recalibration of weights and vulnerability layers, in Mozambique (cyclonic floods), in the Sahel region (drought and degradation) or in East Africa (landslides and volcanic risks), creating the basis of an African geo-environmental risk intelligence system, aligned with Agenda 2063 and with the African Union's disaster risk reduction mechanisms.

6.5 Illustrative ICRG calculation example

To make the formalization of Section 5.3 concrete and reproducible, a didactic example with hypothetical values is presented for a fictitious territorial unit (“Municipality X”), representative of a municipality in the Angolan semi-arid region. The values do not result from primary data collection; they serve only to demonstrate the calculation mechanics that any team can replicate with its own data.

Table 4 – Illustrative ICRG calculation for “Municipality X” (hypothetical values)

Component	Value	Source / calculation	Observation
Socio-ecological vulnerability V(i)	0.78	Aggregated social, economic, institutional and ecological indicators (MCDA)	High agro-pastoral dependence; limited institutional capacity
Exposure E(i)	0.72	Population, infrastructure, agricultural areas and ecosystems in the affectable zone	High population concentration in risk zones





Component	Value	Source / calculation	Observation
Hazard 1 - Drought ($w_1 = 0.35$)	0.90	Precipitation and NDVI anomalies (Layer 1)	Dominant hazard in the semi-arid region
Hazard 2 - Flood ($w_2 = 0.25$)	0.65	Flood-prone area mapping	Episodic, but severe
Hazard 3 - Erosion ($w_3 = 0.20$)	0.75	Digital terrain model and vegetation cover	Expanding gullies
Hazard 4 - Wildfire ($w_4 = 0.12$)	0.50	MODIS heat spots	Seasonal
Hazard 5 - Contamination ($w_5 = 0.08$)	0.35	Water quality records	Localized
Weighted sum of hazards $\Sigma w(k) \cdot H(k,i)$	0.72	$0.35 \times 0.90 + 0.25 \times 0.65 + 0.20 \times 0.75 + 0.12 \times 0.50 + 0.08 \times 0.35$	Rounded to two decimal places
ICRG(i) = $V(i) \cdot E(i) \cdot \Sigma w(k) \cdot H(k,i)$	0.40	$0.78 \times 0.72 \times 0.72$	MODERATE level, at the upper threshold of the class
Source: prepared by the author (2026) - didactic example with hypothetical values, without primary data collection.			

Reading the result: an ICRG of 0.40 places “Municipality X” at the moderate level, at the upper threshold of the class a situation that, in the operational cycle (Section 5.4), would recommend reinforced surveillance, anticipatory response in the following dry season and priority in budgeting for water points and drought-tolerant seeds. The transparency of each component allows local teams to replace each value with their own data and repeat the calculation, fulfilling principle P2 of auditable computational mediation.

7. DISCUSSION: CONTRIBUTIONS, CHALLENGES AND FUTURE AGENDA

7.1 Theoretical and methodological contributions

The first contribution is theoretical: GeoARIA-Africa demonstrates that the quaternary intersection between geospatial data, information technologies, environment and nature, and



risk analysis is not a sum of disciplines, but a new theoretical object, with its own axioms (Section 2.5), principles (P1–P5) and formalization (ICRG). By treating nature as an active variable of the risk engine and the citizen as a legitimate sensor, the framework extends socio-ecological resilience theory (FOLKE et al., 2010) into the computational domain and extends the quantitative definition of risk (KAPLAN; GARRICK, 1981) into the spatial domain. The second contribution is methodological: the five-step conceptual convergence protocol (Section 3.4) is transferable to other interdisciplinary problems planetary health, water security, food risks offering a disciplined procedure for the “crossing of ideas” that the interdisciplinary literature often invokes without operationalizing.

7.2 Practical and public policy contributions

At the practical level, the framework offers a concrete roadmap for Angola and, by extension, other African states to convert dispersed investments in Earth observation and digitalization into a coherent environmental risk management system, responding to the Sendai Framework's call for accessible and disaggregated risk data (UNITED NATIONS, 2015) and to SDGs 6, 11, 13 and 15. The ICRG, being a single, spatially explicit index communicable in five levels, is instrumentally suited to territorial-priority budgeting, environmental licensing and the activation of anticipatory response. The replication protocol (Section 5.6) and the illustrative example (Section 6.5) lower the entry barrier for technical teams with limited resources, a decisive condition for the framework's real impact on communities.

7.3 Implementation challenges

Implementation faces real challenges, systematized in Table 5 with the respective mitigation strategies already inscribed in the framework's design. Scientific honesty requires acknowledging that no conceptual architecture eliminates, by itself, financing, capacity and institutional coordination constraints but a well-architected framework reduces the cost of each subsequent stage and avoids duplicated investments in silos.





