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Deliverable Phase 2 – Climate risk assessment

Climate Resilience and Risk Management Approach to Flood and Erosion through Data-Driven Adaptation Response in Libohova (CLEAR-AL)

Albania, Libohova Municipality

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1 Document Information

Deliverable Title	Phase 2 – Climate risk assessment
Brief Description	This document constitutes the Phase 2 report prepared for the Municipality of Libohovë under the CLEAR AL project, within the framework of CLIMAAX. It provides a clear and comprehensive overview of the climate risk assessment, strengthening the link between analytical findings and their practical implementation, while ensuring both methodological rigor and local relevance. The objective of Phase 2 is to build upon the baseline analysis from Phase 1 by incorporating enhanced datasets, hydrological models, and insights from stakeholders. Compared to the initial version, this revised document refines the presentation of risk profiles and adaptation strategies, highlighting Libohova's mountainous terrain, reliance on agriculture, and socio-economic vulnerability as key factors influencing exposure to climate variability.
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5 Abbreviations and acronyms

Abbreviation / acronym	Description
NCPA	National Civil Protection Agency / Agjencia Kombëtare e Mbrojtjes Civile
NTPA	National Territorial Planning Agency / Agjencia Kombëtare e Planifikimit të Territorit
WRMA	Water Resources Management Agency / Agjencia e Menaxhimit të Burimeve Ujore
APSFR	Area of Potential Significant Flood Risk
ASIG	State Authority for Geospatial Information, Albania
CLEAR-AL	Climate Resilience and Risk Management Approach to Flood and Erosion through Data-Driven Adaptation Response in Libohova
CLIMAAX	CLIMAte risk and vulnerability Assessment framework and toolboX (Horizon Europe project)
CORDEX	Coordinated Regional Climate Downscaling Experiment
CRA	Climate Risk Assessment
D1/D2/D3	Project deliverables for Phases 1, 2 and 3
D8	Eight-direction flow-routing method
DEM	Digital Elevation Model
FRMP / PMRP	Flood Risk Management Plan / Plani i Menaxhimit të Riskut nga Përmbytjet
FSTP	Financial Support to Third Parties (CLIMAAX funding mechanism)
GDP	Gross Domestic Product
GEV	Generalised Extreme Value distribution
GIS	Geographic Information System
HAND	Height Above Nearest Drainage
HQ	Flood discharge for a given return period (e.g. HQ100 = 100-year flood), as used in the AMBU/Vjosa FRMP maps
IPF10	Infrastructure Project Facility 10, a WBIF technical-assistance provider supporting preparation of the Vjosa FRMP
JRC	European Commission Joint Research Centre
KKU	National Water Council / Këshilli Kombëtar i Ujit

KPI	Key Performance Indicator
KS	Kolmogorov–Smirnov
LUISA	Land-Use-based Integrated Sustainability Assessment
QA	Quality Assurance
RCP	Representative Concentration Pathway
RP	Return Period
SD	Standard deviation
WRB	World Reference Base for Soil Resources
WRI	World Resources Institute

6 Executive summary

Phase 2 of the CLEAR-AL project has significantly strengthened the climate risk assessment framework for Libohovë Municipality, providing a more robust and locally relevant evidence base than the initial baseline established in Phase 1. By integrating high-resolution local datasets, hydrological and erosion analyses, crop water-balance modelling, wildfire indicators, and future climate projections, the assessment now offers a comprehensive understanding of climate risks and their implications for agriculture, infrastructure, and community wellbeing.

The analysis confirmed that extreme rainfall and flood-related impacts are already causing documented damage and are projected to intensify in the future. Agricultural drought and heat stress emerged as the second priority, with modelled yield losses and economic impacts showing a sharp increase under hotter and drier scenarios. Wildfire hazard is also expected to worsen, though limited local records mean that its priority status remains provisional until further validation in Phase 3.

Stakeholder engagement was expanded during this phase, involving municipal staff, civil society, farmers, youth and women's groups, and technical experts. Their input enriched the interpretation of severity, urgency, and resilience capacity, and confirmed the relevance of rainfall and drought as priority risks. This participatory approach improved ownership and legitimacy, ensuring that results are not only technically sound but also locally trusted.

Phase 2 also highlighted several challenges. Data gaps persist in socio-economic projections, hydraulic flood modelling, and geo-referenced impact records. Climate models continue to operate at coarse resolution, and institutional capacity for systematic monitoring remains limited. These constraints were managed through quality checks, conservative assumptions, and clear documentation of limitations, but they underline the need for further investment in Phase 3.

Key take-away messages from Phase 2 are:

- Extreme rainfall is the most urgent risk, requiring immediate attention to drainage, runoff, and erosion control.
- Agricultural drought and heat stress demand stronger water-management and agricultural adaptation measures.
- Wildfire hazard is increasing and requires preventive landscape management and preparedness.
- Stakeholder involvement is essential for ensuring that adaptation strategies are both evidence-based and socially equitable.

Looking ahead, Phase 3 will focus on turning these validated priorities into practical adaptation options. The work plan includes field validation of hotspots, development of site-specific measures, prioritisation based on feasibility and stakeholder acceptance, implementation of a pilot adaptation measure, and integration of results into Libohovë's Climate Adaptation Plan. In this way, the project will move from assessment to action, embedding resilience strategies into municipal planning and ensuring that adaptation is both technically rigorous and locally relevant.

1 Introduction

1.1 Background

Libohova Municipality, located in southern Albania within Gjirokastër Region, covers 230.44 km² in the boundary used for this assessment. Elevation ranges from about 201 m to 2,156 m, with steep mountain slopes, valley floors, local drainage lines, agricultural land, and dispersed settlements shaping both ecological richness and socio-economic identity. With a population that relies primarily on agriculture and livestock, fertile valley soils support cereals, vegetables, vineyards, and fruit trees, forming the backbone of local livelihoods.

The municipality faces both sudden and slow-onset climate pressures. Heavy rainfall leads to runoff, river flooding, erosion, slope instability, and damage to roads and infrastructure, while prolonged dry periods and rising temperatures increase crop water demand and strain water resources. Phase 2 results also indicate that fire weather is becoming a growing risk, with seasonal fire indices shifting from Very High to Extreme.

The CLEAR-AL project applies the CLIMAAX Climate Risk Assessment Framework to support Libohova's local decision-making. European risk methods are combined with locally collected data—topography, hydrology, soils, land use, rainfall, and exposure—so that results can be used in municipal planning, emergency preparedness, agriculture, ecosystem protection, and the design of adaptation measures. The Phase 2 implementation plan sets specific targets, including refined datasets, expert consultations, high-resolution GIS maps, policy notes, and a comprehensive risk-assessment report, ensuring that the analysis is both methodologically rigorous and locally relevant.

1.2 Main objectives of the project

The CLEAR-AL project represents a strategic effort to strengthen Libohova Municipality's resilience to climate change by applying the CLIMAAX Handbook within the local context. Its overarching goal is to provide the municipality with a stronger foundation for managing flood and erosion risks, while safeguarding critical sectors such as agriculture, infrastructure, tourism, and public health against hazards like heavy rainfall, river flooding, erosion, and other extreme weather events. By embedding European methodologies into local planning, the project enhances evidence-based decision-making, builds institutional capacity, and promotes inclusive, community-driven responses to climate challenges.

Phase 2 focuses on transforming the regional CLIMAAX assessment into a locally relevant and usable evidence base, while keeping the main risk components—climate pressure, hazard, exposure, vulnerability, and risk—clearly distinguished. This involves:

- **Integrating local data**: High-resolution topographic, hydrological, soil, land-use, rainfall, and exposure information are incorporated into a traceable dataset.
- **Ensuring comparability**: CLIMAAX/JRC workflows are retained, while local analysis is added where European-scale products are too coarse to capture Libohova's drainage and terrain conditions.
- **Producing practical outputs**: Refined datasets, high-resolution GIS maps, quantitative indicators, and policy notes are generated to support municipal decision-makers in planning, field verification, and adaptation strategies.

