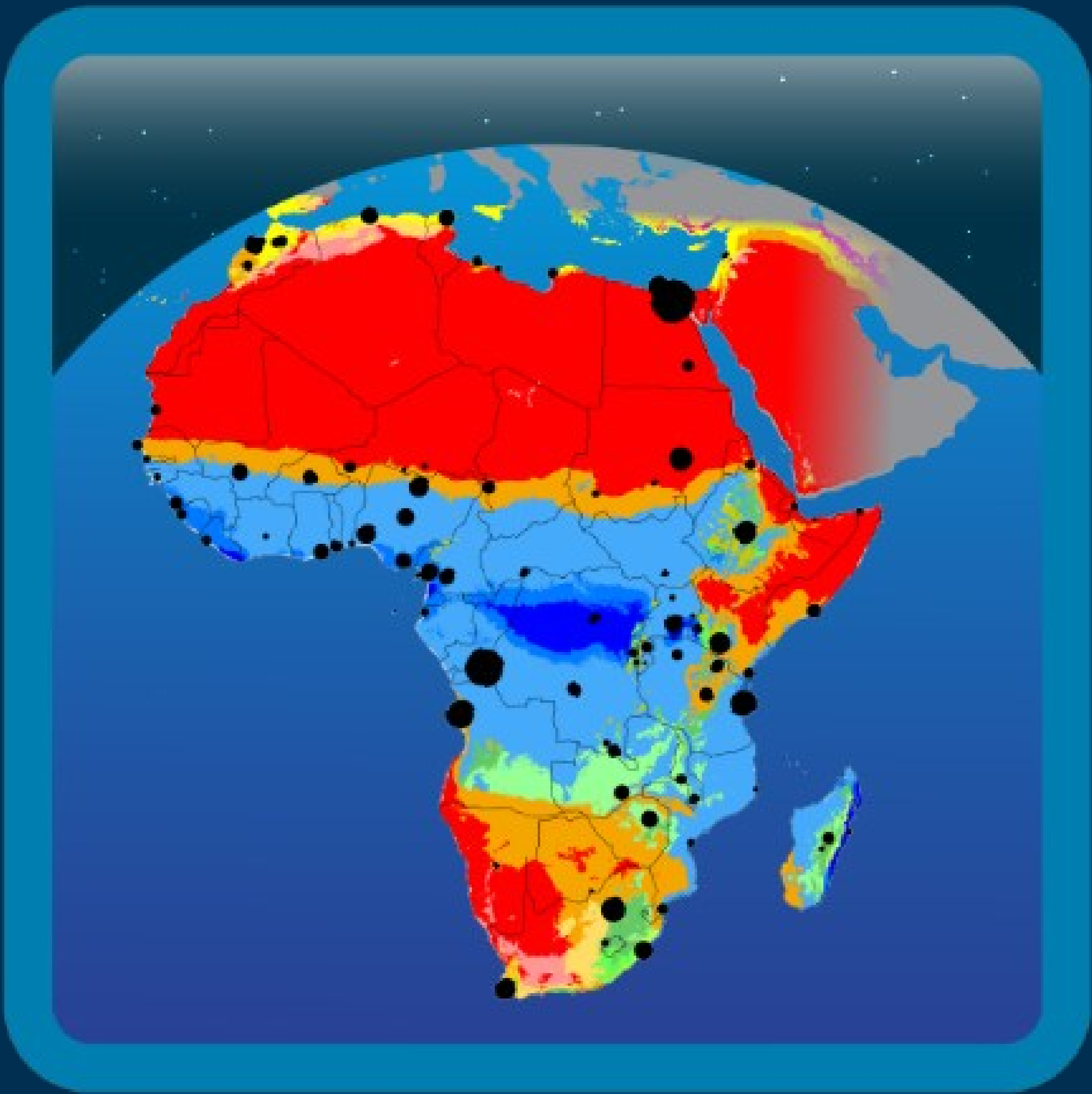

CLIMATE ANALYSIS IN AFRICAN CITIES (CAIAC)

D1.2 Science Requirements Document

Study accomplished under the authority of the European Space Agency
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D1.2 Science Requirements Document

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SUMMARY

This document sets out the science requirements for the Climate Analysis in African Cities (CAIAC) project. It addresses the central research question: *"How do rapid urban growth and climate change interact to intensify heat and flood risks in African cities, and how can Earth Observation-driven modelling help overcome data scarcity to provide robust insights?"*

The report first outlines the rationale for focusing on Africa, a continent that has contributed little to global greenhouse gas emissions yet faces disproportionate climate impacts. African cities are particularly vulnerable because rapid and largely unplanned urbanisation amplifies exposure to extreme heat, flooding, and related health risks, especially in informal settlements where infrastructure is limited.