Table 5 - Implementation challenges and strategies inscribed in GeoARIA-Africa

Challenge	Manifestation in the African context	Strategy proposed in GeoARIA-Africa
Infrastructure and connectivity	Unequal network coverage; power outages; data costs	Offline-first architecture; USSD/SMS channels; edge computing at provincial hubs
Installed technical capacity	Scarcity of specialists in GIS, data science and risk modelling	Open source and network training with African universities; local master's programmes
Sustainable financing	Dependence on short-term external projects	Integration into national civil protection budgets and climate financing mechanisms
Data quality and bias	African under-representation in global datasets; short instrumental series	Bias auditing; citizen science as a complement; local calibration (P4, P5)
Institutional fragmentation	Silos between civil protection, environment, mines and telecommunications	Layer 5 as a neutral decision space; interministerial sharing protocols
Data sovereignty and ethics	Data extraction by external platforms without local return	Sovereign replicas; consent and return of value to communities
<i>Source: prepared by the author (2026).</i>		

7.4 Future research agenda

The future agenda unfolds along four lines: (i) empirical validation of the ICRG in an Angolan municipal or sub-basin pilot, with primary data collection; (ii) development of an open software prototype of Layers 2 to 4, in collaboration with African graduate programmes; (iii) research on the effects of mobile-phone-mediated risk communication in rural communities; and (iv) extension of the conceptual convergence method to other pairs of domains, assessing its generality. The submission of the framework to the appreciation of African and Iberian scientific networks is also foreseen, promoting the peer review that this proposal, given its inaugural character, requires.





8. FINAL CONSIDERATIONS

This article proposed GeoARIA-Africa, the first conceptual framework of continental African scope to cross, in an integrated and formally grounded manner, geospatial data, information technologies, environment and nature, and environmental risk analysis. The review of 36 studies confirmed the gap: no previous publication had operated the quaternary integration carried out here, which confers on the work its novel character at the continental level. The contributions are theoretical (a conceptual synthesis with its own axioms, principles and mathematical formalization), methodological (a replicable domain convergence protocol) and practical (a five-layer architecture, a ten-step replication protocol and an implementation roadmap aligned with the Sendai Framework, the SDGs and Agenda 2063).

For Angola a country that simultaneously faces droughts, floods, erosion and extractive technological risks, and is undergoing an expansion of its digital and spatial capabilities GeoARIA-Africa offers the opportunity of a leapfrog: to build, from now on, environmental risk governance upon the convergence of the four domains, instead of repeating the fragmented path that other regions had to undo at great cost. Gregório Semedo University, by hosting this proposal, positions itself at the frontier of African environmental scientific production. The invitation this article extends is one of collaboration: may Angolan, African and international institutions join in the validation, refinement and implementation of the framework, transforming a pioneering concept into a concrete instrument for protecting the continent's nature and populations.

REFERENCES

AFRICAN UNION. Agenda 2063: The Africa We Want. Addis Ababa: African Union Commission, 2015.

AMATEBELLE, C. E.; OWOLABI, S. T.; OGUNDEJI, A. A. et al. A systematic analysis of remote sensing and geographic information system applications for flood disaster risk management. *Journal of Spatial Science*, 2025.

Revista OWL Journal, Campina Grande - PB, v. 4 n. 9 (2026) - ISSN 2965-2634

A Revista OWL Journal está licenciada com uma Licença Creative Commons Atribuição (CC BY)





- COSTA, A. M. et al. Natural risks in Angola: vulnerability and disasters in the context of southern Angola. *Journal of Geography and Territorial Planning*, n. 15, p. 45-68, 2018 [in Portuguese].
- COVELLO, V. T.; MUMPOWER, J. Risk analysis and risk management: a historical perspective. *Risk Analysis*, v. 5, n. 2, p. 103-120, 1985.
- FOLKE, C. et al. Resilience thinking: integrating resilience, adaptability and transformability. *Ecology and Society*, v. 15, n. 4, p. 20, 2010.
- FREITAS, C. M.; MACHADO, J. M. H. Risks, disasters and society. *Science and Collective Health*, v. 7, n. 3, p. 473-478, 2002 [in Portuguese].
- GAIVÃO, A. et al. Natural disasters in Angola: vulnerability analysis and mitigation proposals. *UAN Scientific Journal*, v. 12, n. 1, p. 23-41, 2017 [in Portuguese].
- GEVAERT, C. M.; BUUNK, T. et al. Auditing geospatial datasets for biases: using global building datasets for disaster risk management. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, 2024.
- GOODCHILD, M. F. Citizens as sensors: the world of volunteered geography. *GeoJournal*, v. 69, n. 4, p. 211-221, 2007.
- HENLEY, E. J.; KUMAMOTO, H. *Reliability Engineering and Risk Assessment*. Englewood Cliffs: Prentice-Hall, 1981.
- IBRAHIM, R. E.; ABOU EL-MAGD, I.; MOTSHEGWA, T. et al. The role of open science and geoinformatics in advancing sustainable development goals in Africa: a strategic framework and an action plan. *Data Science Journal*, v. 23, 2024.
- KAPLAN, S.; GARRICK, B. J. On the quantitative definition of risk. *Risk Analysis*, v. 1, n. 1, p. 11-27, 1981.
- KATES, R. W. et al. Transformational adaptation when incremental adaptations to climate change are insufficient. *Proceedings of the National Academy of Sciences*, v. 109, n. 19, p. 7156-7161, 2012.
- LUPEDIA, L.; CACHINJUMBA, A.; JUNIOR, J.; LISSOUBA, A. et al. Use of SAR imagery for oil spill detection and mapping in Angola. In: *Space Fostering African Societies*. Cham: Springer, 2023.
- MANYENA, S. B. The concept of resilience revisited. *Disasters*, v. 30, n. 4, p. 434-450, 2006.
- MARCHETTI, D. *Risk Analysis: Fundamentals and Applications*. Curitiba: Juruá Editora, 2015 [in Portuguese].