- **Documenting uncertainty**: Limitations and data gaps are explicitly recorded, avoiding false precision where local hydraulic, soil-property, or asset-value information is unavailable.
- **Preparing for Phase 3**: Establishing a solid technical basis for identifying, prioritizing, and designing adaptation options and pilot measures.

Beyond identifying risks, Phase 2 emphasizes co-creation of solutions. It combines scientific expertise, detailed local datasets, and the lived experiences of residents to design practical strategies that protect farms, towns, and cultural assets while safeguarding community wellbeing. By involving local voices and institutions at every stage, CLEAR-AL ensures that adaptation plans are technically sound yet deeply rooted in Libohova's realities.

Thanks to the CLIMAAX Handbook, Libohova now has a clear roadmap for managing climate risks. The framework ensures comparability with European practice, while the inclusion of local evidence makes results more relevant and actionable for municipal planning. Together, these elements lay the groundwork for stronger partnerships, better tools for decision-making, and a more resilient and sustainable future for the community.

1.3 Project team

The CLEAR-AL project team in Libohova brings together municipal authority and external expertise in a collaborative structure. The Municipality of Libohova serves as the lead institution, retaining ownership of risk management, public decision-making, and acceptance of project outputs. Phase 2 is organized into four technical pillars: coordination and reporting, climate methodology and leadership, GIS and data integration, and hydrology with erosion and agricultural-risk analysis. Technical inputs for GIS and hydrology are provided by experts, ensuring reproducible analytical modules that strengthen the evidence base. External reviewers and relevant institutions contribute independent validation through structured consultations, guaranteeing credibility and transparency. This integrated team combines local governance with scientific knowledge, aligning municipal priorities with national adaptation frameworks. By merging technical rigor with community relevance, the team ensures that risk assessments are practical, inclusive, and sustainable. Together, they provide Libohova with a stronger foundation for climate resilience and adaptive planning.

1.4 Outline of the document's structure

This deliverable is organized to present a clear, structured, and evidence-based account of Phase 2 of the CLEAR-AL project in Libohova Municipality. It follows the methodological flow of the CLIMAAX Framework, ensuring coherence between technical analysis, stakeholder engagement, and adaptation planning.

- **Executive Summary** – Provides an overview of the objectives, activities, and key findings of the climate risk assessment, summarizing how Phase 2 builds upon the baseline established in Phase 1.
- **Section 1** – **Introduction** – Sets the context by describing Libohova Municipality, defining the main objectives of Phase 2, introducing the project team, and explaining the overall structure and purpose of the report.
- **Section 2 – Climate Risk Assessment (Phase 2)** – Constitutes the core of the deliverable. It details the scoping process, risk exploration, localized risk analysis, and the key findings

on severity, urgency, resilience capacity, and risk prioritization. It also outlines the monitoring and evaluation framework and the work plan for Phase 3.

- **Section 3** – **Conclusions** – Synthesizes the strategic significance of Phase 2, highlighting how the results strengthen local resilience and inform adaptation planning.
- **Section 4 – Progress Evaluation** – Reviews the achievements of Phase 2, assesses methodological improvements, and situates them within the broader CLIMAAX framework.
- **Section 5 – Supporting Documentation** – Includes annexes, maps, visuals, and technical materials that complement the analysis.
- **Section 6 – References** – Lists all data sources, methodologies, and tools used throughout the assessment.

This structure ensures clarity, transparency, and alignment with the CLIMAAX Handbook, while embedding local knowledge and stakeholder participation. It enables the deliverable to function both as a technical report and as a practical guide for advancing climate risk management and adaptation planning in Libohova Municipality.

2 Climate risk assessment – phase 2

This section follows the methodological steps outlined in the CLIMAAX Framework, applying its guiding questions to structure the analysis of climate risks and adaptation planning for Libohova Municipality. Building on the scoping and preliminary assessment conducted in Phase 1, the emphasis here is on identifying what has changed, refining risk profiles with updated local data, and explicitly noting where information remains limited.

The guiding questions of the CLIMAAX Handbook provide a structured framework that ensures both consistency and transparency throughout the assessment. Where sufficient evidence is available, detailed responses are provided; where data gaps persist, these are clearly stated to highlight areas requiring further investigation. In this way, Phase 2 strengthens the evidence base, deepens the analytical process, and lays the foundation for actionable adaptation strategies tailored to Libohova's local context.

The assessment builds directly on the baseline established in Phase 1, while introducing additional work specific to Phase 2. Future climate conditions are examined across all three risk pathways. However, due to the absence of consistent local projections for population, land use, and assets, exposure and vulnerability are maintained at present-day levels. As a result, observed differences between time periods reflect the effects of climate change alone, isolating its impact from other socio-economic variables.

Where available evidence does not support a definitive answer—particularly regarding stakeholder-derived ratings, complete numerical tables from Phase 1, or final consultation outcomes—limitations are stated explicitly rather than inferred. This approach ensures transparency, avoids false precision, and maintains the credibility of the assessment.

2.1 Scoping

The scoping phase of Phase 2 in Libohova defines the objectives of the climate risk analysis, the conditions for its implementation, and the actors whose engagement is essential to ensure meaningful results. Building on the foundations of Phase 1, this updated scoping reflects new pathways of stakeholder involvement, expanded local datasets, and stronger sectoral interfaces.

The focus is on clarifying desired outcomes, situating them within Libohova's evolving socio-economic and environmental context, and identifying stakeholders, experts, and priority groups whose participation is critical for shaping adaptation strategies. Municipal staff provide local knowledge and continuity, while external experts contribute scientific precision, ensuring that the Climate Adaptation Plan is both technically sound and rooted in community realities.

This integrated approach moves the assessment beyond vulnerability mapping toward practical, evidence-based measures for resilience. By embedding ownership and sustainability into Libohova's climate governance framework, Phase 2 ensures that adaptation planning is inclusive, credible, and aligned with both local priorities and national strategies.

2.1.1 Objectives

The Climate Risk Assessment in Phase 2 for Libohova Municipality aims to refine and expand the initial findings of Phase 1 by integrating high-resolution local datasets, updated hydraulic models, and stakeholder insights. Its purpose is to move beyond baseline risk identification toward actionable adaptation strategies that address the municipality's most pressing hazards, including

floods, extreme rainfall, erosion, landslides, and drought. The expected outcome is a locally tailored Climate Adaptation Plan that strengthens resilience in agriculture, infrastructure, tourism, and public health, while embedding ownership within municipal institutions and communities.

The assessment is conducted at the municipal scale, ensuring that results feed directly into risk-management planning, civil-protection preparedness, land-use discussions, and the selection of Phase 3 adaptation options. However, several limitations were encountered: European datasets remain too coarse to capture local drainage and terrain, rainfall records are incomplete, hydraulic modelling lacks detailed discharge and roughness data, and building inventories are not comprehensive. In addition, the pedology dataset is outdated and erosion-screening weights carry uncertainty.

To address these challenges, European-scale data were used only for the purposes they can reliably support, while local terrain and exposure evidence were added where available. Stakeholder workshops and expert consultations helped fill knowledge gaps, and uncertainties were reported explicitly to avoid false precision. By combining scientific analysis with community knowledge, Phase 2 delivers risk maps and evidence that are credible, transparent, and decision-relevant, embedding climate risk management into everyday governance and planning in Libohova.

2.1.2 Context

Until now, climate risks in Libohova have largely been managed through fragmented, event-based responses and local documentation of damages. Flooding, erosion, landslides, and drought have repeatedly affected villages, agricultural land, roads, and water resources, yet these impacts were not connected to a structured climate risk assessment. This reactive approach limited the municipality's ability to anticipate and mitigate growing threats, leaving livelihoods, infrastructure, and public health exposed.