While a dedicated literature review will be delivered separately (D1.1, due in March 2026), preliminary findings already highlight important advances in diagnosing historical trends, such as the intensification of urban heat islands through land-cover change, alongside persisting knowledge gaps. These gaps include the scarcity of forward-looking analyses that combine climate projections with urban growth, the limited application of high-resolution urban climate and flood models, and the underrepresentation of smaller cities. Research on socio-economic impacts, such as health outcomes, labour productivity, and infrastructure resilience, also remains sparse.

The stakeholder survey reinforced these findings, with respondents prioritising high-resolution urban climate indicators, integrated climate and urban growth projections, assessments of flood risk that account for infrastructure and exposure, and evaluations of adaptation measures such as green infrastructure. Stakeholders further emphasised the need to address social differentiation, particularly between formal and informal settlements, and to produce applied outputs to underpin adaptation strategies.

Building on this combined evidence base, the document translates these gaps into concrete science requirements. These include the generation of high-resolution climate and flood maps, the use of AI methods for scaling, the development of urban growth projections, the integration of climate scenarios, the application of robust impact metrics, and the incorporation of vulnerability and demographic data.

A central enabler across all requirements is the strategic use of Earth Observation data. Satellite products, including high-resolution land cover and vegetation indices, land surface temperature, soil moisture and river discharge records, provide essential inputs to urban climate and flood models, help overcome gaps in ground-based monitoring, and support the validation and scaling of model outputs.

The science requirements are brought together in a consolidated table that also highlights how Earth Observation data will support their implementation.

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LIST OF ACRONYMS

ACMAD	African Centre of Meteorological Applications for Development
AI	Artificial Intelligence
CAIAC	Climate Analysis in African Cities
CCI	Climate Change Initiative (ESA)
EO	Earth Observation
GHLS	Global Human Settlement Layer (Settlement grid)
GHS-UCDB	Global Human Settlement – Urban Centres Database
IPCC	Intergovernmental Panel on Climate Change
LST	Land Surface Temperature
ML	Machine Learning
NDVI	Normalised Difference Vegetation Index
PET	Physiological Equivalent Temperature
PMV	Predicted Mean Vote
SAR	Synthetic Aperture Radar
SET	Standard Effective Temperature
SST	Sea Surface Temperature
THI	Temperature Humidity Index
UHI	Urban Heat Island
UTCI	Universal Thermal Climate Index
WBGT	Wet-Bulb Globe Temperature
WoS	Web of Science

1 INTRODUCTION

This document presents the science requirements for the CAIAC project's central research question, which is formulated as follows:

"How do rapid urban growth and climate change interact to intensify heat and flood risks in African cities, and how can Earth Observation–driven modelling help overcome data scarcity to provide robust insights?"

The remainder of this report begins with a brief background section, outlining why the CAIAC project focuses specifically on Africa and African cities. We then provide an overview of the main outcomes from:

- a literature review (D1.1) concerning the current state-of-the-art and knowledge gaps on climate risk in African cities;
- an online stakeholder survey, in which African climate professionals shared their perspectives on the current research priorities in urban climate science.

The key research question of the CAIAC project (as stated above) is then analysed in relation to the identified knowledge gaps, from which the corresponding science requirements are derived. Particular attention is given to the incorporation of satellite-derived climate data records.

2 BACKGROUND – WHY AFRICA AND AFRICAN CITIES

Africa bears a disproportionate burden of climate change despite its historically negligible greenhouse gas emissions. The continent has contributed only modestly to global warming (Ayompe et al., 2021), yet remains one of the most profoundly vulnerable regions (Houghton, 2015). This inequity reflects a fundamental issue of climate justice: while Africa has done little to cause the problem, it faces some of the harshest consequences. With continued warming, extreme heat and other hazards are projected to intensify dramatically across the continent (Mora et al., 2017; IPCC, 2022).

African cities are at the centre of this challenge. Urban areas concentrate people and assets, while local characteristics such as impervious surfaces and anthropogenic materials aggravate heat and flood risks. Rising temperatures also interact with health issues, for example by expanding the habitat of malaria-carrying mosquitoes (Sinka et al., 2020). At the same time, floods and storms continue to expose the fragility of urban infrastructure, particularly in informal settlements, where homes may easily overheat, collapse in storms, or be swept away in floods (UN Habitat, 2022). More than half of Africa's urban residents, around 230 million people, live in such settlements, and their number is rising[1].