- MARENGO, J. A. et al. The role of climate change in natural disasters in Africa. *Environmental Research Letters*, v. 13, n. 9, 2018.
- MATOS, R. V.; FERREIRA, F.; ALVES, L.; RAMOS, E.; COSTA, L. et al. Multi-criteria framework for selection of city-wide sanitation solutions in coastal towns in northern Angola. *Sustainability*, v. 13, n. 10, 5627, 2021.
- MILLENNIUM ECOSYSTEM ASSESSMENT. *Ecosystems and Human Well-being: Synthesis*. Washington, DC: Island Press, 2005.
- OKUNOLA, O. H. Beyond institutional silos: rethinking multilevel disaster risk governance in Africa a decade into the Sendai Framework implementation. *International Journal of Disaster Risk Reduction*, 2025.
- ORIMOLOYE, I. R.; OLOLADE, O. O.; MAZINYO, S. P.; KALUMBA, A. M. et al. Spatial assessment of drought severity in Cape Town area, South Africa. *Heliyon*, v. 5, n. 7, 2019.
- OUEDRAOGO, I. et al. Environmental risk assessment in West Africa: challenges and perspectives. *Journal of Environmental Management*, v. 250, 2019.
- PERROW, C. *Normal Accidents: Living with High-Risk Technologies*. New York: Basic Books, 1984.
- QUISSINDO, I. A. B.; SAMANJATA, U. N. J. et al. GIS applied to ravine mapping in the peripheral zones of Huambo (Central Angolan Plateau). In: *IST-Africa Conference Proceedings*. IEEE, 2021.
- REDSHAW, P.; DIJKSTRA, T.; FREE, M.; JORDAN, C. et al. Landslide risk assessment for the built environment in sub-Saharan Africa. In: *Workshop on World Landslide Forum*. Cham: Springer, 2017.
- SMITH, H.; JENKINS, P. Trans-disciplinary research and strategic urban expansion planning in a context of weak institutional capacity: case study of Huambo, Angola. *Habitat International*, v. 46, p. 244-251, 2015.
- SMITH, K. *Environmental Hazards: Assessing Risk and Reducing Disaster*. 6. ed. London: Routledge, 2013.
- TEODORO, A. C.; DUARTE, L.; BARRADAS, P.; MATEUS, T. L.; NETO, Z. NDVI and LST extraction of MODIS data under a GIS open source application — Rickettsia study case in Angola. *Repository of the Polytechnic Institute of Viana do Castelo*, 2018.





UNITED NATIONS. Sendai Framework for Disaster Risk Reduction 2015-2030. Geneva: UNISDR, 2015.

WISNER, B. et al. At Risk: Natural Hazards, People's Vulnerability and Disasters. 2. ed. London: Routledge, 2004.

ZABALA, A. et al. Community-based disaster risk management in rural Africa: lessons from Angola and Mozambique. *Disasters*, v. 42, n. 4, p. 689-710, 2018

FINAL DECLARATIONS

Declaration of originality and absence of plagiarism: the author declares that this article is the result of original authorship; that all third-party ideas, data and formulations are duly cited in the text and referenced in the bibliography, in the author-date system; and that the text was written originally, containing no form of plagiarism, self-plagiarism or undue appropriation of content.

Figures and tables: all figures (Figures 1 to 4) and tables (Tables 1 to 5) were prepared by the author (2026), as indicated in their respective sources; where classic matrices were adapted, the provenance is explicitly indicated.

Footnotes: the footnotes present the meaning of the acronyms, concepts and cited sources at their first occurrence, to facilitate reading by the international scientific community and by non-specialist decision-makers.

Data availability: the review's bibliographic corpus and the domain classification codes are available upon request to the author, in accordance with the FAIR principles.

Funding: this research received no specific funding from public, commercial or non-profit agencies.

Conflicts of interest: the author declares that there are no conflicts of interest associated with this publication.

Authorship contribution: Pedro Silva conception, methodology, analysis, original writing, review and editing (sole author).



REVISTA OWL (*OWL Journal*)

www.revistaowl.com.br – ISSN: 2965-2634



Acknowledgements: to Gregório Semedo University (Luanda, Angola), for the institutional research environment, and to the African and international scientific communities whose future dialogue this article invites.

Recebido em: 10/08/2026

Aprovado em: 29/08/2026

Publicado em: 17/09/2026

Revista *OWL Journal*, Campina Grande - PB, v. 4 n. 9 (2026) - ISSN 2965-2634

A Revista *OWL Journal* está licenciada com uma Licença Creative Commons Atribuição (CC BY)