The CLEAR-AL project addresses this gap by introducing a systematic Climate Risk Assessment under the CLIMAAX Framework. The core problem is the absence of integrated climate governance at the local level. While Albania has adopted national strategies such as the National Climate Change Strategy (2019–2030), the Climate Change Law (2020), and the Second National Adaptation Plan (2026–2036), municipal institutions like Libohova continue to face constraints in technical expertise, financial resources, and access to climate-relevant data. Phase 2 seeks to bridge this disconnect by refining risk profiles with high-resolution local datasets, hydraulic models, and stakeholder input, thereby embedding climate adaptation into local planning and decision-making.

Relevant sectors—agriculture, infrastructure, civil protection, ecosystem management, and public health—are highly sensitive to climate variability. Droughts threaten crop yields and water availability, floods and erosion damage roads and buildings, and heatwaves pose risks to vulnerable populations. These vulnerabilities are compounded by socio-economic pressures and limited institutional capacity, but external initiatives on biodiversity conservation, water resource management, and rural revitalization provide opportunities for synergy and knowledge exchange.

Phase 2 also confronts important limitations: incomplete local datasets, outdated soil information, lack of detailed hydraulic measurements, and uneven stakeholder participation. To address these challenges, European-scale data are used only for the purposes they can reliably support, while local terrain and exposure evidence are added where available. Community workshops and expert consultations help fill knowledge gaps, and uncertainties are reported explicitly to avoid false precision.

Possible adaptation interventions include upgrading and modernizing infrastructure to reduce flood risk, restoring vegetation cover on erosion-prone slopes, applying nature-based solutions such as afforestation and watershed restoration, introducing water-saving measures for agriculture, and incorporating rainwater collection into urban planning. Together, these measures will feed into Libohova's Local Climate Change Adaptation Plan, ensuring alignment with the National Adaptation Plan and embedding resilience into local and regional development strategies.

2.1.3 Participation and risk ownership

In Libohova, risk ownership is primarily municipal, but it is shared across several services and reinforced by community participation. The Municipality chairs the process, convenes relevant departments, provides local information, and is responsible for accepting and using the results of the Climate Risk Assessment. Technical experts contribute analysis and validation, external reviewers ensure credibility, and local stakeholders provide knowledge that maps alone cannot capture.

Phase 2 of CLEAR-AL has strengthened stakeholder involvement by expanding participation and deepening collaboration across local, regional, and national levels. Building on the mapping conducted in Phase 1, the municipality has worked closely with civil society, technical experts, and community representatives to ensure that outcomes are inclusive and actionable. Stakeholders engaged in CLIMAAX-related meetings include municipal departments, civil protection staff, water-management and data-holding institutions, local NGOs, youth and women's groups, farmers' associations, agribusinesses, and academic experts. Their involvement has been formalized through workshops, consultations, and technical sessions coordinated by INCA, the implementing partner.

An organogram (Figure 2-1) illustrates how municipal authorities, regional institutions, civil society, and technical experts interact, clarifying responsibilities for risk identification, data collection, and decision-making. It highlights the central role of Libohova Municipality in coordinating local action, supported by INCA's technical expertise and reinforced by community stakeholders who provide monitoring capacity.



Figure 2-1 Organogram of key actors and their connection

Priority groups include residents and land users in exposed areas, smallholder farmers, pastoralists, older people, and women in rural communities. Their perspectives ensure that adaptation priorities reflect lived realities and promote equitable resilience. No formal municipal threshold for acceptable or tolerable climate risk was available in the current evidence package; therefore, the analysis uses relative severity, urgency, exposure, and uncertainty to help rank priorities.

In practice, risk ownership follows a simple sequence: verify the mapped location, identify who is responsible for the asset or land, decide whether routine maintenance is sufficient or a dedicated adaptation measure is needed, and record what was done. This shared ownership model fosters accountability and sustainability, ensuring that climate adaptation is not only a technical exercise but also a community-driven process embedded in Libohova's governance framework.

2.1.4 Application of principles

The Phase 2 analysis for Libohova Municipality has been guided by the principles of the CLIMAAX Framework—social justice and inclusivity, quality and transparency, and the precautionary approach—to ensure that the Climate Adaptation Plan is both technically rigorous and socially equitable.

Social justice and inclusivity are reflected in the explicit attention given to rural communities, smallholder farmers, exposed settlements, public facilities, roads, and agricultural land. Their perspectives were integrated through consultations, ensuring that adaptation measures respond to the realities of those most at risk. The analysis also separates technical hazard from exposure, making visible the vulnerabilities of priority groups even where facility inventories remain incomplete.

Quality, rigour, and transparency were ensured through reproducible workflows, dataset registers, boundary checks, and explicit tracing of data sources. All methodological guardrails were kept visible—for example, resampling was not treated as new information, susceptibility was not equated with hydraulic depth, and soil classifications were not automatically converted into erodibility factors. Uncertainties were clearly documented so that decision-makers and citizens understand both the strengths and the limits of the evidence.

The precautionary approach was applied by treating strong projected changes as relevant for decisions, even where detailed impact models are not yet available. Local areas identified as susceptible outside the JRC footprint were prioritized for verification rather than labelled as confirmed inundation. Long-return-period rainfall and flood results were presented with caution, and investment-grade recommendations were deferred until further hydraulic modelling or field data could support them.

By embedding these principles, Phase 2 strengthens the credibility of the Climate Adaptation Plan, making it scientifically sound, socially fair, transparent, and practical for guiding Libohova's future resilience.

2.1.5 Stakeholder engagement

Stakeholder engagement in Phase 2 of the CLEAR-AL project in Libohova was designed to ensure that climate risk assessment outcomes are inclusive, credible, and directly relevant to local realities. The process combined institutional data requests, expert analysis, and community consultations, creating a multi-level dialogue between municipal staff, technical experts, and priority groups.

Three structured consultations were held in October 2026: on 12 October with the civil emergencies group, on 13 October with municipal staff, and on 14 October with business representatives, farmers, and community groups. These meetings reviewed hydrological and erosion analyses, validated agricultural exposure, and discussed integrated multi-risk findings. Participants included municipal departments, civil protection staff, farmers' associations, local businesses, youth and women's groups, and NGOs.

Project goals and intermediate results were communicated through presentations, annotated maps, and open discussions. Stakeholders welcomed the structured approach, noting that the CRA provides practical insights for agriculture, infrastructure, and water management. Feedback emphasized the importance of integrating risk information into municipal planning and strengthening early warning mechanisms.

The consultations confirmed that flooding, erosion, landslides, and drought are highly relevant hazards for Libohova. Local evidence of past damages—affecting houses, farmland, and roads—was critical in shaping risk profiles. While challenges included incomplete datasets, uneven technical capacity, and difficulties in ensuring consistent participation, these were addressed through simplified communication materials, technical support from INCA, and active facilitation during workshops.

The outcomes of Phase 2 will be further used by participants to guide local development plans, improve emergency preparedness, and inform sectoral strategies in agriculture and tourism. This inclusive process demonstrates that even in the absence of complete official datasets, the CRA results remain scientifically robust and socially grounded, fostering ownership and practical application of adaptation measures in Libohova.

2.2 Risk Exploration

Risk exploration in Libohova begins with a broad screening of climate-related risks that are most visible or of greatest concern to stakeholders and the wider public. This step examines the underlying hazards, exposures, and vulnerabilities that shape local impacts, ensuring that the assessment reflects both scientific evidence and community experience.

The process draws on institutional datasets, local records of past damaging events, and stakeholder consultations to identify priority risks such as flooding, erosion, landslides, and drought. These hazards have repeatedly affected agricultural land, rural settlements, public facilities, and road infrastructure, making them central to the municipality's resilience agenda.

By combining technical analysis with local knowledge, risk exploration provides the foundation for deeper assessment. It clarifies which risks are most urgent, which areas and groups are most exposed, and where adaptation measures should be prioritized. This integrated approach ensures that subsequent phases of the Climate Risk Assessment are firmly rooted in Libohova's realities while remaining aligned with the CLIMAAX Framework.