The speed of urbanisation adds another layer of urgency. Africa is projected to host some of the world's largest cities by the end of this century (Hoornweg and Pope, 2017). Much of this growth is informal and unplanned, which increases exposure to hazards and limits adaptive capacity. This creates a triple risk: (1) the concentration of resources and people in cities, (2)

[1] https://unstats.un.org/sdgs/report/2023/goal-11/

structural vulnerability and limited adaptation options, and (3) urban features that amplify climate impacts. In line with this, the Intergovernmental Panel on Climate Change (IPCC, 2022) states that Africa's rapidly growing cities are projected to become hotspots of climate risks, compounding existing stresses linked to poverty, informality, social and economic exclusion, and governance.

Despite these realities, climate research in Africa has traditionally focused more on rural concerns – such as agriculture and water resources – than on urban challenges (IPCC, 2023; Overland et al., 2021 – also see Figure 1). Human settlements are an adaptation priority in only a minority of national climate plans (AfDB, 2019). Funding flows are also skewed, with most climate research funds directed to institutions outside Africa, leaving African researchers with limited resources to generate locally relevant knowledge (Overland et al., 2021). As a result, decision-relevant climate information at the city scale remains scarce, undermining efforts to support adaptation and limiting access to international climate finance.

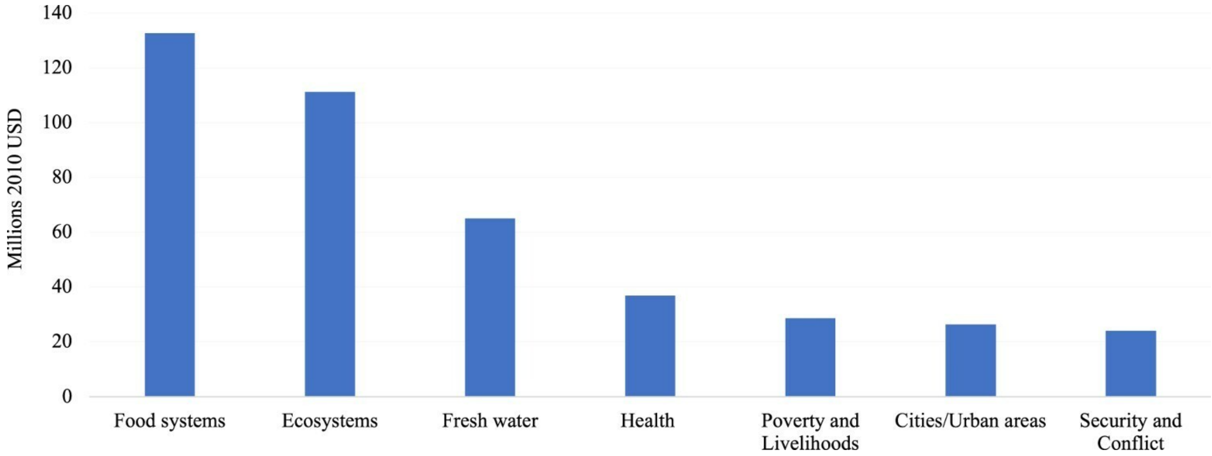

Figure 1. Distribution of climate funding in Africa across risk categories, 1990-2020. The category 'Cities / Urban areas' ranks second to last. Source: Overland et al., 2021.

Model-based climate information is particularly lacking at the urban scale. Global and regional climate models operate at spatial resolutions too coarse to capture city-level processes, creating a mismatch between research outputs and local adaptation needs (Hamdi et al., 2020; Graça et al., 2022). Emerging approaches, such as high-resolution urban climate modelling and Earth observation datasets, offer ways forward, but their application in Africa remains limited (Souverijns et al., 2022).

In short, African cities are growing rapidly while facing intensifying climate risks, but the knowledge base needed to support adaptation planning and financing remains underdeveloped.

3 OUTCOME OF THE LITERATURE REVIEW

In this section, we present the main outcomes of a review exercise, based on the scientific literature, and focusing on the existing state-of-the-art and key knowledge gaps. These results are a summary of a broader review, the full analysis of which will be provided in Deliverable D1.1 (due in March 2026, not yet finalised but already sufficiently advanced to serve as input to the present deliverable D1.2).