2.2.1 Screen risks (selection of main hazards)

The hazard selection in Phase 2 for Libohova remains consistent with the project scope: flooding and erosion are confirmed as the principal risks. This stage is not a new broad hazard-screening exercise but a refinement of the priorities identified in Phase 1, strengthened with updated datasets and local evidence.

Heavy rainfall is analysed as a key climate pressure, intensifying runoff and flood response. Flooding is relevant both along established fluvial corridors represented in JRC hydraulic-depth products and along smaller local drainage pathways highlighted by terrain analysis. Potentially affected receptors include agricultural and semi-natural land, rural roads, settlements, and public/critical facilities.

Erosion is concentrated in distinct terrain bands where slope, flow concentration, and land-cover conditions combine to increase susceptibility. The most exposed receptors are roads and productive land, while direct point exposure of settlements and facilities remains relatively low in the final High/Very High erosion classes.

The climate-pressure basis for Phase 2 is drawn from EURO-CORDEX projections, complemented by locally observed rainfall records. No new Copernicus Atlas extract was produced in this phase; instead, the Atlas findings from Phase 1 remain valid, confirming stronger rainfall extremes and seasonal variability in Albania under warming scenarios.

Further data are still needed to refine the analysis, particularly sub-daily rainfall observations, local discharge and roughness measurements for hydraulic modelling, and updated inventories of buildings and assets. Despite these gaps, the Phase 2 screening provides a clearer, evidence-based picture of Libohova's priority hazards, ensuring that subsequent risk assessment steps remain focused and decision-relevant.

2.2.2 Choose Scenario

The scenario development in Phase 2 for Libohova builds directly on the CLIMAAX Framework, combining observed local evidence with regional climate projections. Extreme-precipitation analysis uses EURO-CORDEX data for the historical period 1976–2005 and future conditions 2041–2070 under RCP8.5, anchored with locally observed daily rainfall to validate the 24-hour signal. Present-day river-flood hazard is assessed using JRC return periods (RP10, RP50, RP100, RP200, RP500), while Aqueduct Floods provides a coarse future context under RCP4.5 and RCP8.5 for 2030, 2050, and 2080. These datasets are used to frame climate pressures but not as substitutes for local hydraulic modelling.

Future socio-economic developments were not explicitly modelled in this phase. The risk calculations rely on LUISA 2018 as the exposure basis and present screening-level vulnerability and maximum-damage relationships. This represents an important limitation: monetary risk outputs reflect potential direct damages under current exposure and economic assumptions, rather than a combined future climate-and-socioeconomic projection.

The analysis considers three-time horizons: short-term (next 5 years) to capture immediate risks and adaptation needs, medium-term (20–30 years) to inform municipal planning and integration into development strategies, and long-term (50–100 years) to support strategic decisions in climate-sensitive sectors such as agriculture, water management, and infrastructure.

By combining EURO-CORDEX projections with local rainfall records and maintaining present-day socio-economic baselines, Phase 2 provides a transparent evidence chain. It highlights how climate change alone may alter hazard intensity and frequency, while clearly stating the limits of current data and the need for further socio-economic scenario integration in Phase 3.

Table 2-1 Scenario and time-horizon design

Component	*Baseline / present*	*Future / return periods*	*Role*
Heavy rainfall	Poliçan observations 1968–1994; EURO-CORDEX historical 1976–2005	RCP8.5, 2041–2070; RP2–RP100	Climate-pressure signal and locally anchored 24 h change
JRC river flood	Present-day JRC depth maps	RP10, 50, 100, 200, 500	Hydraulic hazard baseline for current risk
Aqueduct river flood	Baseline around 1980	RCP4.5/RCP8.5; 2030, 2050, 2080; RP250	Qualitative future flood context only
Socio-economic exposure	LUISA 2018 + local exposure layers	No explicit future socio-economic scenario	Present screening exposure basis; maximum-damage values scaled with Albania GDP/capita 2023 in constant 2010 US$

2.3 Regionalized Risk Analysis

The Phase 2 analysis for Libohova is organized into four linked modules, combining the standard CLIMAAX/JRC workflows with locally refined evidence. Flood hazard and risk calculations follow the CLIMAAX methodology, but are enhanced with local inputs such as rainfall validation, municipal boundary masking, terrain and drainage detail, soil interpretation, and the overlap between flood and erosion zones. The erosion module represents a CLEAR-AL local extension, developed specifically for Libohova, since no official CLIMAAX erosion workflow exists.

Eight core GIS datasets form the backbone of the analysis, including locally processed terrain, hydrology, soil, land-use, and exposure layers. These are complemented by six supplementary datasets, such as EURO-CORDEX climate projections, national reference data, and scenario products, which provide validation and broader context. Together, these datasets allow for a high-resolution analysis that is both scientifically robust and locally relevant.

New impact metrics have been introduced to better fit the local context, including refined susceptibility maps for erosion, exposure overlays for agricultural land and rural roads, and combined flood-erosion screening outputs. These metrics help clarify which areas and groups are most vulnerable, and where adaptation measures should be prioritized.

Indirect impacts were also considered, particularly the cascading effects of road blockages on access to services, the implications of soil erosion for agricultural productivity, and the potential knock-on effects of flooding on public health and local economies.

Despite these advances, important limitations remain. Local discharge and roughness data required for hydraulic modelling are incomplete, soil datasets are partly outdated, and building inventories are not comprehensive. Climate projections are available at coarse resolution, and socio-economic scenarios were not explicitly modelled in this phase. These constraints are acknowledged transparently, with uncertainties reported explicitly to avoid false precision.

By fine-tuning the CLIMAAX workflows and integrating local evidence, Phase 2 delivers a regionalized risk analysis that strengthens the credibility of the Climate Adaptation Plan. It provides

Libohova with a clearer, decision-relevant picture of flood and erosion risks, laying the foundation for targeted adaptation strategies in Phase 3.

Table 2-2 Phase 2 core and refined datasets

Dataset	Source	Scale/resolution	Use	Key limitation
Local DEM	Local project input	~3.807 m	Flood/erosion terrain refinement	Date and original licence are not stated in the supplied source metadata; project access is documented.
DEM-derived hydrographic / stream network	Derived from the local DEM	~3.807 m terrain-derived network	Internal drainage interpretation / terrain-model support	Not an independent observed hydrographic dataset; reservoirs/ponds are not explicitly represented as storage features.
WRB soils	ASIG, Pedology	2001 study; vector	Erosion hotspot stratification	Based on a 2001 study; not compliant with the current Albanian Pedology technical specification
LUISA 2018	JRC	100 m	Exposure / land-cover screening	Retains native information content after alignment
Settlements & roads	Local project GIS input	Vector	Local exposure	Date and original licence are not stated in the supplied source metadata; project access is documented.
Public/critical facilities	Local project GIS input	44 points	Local exposure	Not a complete building inventory
Poliçan daily rainfall	Local historical station series	Daily	24 h validation and frequency analysis	No sub-daily observations

Dataset	Source	Scale/resolution	Use	Key limitation
EURO-CORDEX	EC-EARTH / KNMI-RACMO22E	Regional climate grid	Historical/future extremes	Model bias / scale limitations
JRC river-flood hazard	European Commission JRC	European-scale raster	Flood depth and extent	Small tributaries may be underrepresented
Aqueduct Floods	WRI Aqueduct	Coarse global/regional	Qualitative future context	Not local hydraulic modelling
Official hydrographic reference map	Official hydrographic/topographic reference supplied for Libohovë	Map scale 1:82,000	Independent qualitative validation of watercourses and permanent water bodies	Map/reference evidence rather than model-ready vector geometry in the current package.
AMBU / Vjosa FRMP hazard & risk maps	AMBU / IPF10; KKU-approved national flood maps	1:25,000; HQ33, HQ50, HQ100, HQ200	Independent national flood-hazard/risk reference and policy context	Current package contains PDF map products; direct GIS overlay requires original digital layers.