The review began with a broad search of the Web of Science (WoS) database using a deliberately inclusive set of keywords. Variants of “urban” or “city” were required in article titles, combined with the topical keyword “climat*” in the topic field, and geographic identifiers covering Africa as a continent and all 54 African countries. The search was restricted to the period 2015–2025 and yielded 1,832 records. Titles were manually screened for relevance, with abstracts consulted when in doubt, applying a conservative approach that favoured retaining potentially relevant papers. This process resulted in 272 selected articles. The broad keyword strategy ensured an unbiased sample with respect to hazards or methods, although the manual screening inevitably introduced some subjectivity.

3.1 Quantitative analysis

Several quantitative analyses were conducted based on the selected articles, including an analysis of the representativity of the study cases of the literature, both in terms of the distribution across climate zones as across city size ranges, showing among other things that smaller cities (below 100,000 inhabitants) are under-represented.

Here, we focus on the analysis of the hazards versus the methodological / contextual flags that were assigned during the manual screening of the titles and abstracts of each of the selected articles (Figure 2).

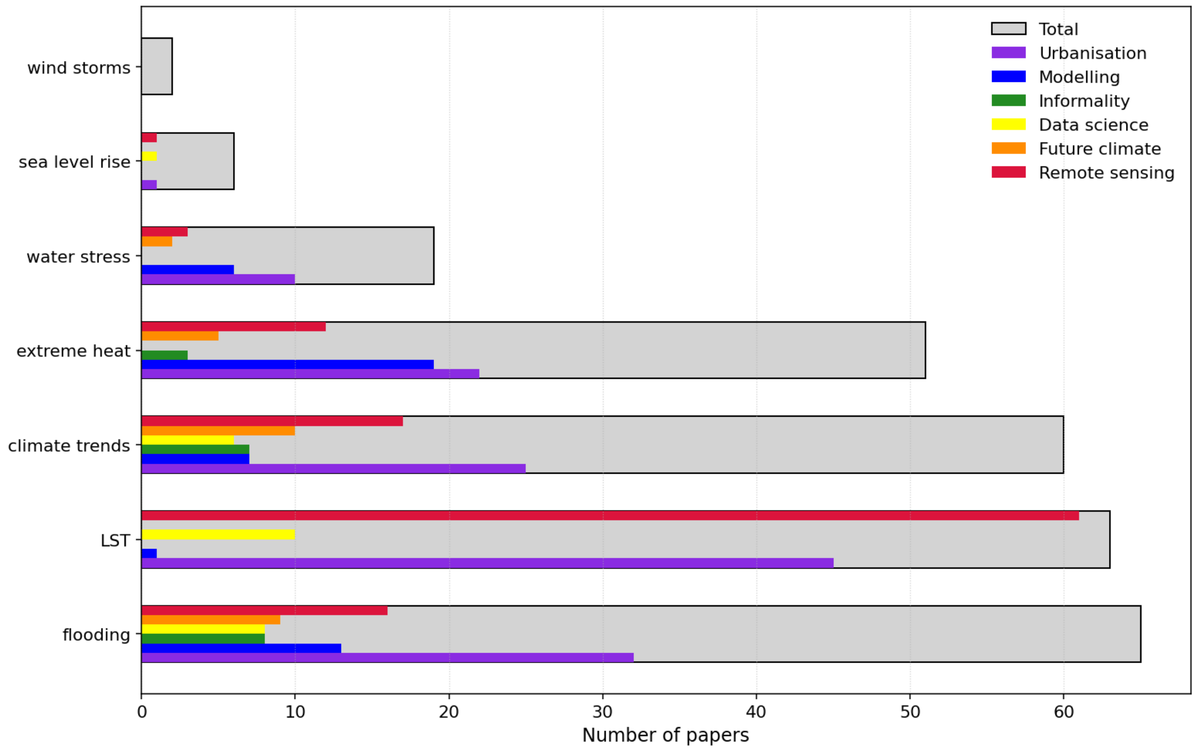

Figure 2. Distribution of reviewed papers across different hazard types. Grey bars show the total number of papers for each hazard, while coloured bars indicate the occurrence of methodological/contextual themes (urbanisation, modelling, informality, data science, future climate, and remote sensing). In this figure, ‘LST’ refers to land surface temperature. ‘Modelling’ refers to deterministic climate or hydrological modelling, and ‘Data Science’ refers to artificial intelligence, machine learning, deep learning, etc.