2.3.1 Hazard #1 - fine-tuning to local context

2.3.1.1 Hazard assessment

Heavy rainfall was analysed first because it is an important climate driver of runoff and flood response. The Poliçan station lies approximately 1.94 km outside the municipal boundary and provides a complete daily annual-maximum series used for local 24-hour validation. Over the common 1976–1994 period, observed annual maxima have a mean of 63.53 mm and a maximum of 167.8 mm, compared with 80.34 mm mean and 128.27 mm maximum in the historical EURO-CORDEX nearest-cell series. The KS statistic of 0.526 (p = 0.0092) indicates a statistically significant difference between the distributions.

Table 2-3 Poliçan / EURO-CORDEX common-period validation

Series	Period	N	Mean (mm)	SD (mm)	Max (mm)	KS D	KS p
Poliçan observed	1976–1994	19	63.53	35.42	167.8	—	—
EURO-CORDEX historical	1976–1994	19	80.34	24.80	128.27	0.526	0.0092

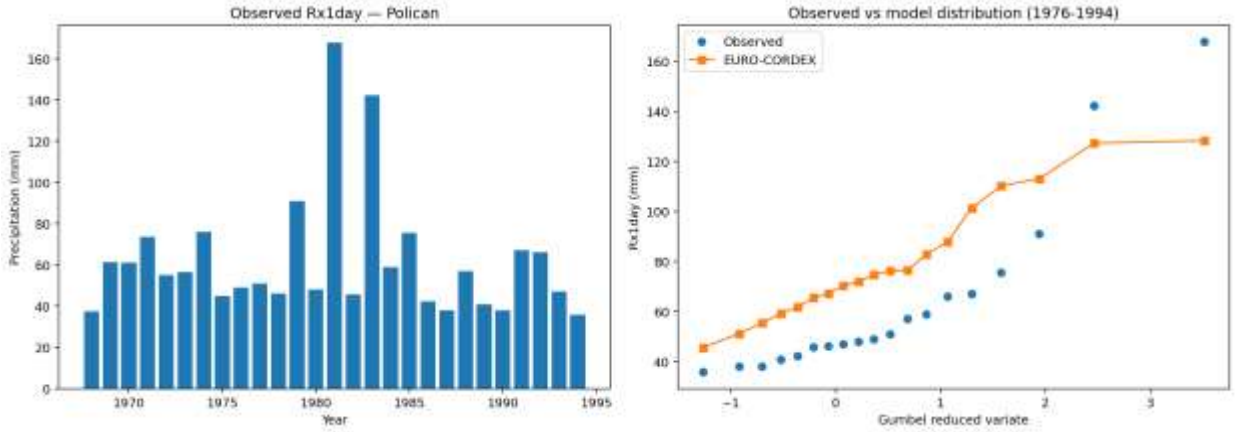


Figure 2-2 Validation of observed Poliçan 24-hour annual maxima against historical EURO-CORDEX.
Source: CLEAR-AL Phase 2 analysis; Poliçan observations and EURO-CORDEX

Because the model distribution is not an exact local match, future 24-hour design values are obtained through a delta-change approach: the relative modelled future change is applied to the observed local baseline. The locally anchored increase is strongest for more frequent extremes (+10.98% at RP2) and declines toward +2.90% at RP100. Area-weighted municipal model results show a comparable pattern (+10.61% at RP2 to +2.67% at RP100).

Table 2-4 Locally anchored 24-hour return levels

RP (years)	Observed baseline (mm)	Model historical (mm)	Model future (mm)	Local future (mm)	Change
2	53.83	70.87	78.65	59.74	+10.98%
5	74.60	92.22	100.30	81.14	+8.76%
10	92.60	109.79	117.82	99.37	+7.31%
25	121.67	136.85	144.39	128.37	+5.51%
50	148.98	161.15	167.91	155.23	+4.19%
100	182.16	189.53	195.04	187.45	+2.90%

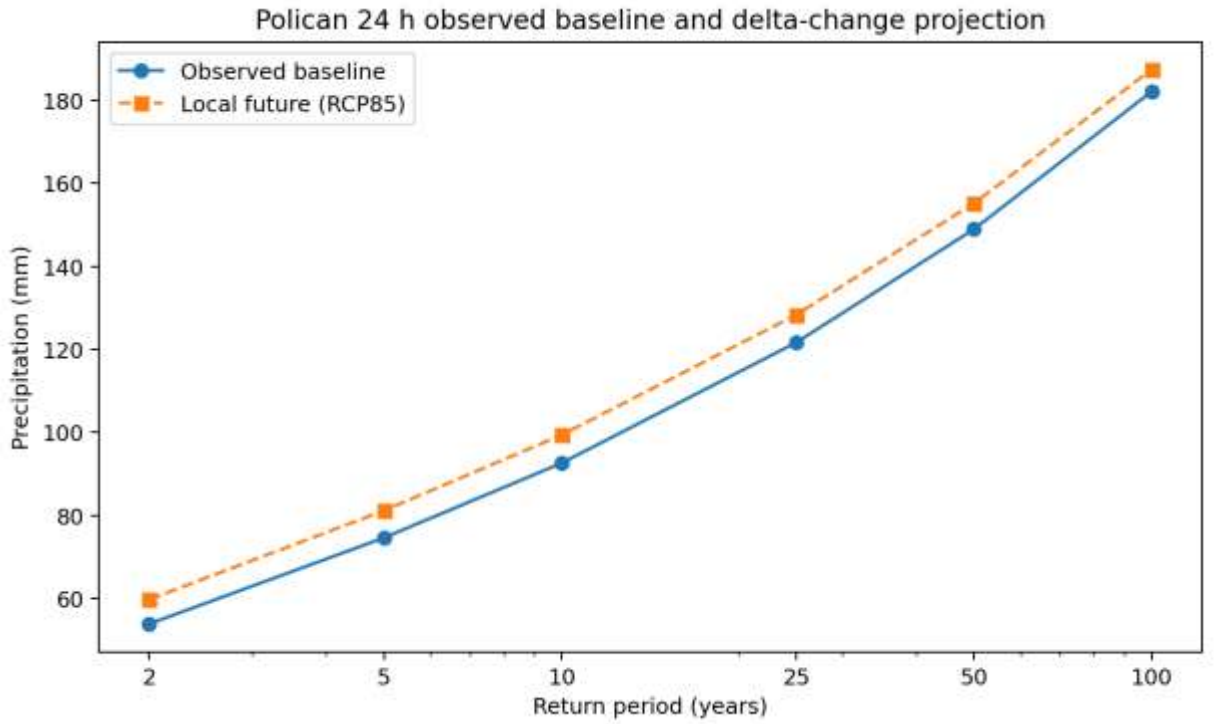


Figure 2-3 Locally anchored 24-hour extreme-precipitation projection using delta change
Source: CLEAR-AL Phase 2 analysis.

For river-flood hazard, JRC present-day maps provide the primary hydraulic-depth reference. Flooded area increases from 4.879 km² at RP10 to 5.560 km² at RP500. Mean depth over flooded cells remains below 1 m, while the 95th percentile is about 2.1–2.4 m. Absolute maxima above 10 m are retained for QA but are likely strongly influenced by channel cells and are not used as representative floodplain depth.