Analysing this figure reveals a host of information:

- Remote sensing data is used in a minority of studies, except for land surface temperature (LST) studies.
- Urbanisation, urban growth or urban dynamics is mentioned in nearly half of the papers, yet nearly all of them have a historical focus (past urban growth); only 10 (out of 272) papers concern forward-looking studies.
- The use of artificial intelligence (AI), machine learning (ML) and similar techniques is limited, while these could offer a way to overcome scaling challenges.
- Most studies focus on historical or present-day climate periods; relatively few (~10%) consider future climate projections.
- Deterministic modelling (urban climate and hydrology) is used to a limited extent only; studies often interpolate climate data from coarse model output fields, thus ignoring the local impact of the urban fabric on its own microclimate (e.g., urban heat island).
- Considerations of informality are limited, being mentioned in less than 10% of the selected papers.

With respect to the remote sensing component, a deeper analysis showed that the overwhelming majority of literature cases made use of Landsat imagery, either to observe patterns of land surface temperature, or to assess historical urban growth.

3.2 Qualitative analysis

As a next step, we examined the full set of papers in detail, with the aim of characterising the current state of the art and identifying key scientific knowledge gaps. The results are presented separately for extreme heat and flooding, the two hazards addressed in the CAIAC project. What follows is a condensed synthesis of the full review (D1.1), with bibliographic references omitted here but available in D1.1.

Extreme (urban) heat is increasingly recognised as a critical hazard in African cities. More than fifty studies (in our sample of 272) address the issue, with most emphasising the role of rapid urbanisation and associated land-cover change in amplifying local heat risks. Analyses of historical trends consistently show that expanding built-up areas and declining vegetation intensify the urban heat island (UHI). Yet only a limited number of studies project future urban growth or combine urban expansion scenarios with climate projections, leaving major uncertainties about how urbanisation and climate change will interact in the coming decades.

Informal settlements stand out as hotspots of vulnerability. Low-quality housing, inadequate services, and socio-economic marginalisation create conditions in which residents face disproportionate exposure to dangerous heat. Although urban greening is frequently proposed as a key adaptation strategy, its effectiveness is rarely quantified through modelling or field experiments. Most references remain generic recommendations rather than evidence-based assessments of cooling benefits across different urban contexts.

Research on impacts is comparatively scarce. While some studies link heat exposure to mortality, morbidity, or labour productivity losses, findings are fragmented, and locally calibrated vulnerability functions are uncommon. Even fewer contributions examine the implications for energy demand, electricity supply, or urban infrastructure performance, limiting understanding of broader socio-economic costs.

Methodological gaps further restrict progress. Only a handful of studies apply high-resolution urban climate models that explicitly capture urban form and material properties, although those that do highlight the importance of micro-scale processes. Most analyses still rely on downscaled or interpolated climate model output, which struggles to represent local conditions. Very-high-resolution microclimate assessments, as well as research on indoor and occupational exposures, remain rare.

Indicators are another weak point. Although thermal comfort indices such as UTCI, PET, PMV, THI, SET, and WBGT are mentioned, many studies rely solely on air temperature, or on remotely land surface temperature (LST), the latter being readily available from EO platforms. Yet, neither of these presents a full picture of thermal stress. Remote sensing is also widely used for land-cover and UHI diagnostics, but links to personal exposure and health outcomes are limited.

Overall, the literature has advanced in diagnosing historical urbanisation effects and identifying greening as a potential pathway, but key gaps persist in projecting future risks, quantifying health and infrastructure impacts, and evaluating adaptation measures.

Urban flooding in African cities is increasingly understood as the outcome of interacting climatic and urban drivers. While total annual rainfall has not always risen, clear shifts in rainfall timing and intensity are evident, with more frequent short, heavy downpours and altered seasonal patterns. In coastal areas, sea-level rise and storm surges further heighten flood risks, especially for low-lying settlements.

These pressures are compounded by fragile infrastructure and rapid urbanisation. Drainage networks are often undersized, poorly maintained, and lack storage capacity, so even moderate rainfall can trigger system failure. Expansion into floodplains and wetlands has removed natural buffers, while impervious surfaces and encroachment into drainage corridors accelerate runoff, turning minor ponding into disruptive urban inundation.

The socio-economic consequences are severe. Floods damage homes, disrupt transport, water, and power services, and generate cascading losses through interrupted livelihoods and trade. Evidence from community-level studies highlights the disproportionate exposure of informal settlements, where inadequate housing and limited services heighten vulnerability.

Despite this recognition, significant gaps persist. Monitoring networks for rainfall, river discharge, and tides are sparse or outdated, limiting the detection of short-duration extremes. Systematic event-based datasets linking rainfall, inundation extent, and impacts remain rare, constraining model calibration and comparison across cities. Intensity–duration–frequency curves are seldom updated to reflect non-stationary climate signals, leaving design standards misaligned with future risk. Few studies explore how climate-driven extremes interact with urban growth and land-use change, underscoring the need for integrated assessments.

Methodological advances show promise: Earth Observation and machine learning are increasingly used for flood mapping, but their transferability is limited without local validation and accessible infrastructure data. Evidence suggests that targeted interventions, such as clearing inlets or upgrading key culverts, can be highly effective, yet robust evaluations of such measures remain scarce.

In conclusion, research demonstrates that shifting rainfall regimes, sea-level rise, and unplanned urbanisation are intensifying flood risks across African cities. To move from diagnosis to action, future work must strengthen monitoring, develop consistent event-based datasets, integrate climate and urban growth scenarios, and evaluate adaptation strategies that address both climatic and urban drivers.

4 OUTCOME OF A STAKEHOLDER SURVEY

In early August 2025 an online stakeholder survey was launched to gather insights on user needs regarding priority cities and climate indicators. Respondents were drawn from the network of ACMAD (African Centre of Meteorological Applications for Development) as well as ESA's Earth Observation Africa R&D Facility. The survey also included a question aimed at identifying the main research priorities of stakeholders. While a number of predefined options were provided, respondents also had the opportunity to describe their priorities freely. The summary below presents the outcome of these research priorities, based on the survey responses (N = 34) received up to 12 September 2025.

The stakeholder survey highlights a broad yet consistent set of priorities at the intersection of climate change and urban development. Respondents repeatedly emphasised the importance of high-resolution urban climate indicator maps, which are seen as an essential basis for understanding localised risks and planning targeted adaptation measures. Closely linked is the call for the integration of future climate projections and urban growth scenarios, underlining the recognition that climate impacts in cities cannot be disentangled from demographic and spatial development trends.

A major concern across responses was the need to assess the relative influence of urban growth versus climate change on hazards such as heat and flooding. This comparative perspective was seen as key to disentangling drivers of risk and to inform where adaptation and mitigation investments can be most effective. Stakeholders also pointed to the combined effects of urban expansion, limited drainage infrastructure, and climate change on flood risk in African cities, with a strong interest in linking such analyses to cost–benefit assessments of simple adaptation scenarios.

Heat exposure emerged as another dominant theme. Stakeholders prioritised the mapping of thermal comfort indicators such as the Wet-Bulb Globe Temperature (WBGT). Several contributions stressed the role of cities as hotspots for the occurrence of deadly heat and the importance of understanding the socio-economic impacts of extreme heat, particularly on health and labour productivity. Respondents also highlighted the mitigation potential of urban green infrastructure, and the unequal distribution of risks between formal and informal settlements.

Altogether, the survey reflects a strong consensus on combining fine-scale climate modelling with socio-economic analysis to identify effective, context-specific adaptation strategies. More specifically:

- high-resolution urban climate data – including indicators such as UHI intensity, WBGT, and thermal comfort – is a top research priority;
- flood risk assessments must account not only for hydrological processes but also for urban growth, infrastructure limitations, and socio-economic exposure and damages;
- future-oriented analyses that integrate climate projections with urban expansion scenarios are considered essential for decision-making;
- social differentiation – particularly between formal and informal settlements, and across vulnerable groups – needs to be explicitly incorporated into risk and adaptation studies;
- applied outputs such as cost-benefit evaluations of adaptation measures and assessments of green infrastructure's mitigation potential are strongly requested by stakeholders.

5 SCIENCE REQUIREMENTS

The preceding sections highlighted substantial knowledge gaps in our understanding of how climate change and rapid urbanisation interact to intensify risks in African cities. Both the literature review and the stakeholder survey revealed that current evidence is fragmented, often retrospective, and lacking in the forward-looking, fine-scale analyses that decision-makers require. The remainder of this section therefore translates these identified gaps into specific science requirements that will guide the CAIAC project.

First, the lack of high-resolution urban climate and flood modelling emerged as a fundamental limitation. Most studies rely on coarse climate data or simplified diagnostics, with few examples of models that explicitly represent the urban fabric, vegetation, and drainage networks. To address this, a core requirement is the production of urban climate and flood maps at a resolution of a few hundred metres or better, supported by robust validation datasets and innovative methods such as AI for upscaling.