Table 2-5 JRC river-flood hazard statistics within Libohovë

RP	Flooded area (km²)	Municipality flooded	Mean depth (m)	P95 depth (m)	Max depth (m)
10	4.879	2.116%	0.89	2.22	10.26
50	5.268	2.285%	0.92	2.14	10.48
100	5.324	2.309%	0.94	2.24	10.56
200	5.435	2.357%	0.95	2.32	10.63
500	5.560	2.411%	0.97	2.37	10.72

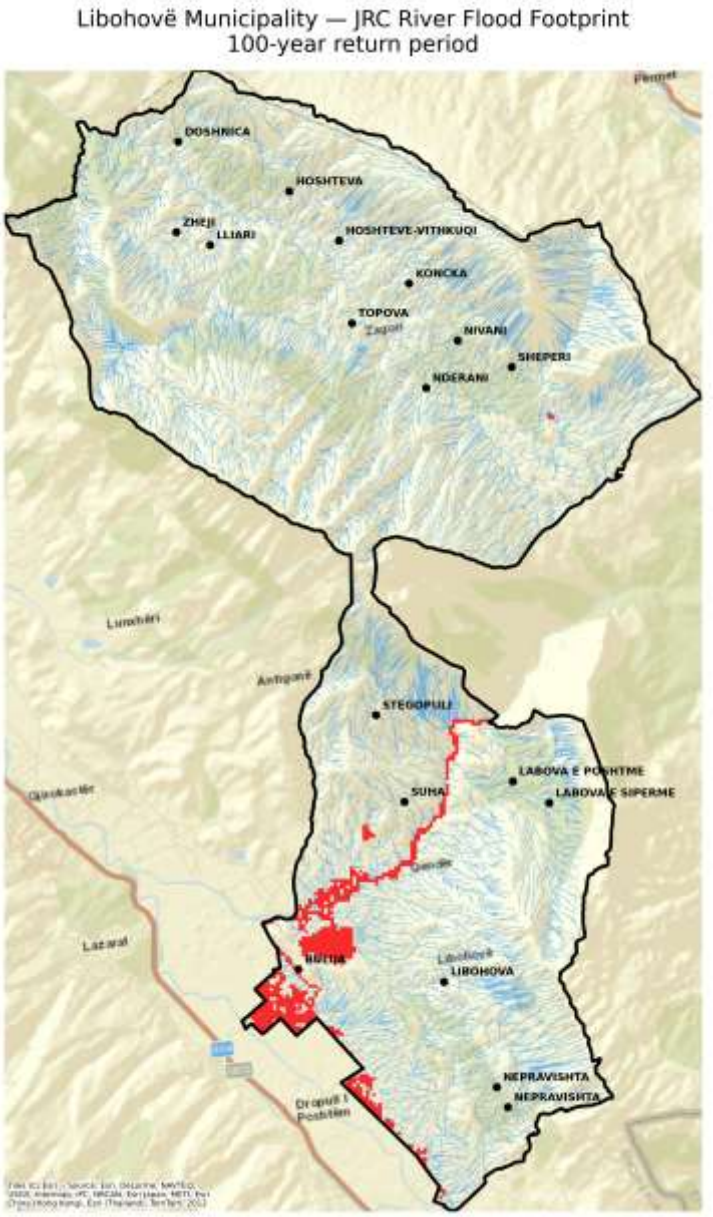


Figure 2-4 JRC RP100 river-flood footprint in Libohovë.
Source: European Commission JRC flood maps processed in the CLIMAAX workflow; CLEAR-AL municipal overlay

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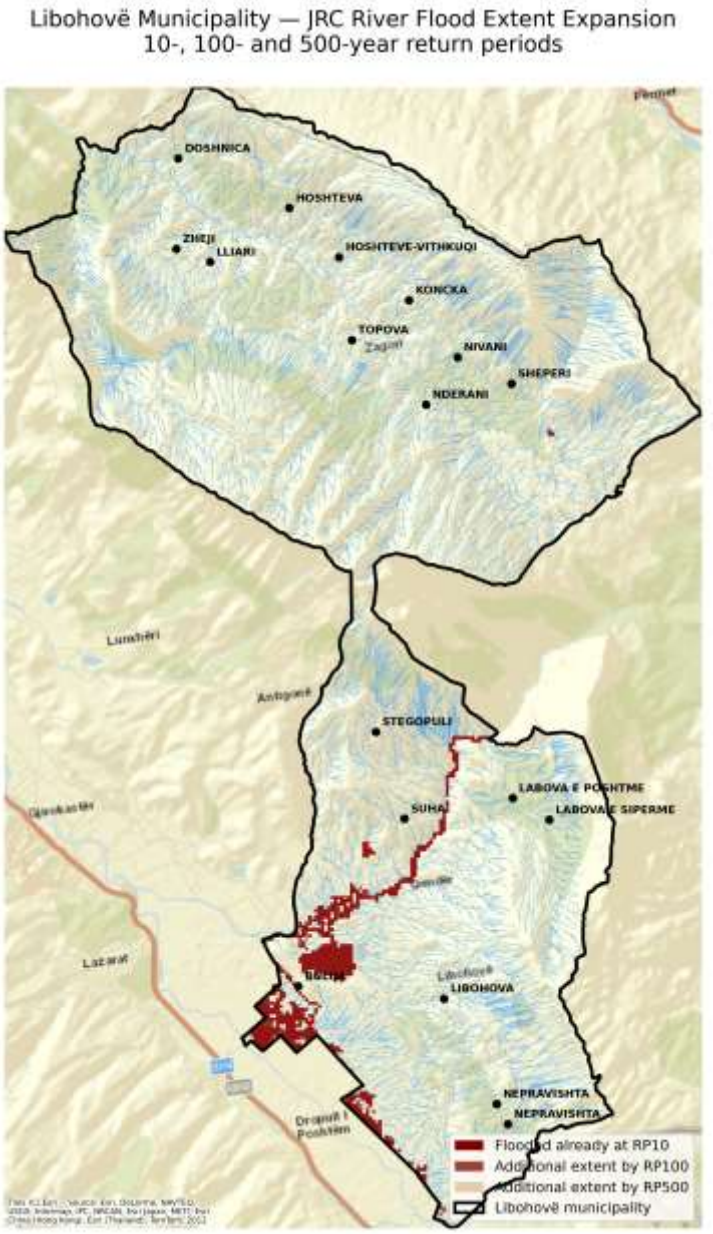


Figure 2-5 Expansion of the JRC flood footprint from RP10 to RP500
Source: European Commission JRC flood maps; CLEAR-AL Phase 2 analysis.

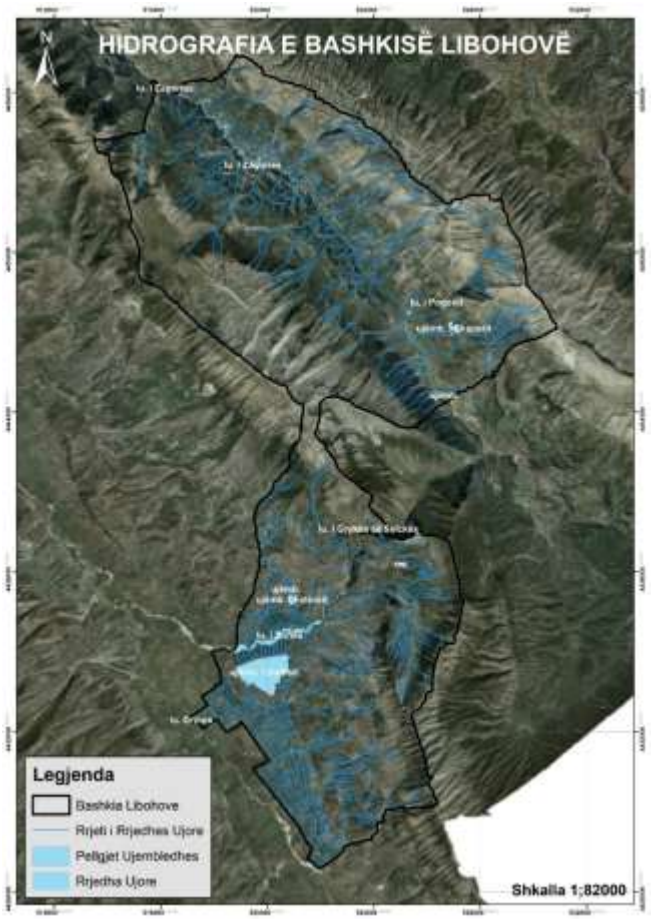
In Phase 2, the standard CLIMAAX input from JRC (hydraulic-depth products) was complemented with an official Albanian source. The **WRMA/IPF10 Vjosa Flood Risk Management Plan** provides flood-hazard and flood-risk maps for the Drinos APSFR system, prepared at 1:25,000 scale and covering return periods HQ33, HQ50, HQ100, and HQ200. These maps were formally approved by NCW Decision No. 2, dated 15 July 2024. For Libohova, the relevant national context is the combined Drinos APSFR 4, 2, and 6 system.

The official risk maps include receptor information that complements the CLEAR-AL DamageScanner outputs. For the administrative unit Qendër Libohovë, the WRMA maps report affected-population indicators of 29 people (2.31%) at HQ33, 32 people (2.55%) at HQ50, 34 people (2.71%) at HQ100, and 36 people (2.87%) at HQ200, out of a total of 1,256 residents. In contrast, the separate administrative unit Libohovë is shown with 0 affected out of 1,945 residents.

These national statistics cannot be directly compared with the municipality-wide potential damage totals produced by CLEAR-AL. Instead, they serve as independent context and validation, helping to cross-check and strengthen the local risk assessment.

Table 2-6 Three-level flood evidence framework used in Phase 2

Evidence level	Principal source	Spatial / scenario basis	Use in CLEAR-AL	Key limitation
European / CLIMAAX reference	European Commission JRC	RP10, RP50, RP100, RP200, RP500; European-scale raster	Hydraulic depth/extent and DamageScanner hazard input	Small tributaries/local runoff pathways may be underrepresented.
National official reference	AMBU / IPF10 Vjosa FRMP; KKU-approved maps	HQ33, HQ50, HQ100, HQ200; 1:25,000; Drinos APSFR 4/2/6	Independent national hazard/risk context, receptor evidence and policy alignment	Current package contains PDF maps rather than original model rasters/vectors.
Local Phase 2 refinement	CLEAR-AL local DEM model	~3.807 m terrain grid; HAND-like, distance, drainage area and slope screening	Small-drainage / terrain susceptibility and integrated multi-risk screening	Not hydraulic inundation; reservoirs are not explicitly simulated as storage/operational features.



In the local model, the stream layer was generated from the DEM. This remains useful for terrain routing, but it does not serve as an independent hydrographic validation source. For that purpose, **the official hydrographic and topographic map** is used as the qualitative reference.

The official map confirms the main drainage structure of the municipality and identifies **the Zagorie, Pogon, Gryka e Selckës, Suhë, and Drinos systems**. It also highlights several reservoirs and pond features, which are particularly relevant in the southern part of Libohova.

Figure 2-6 Official hydrography of the Municipality of Libohovë, including the watercourse network and reservoir/pond features
Source: official hydrographic/topographic reference supplied for CLEAR-AL Phase 2; map scale 1:82,000

In the local terrain model, reservoirs are not simulated with storage capacity, outlet rules, or controlled releases. This does not invalidate the susceptibility analysis, since the model is designed as a **topographic screening tool** rather than a reservoir-routing or hydraulic inundation model. However, depression filling and D8 routing can oversimplify how real water bodies behave, so results immediately around and downstream of reservoirs should be interpreted with extra caution.

This limitation applies to the DEM-based susceptibility layer and the integrated multi-risk map. It does not affect the JRC depth rasters, the AMBU national maps, or the DamageScanner calculations, so a full rerun is not required. If digital reservoir polygons and outlet information become available, a focused sensitivity check around those features would be a useful refinement for Phase 3.

The local refinement starts from the ~3.807 m DEM and derives D8 flow direction and accumulation, contributing drainage area, a DEM-based stream network, HAND-like elevation above drainage, downslope distance, and slope. These variables are combined into a weighted susceptibility index. The official hydrographic map is used only as an external reference. The final product is therefore a **terrain-susceptibility map**, not a hydraulic inundation or reservoir-routing simulation.

High/Very High local flood-terrain susceptibility covers **12.391 km²**. Of this, about **2.621 km² overlaps with JRC RP100**, while **9.769 km² (78.85%) lies outside the JRC RP100 footprint**. This added local domain highlights small-drainage and topographic susceptibility, but it cannot be labelled as additional flooded area without hydraulic modelling.

Table 2-7 Local flood-refinement summary

Indicator	Value	Unit
High + Very High local susceptibility	12.391	km²
Overlap with JRC RP100	2.621	km²
High/Very High susceptibility outside JRC RP100	9.769	km²
Share overlapping JRC RP100	21.15	%
Share outside JRC RP100	78.85	%
JRC RP100 footprint on aligned local grid	5.307	km²

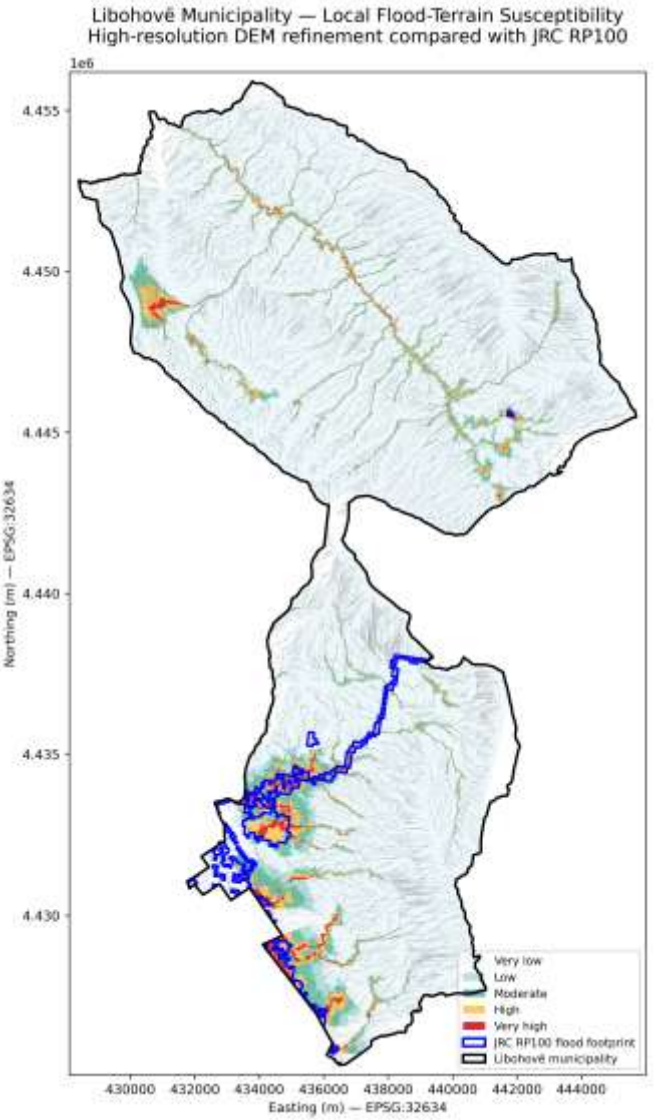


Figure 2-7 KPI Map 1 – Refined local flood-terrain susceptibility and comparison with JRC RP100.
Source: CLEAR-AL Phase 2 DEM-derived terrain/hydrological refinement and JRC RP100; official hydrography used as qualitative reference

2.3.1.2 Risk assessment

Flood risk in Libohova is estimated using the standard **CLIMAAX DamageScanner workflow**. JRC flood-depth data is aligned to the LUISA grid and clipped to the exact municipal boundary. LUISA land-use classes are then combined with JRC depth-damage curves and maximum-damage assumptions. The local terrain-susceptibility raster is kept separate, since it does not simulate water depth but only highlights topographic susceptibility.

For the final Phase 2 calculation, the LUISA maximum-damage workbook was checked against the CLIMAAX method and adjusted for Albania using GDP per capita of **5,444.93 constant 2010 US$** (2023, World Bank WITS/WDI). The vulnerability curves and JRC flood depths remain unchanged; only the class-specific maximum-damage values were rescaled.

As a result, the monetary outputs are reported in **million EUR on the 2010 price basis** used by CLIMAAX. This correction lowers the reported totals but does not affect the spatial hazard patterns or exposure findings.