Second, while rapid urbanisation is widely acknowledged as a driver of risk, the absence of future urban growth projections leaves a critical blind spot. Similarly, few analyses combine urban growth scenarios with climate projections, despite their compounding effects on hazards. The science requirements therefore call for integrated modelling frameworks that quantify the relative contributions of growth versus climate change.

Third, although adaptation measures such as urban green infrastructure are often recommended, their effectiveness remains poorly quantified. This gap motivates requirements for impact metrics such as WBGT and other thermal comfort indices, applied systematically to evaluate mitigation potential across diverse urban contexts.

Finally, the survey and review both underscored the underrepresentation of socio-economic impacts and social differentiation. Informal settlements, vulnerable groups, and sector-specific impacts (health, labour, infrastructure) remain insufficiently addressed. The science requirements therefore include the development of sectoral impact assessment methods that explicitly combine vulnerability & demographic data, and settlement typologies with urban climate and flood models.

To address these four science gaps, the overarching research question articulated in the Introduction is subdivided into the following partial research questions, which henceforth provide the framework for the CAIAC project:

1. *How does the urban fabric of African cities amplify extreme heat and flooding, and how does this amplification vary with city size, morphology (including vegetation cover), and climatic zone?*
2. *What are the relative contributions of urban growth and climate change to future heat and flood risks in rapidly expanding African cities?*
3. *To what extent can urban green infrastructure mitigate heat and/or flooding risk?*
4. *How can vulnerability curves and demographic data be combined with urban climate and flood models to estimate economic and social risks (health, labour, infrastructure)?*

Table 1 summarises the science requirements in relation to these research questions and the identified knowledge gaps, and further outlines the role of Earth Observation data.

Table 1. Science requirements specified in the context of the four key scientific questions.

Key research question	Knowledge gaps	Science requirements	Role of Earth Observation data
1. How does the urban fabric of African cities amplify extreme heat and flooding, and how does this amplification vary with city size, morphology (including vegetation cover), and climatic zone?	• Lack of high-resolution urban climate and flood modelling results • Limited use of AI methods in modelling (hence efficient scaling compromised) • Underrepresentation of small cities (<100k inhabitants) despite demographic evidence • Lack of validation data	• Urban climate and flood maps at a spatial **resolution of a few hundred metres** or better • Demonstration of **AI methods** in modelling • Ensure **representative selection** of cities by size, while maintaining coverage across climate zones • Promote trust in simulations through **validation**	• CCI 300-m Land Cover and Copernicus GHLS to specify terrain parameters (CCI High-Resolution Land Cover for selected cases) • CCI SST for coastal cities • CCI River Discharge, Soil Moisture, Copernicus Sentinel-1 SAR for hydrological input • Copernicus GHS-UCDB to aid city selection • CCI LST maps for validation (where ground-based urban measurements are lacking)
2. What are the relative contributions of urban growth and climate change to future heat and flood risks in rapidly expanding African cities?	• Very few future urban growth projections, despite considerable growth expected in Africa • Limited use of future climate projections in existing studies	• Generate urban **growth projections** as input for urban heat and flood models • Combine with **climate projections** to quantify relative contributions of growth vs. climate change	• CCI Land Cover and Copernicus GHSL time series to guide urban growth modelling
3. To what extent can urban green infrastructure mitigate heat and/or flooding risk?	• Few studies consider the *quantitative* micro-climatic impact of urban green	• Employ suitable **climate impact metrics** beyond sole air temperature (e.g., WBGT for thermal comfort)	• CCI NDVI and Copernicus Sentinel-2 vegetation indices to represent vegetation cover fraction
4. How can vulnerability and demographic data be combined with urban climate and flood models to estimate economic and social risks (health, labour, infrastructure)?	• Not many studies consider sector-specific climate impacts on cities • Influence of informality remains understudied	• Develop **sectoral impact assessments** • Address differences between formal and **informal settlements** in risk estimation	• To be further detailed (e.g. population and settlement datasets, informal settlement mapping, nighttime lights)

6 CONCLUSIONS

This Science Requirements Document (D1.2) has translated the state of knowledge and stakeholder priorities into a set of concrete requirements for the CAIAC project. The review of scientific literature (D1.1) revealed that – while considerable progress has been made in diagnosing historical trends of urban heat and flooding – the field remains dominated by retrospective analyses and limited methodological innovation: forward-looking, high-resolution studies that integrate climate change and urban growth are largely absent, as are systematic assessments of socio-economic consequences.

The stakeholder survey reinforced these findings, highlighting the urgent need for applied, fine-scale outputs that can support adaptation planning in African cities. Respondents expressed a strong demand for robust urban climate indicators, integrated projections of climate and urban expansion, and assessments of adaptation strategies such as green infrastructure. They also underscored the importance of explicitly addressing social differentiation between formal and informal settlements, given their contrasting vulnerabilities and adaptive capacities.

Building on this evidence base, the science requirements outlined in this report provide a structured framework to guide the CAIAC project. They emphasise the production of high-resolution climate and flood maps, the integration of urban growth and climate projections, the use of advanced methods such as AI to overcome scaling challenges, and the development of impact metrics tailored to urban health, labour, and infrastructure sectors. Equally, they highlight the central enabling role of Earth Observation data in providing consistent, scalable, and validation inputs where ground-based information is sparse.

Together, these requirements establish a roadmap for addressing the project's central research question: *How do rapid urban growth and climate change interact to intensify heat and flood risks in African cities, and how can Earth Observation–driven modelling help overcome data scarcity to provide robust insights?*

REFERENCES

AfDB, 2019. Analysis of Adaptation Components in African NDCs. African Development Bank, 46 pp, available at https://africandchub.org/sites/default/files/2021-08/Analysis_of_Adaptation_Components_in_African_NDCs_2019.pdf

Ayompe, L.M., S.J. Davis, and B.N. Egoh, 2021. Trends and drivers of African fossil fuel CO_2 emissions 1990-2017. Environ. Res. Lett., 15, 124039. https://doi.org/10.1088/1748-9326/abcbb3

Graça, M., S. Cruz, A. Monteiro, T.-S. Neset, 2022. Designing urban green spaces for climate adaptation: A critical review of research outputs. Urban Climate, 42, 101126, https://doi.org/10.1016/j.uclim.2022.101126

Hamdi, R., H. Kusaka, Q.-V. Doan, P. Cai, H. He, G. Luo, W. Kuang, et al., 2020. The state-of-the-art of urban climate change modeling and observations. Earth Syst. Environ., 4(4), 631–46. https://doi.org/10.1007/s41748-020-00193-3

Hoornweg, D., and K. Pope, 2017. Population predictions for the world's largest cities in the 21st century. Environ. Urban., 29, 195–216. https://doi.org/10.1177/0956247816663557

Houghton, J. T., 2015. Global Warming: The Complete Briefing. 5th ed. Cambridge: Cambridge University Press, 396 pp.

IPCC, 2022. Africa. In: Climate Change 2022 – Impacts, Adaptation and Vulnerability: Working Group II Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press; 2023:1285-1456.

IPCC, 2023. Climate Change 2021 – The Physical Science Basis: Working Group I Contribution to the 6th Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte et al. (eds.)]. Cambridge Univ. Press, 2391 pp. https://doi.org/10.1017/9781009157896

Mora, C., B. Dousset, I.R. Caldwell, F.E. Powell, R.C. Geronimo, C.R. Bielecki, C.W. W. Counsell, B.S. Dietrich, E.T. Johnston, L.V. Louis, M.P. Lucas, M.M. McKenzie, A.G. Shea, H. Tseng, T.W. Giambelluca, L.R. Leon, E. Hawkins, and C. Trauernicht. 2017. Global Risk of Deadly Heat. Nature Climate Change, 7, 501-506. https://doi.org/10.1038/nclimate3322

Overland, I., Fossum Sagbakken, H., Isataeva, A., Kolodzinskaia, G., Simpson, N. P., Trisos, C., & Vakulchuk, R. (2021). Funding flows for climate change research on Africa: where do they come from and where do they go? Climate and Development, 14(8), 705–724. https://doi.org/10.1080/17565529.2021.1976609

Souverijns, N., K. De Ridder, N. Veldeman, F. Lefebre, F. Kusambiza-Kiingi, W. Memela, N. K.W. Jones, 2022. Urban heat in Johannesburg and Ekurhuleni, South Africa: A meter-scale assessment and vulnerability analysis. Urban Climate, 46, 101331, https://doi.org/10.1016/j.uclim.2022.101331

UN-Habitat, 2022. Envisaging the Future of Cities. World Cities Report 2022. United Nations Human Settlements Programme (UN-Habitat), 422 pp., available online at https://unhabitat.org/sites/default/files/2022/06/wcr_2022.pdf

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