Table 2-8 Potential direct flood damage (million EUR, 2010 price basis)

Return period	Potential direct damage (million EUR, 2010 prices)
RP10	27.194
RP50	32.076
RP100	33.378
RP200	34.879
RP500	36.531

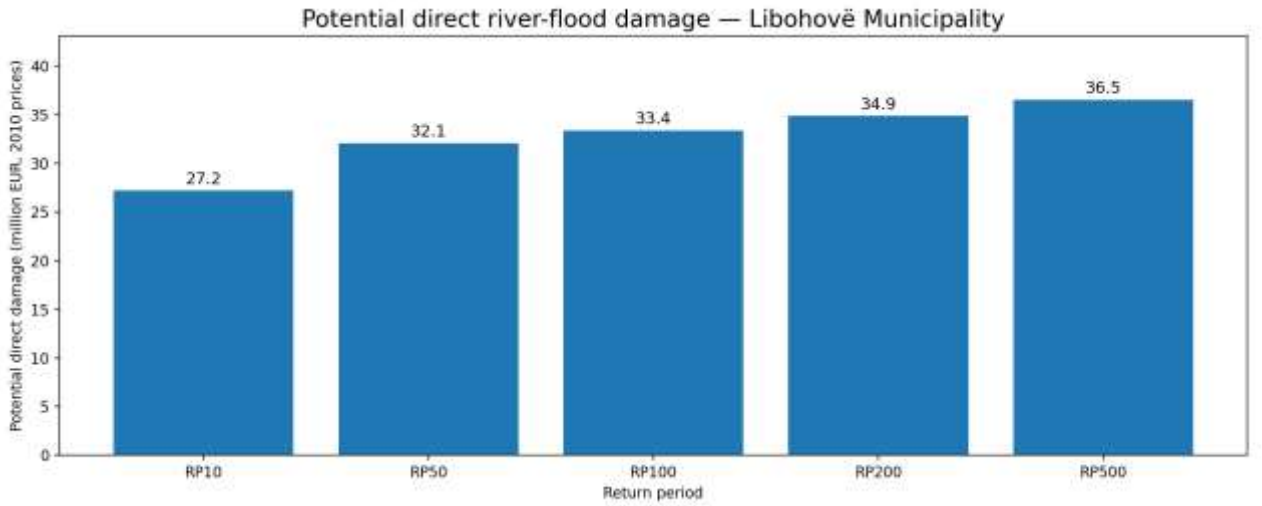


Figure 2-8 Potential direct flood damage by return period (million EUR, 2010 price basis)
Source: CLEAR-AL Phase 2 DamageScanner workflow using JRC flood depth, LUISA 2018, JRC vulnerability curves and Albania GDP/capita 2023 = 5,444.93 constant 2010 US$ for maximum-damage scaling.

Flood damage estimates in Libohova are dominated by non-irrigated arable land and complex cultivation patterns, followed by transitional woodland/shrub, sclerophyllous vegetation, and pastures. At the RP100 return period, these land-use classes account for most of the EUR 33.38 million screening estimate.

The values are expressed on a 2010 price basis and represent potential direct damages, not observed losses. Indirect impacts such as wider economic disruption, recovery costs, cascading effects on networks, or site-specific asset values are not included in the current calculation.

Table 2-9 Local flood-exposure screening

Exposure layer	Total	High/Very High local	Inside JRC RP100	Local High/Very High outside JRC RP100
Settlements	18	1	0	1
Public / critical facilities	44	0	4	0

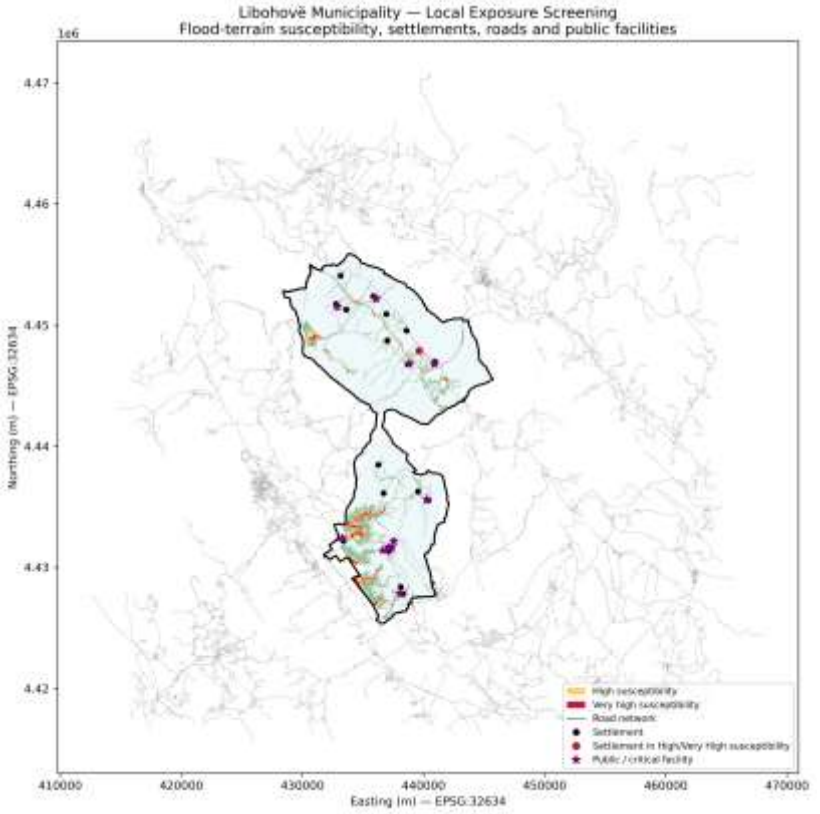


Figure 2-9 KPI Map 2 – Local flood exposure screening
Source: CLEAR-AL Phase 2; local settlements/facilities and flood hazard/susceptibility layers.

Within the JRC RP100 flood footprint, **four public/critical facilities** are identified. However, none of these falls inside the local High/Very High susceptibility classes. This difference reflects the distinct nature of the two products:

- **JRC maps** represent simulated fluvial inundation along the main river corridor.
- The **local susceptibility index** highlights terrain close to smaller drainage lines.

Only about **21% of the local High/Very High area overlaps with the JRC RP100 footprint (see Table 9)**. For this reason, the two layers should be read **together as complementary evidence**, rather than as alternatives.

2.3.2 Hazard #2 – fine-tuning to local context: erosion

Table 2-2 Data overview workflow #2 – erosion

Hazard data	*Vulnerability data*	*Exposure data*	*Impact metrics/Risk output*
Local DEM slope; contributing drainage area; LUISA land-cover	No calibrated fragility/soil-loss function; relative screening assumptions and sensitivity analysis	Agricultural land; roads; settlements; public/critical facilities	Erosion susceptibility class; hotspot area; agricultural/road/point exposure; soil-class hotspot shares

Hazard data	*Vulnerability data*	*Exposure data*	*Impact metrics/Risk output*
screening; WRB soils for stratification			
…	…		

2.3.2.1 Hazard assessment

CLIMAAX does not provide an erosion workflow, so in Phase 2 CLEAR-AL treats erosion as a local susceptibility assessment rather than a calculation of absolute soil loss. The index combines three weighted factors: slope (0.40), drainage/flow concentration (0.30), and land-cover screening (0.30). Results are classified from Very Low to Very High. A full RUSLE-type estimate was not attempted because locally validated data on rainfall erosivity, soil erodibility, management, and support practices are incomplete.

WRB soil classes are used only to describe where erosion hotspots occur, not to assign numerical erodibility values. The ASIG pedology layer is based on a 2001 soil study and, according to its metadata, does not conform to the current Albanian technical specification for the Pedology theme. No RUSLE K-factor or hydrological soil group is inferred directly from WRB class names.

Table 2-10 Erosion susceptibility classes

Class	Area (km²)	Share of valid domain
Very low	18.756	8.211%
Low	126.119	55.212%
Moderate	79.221	34.681%
High	4.256	1.863%
Very high	0.076	0.033%

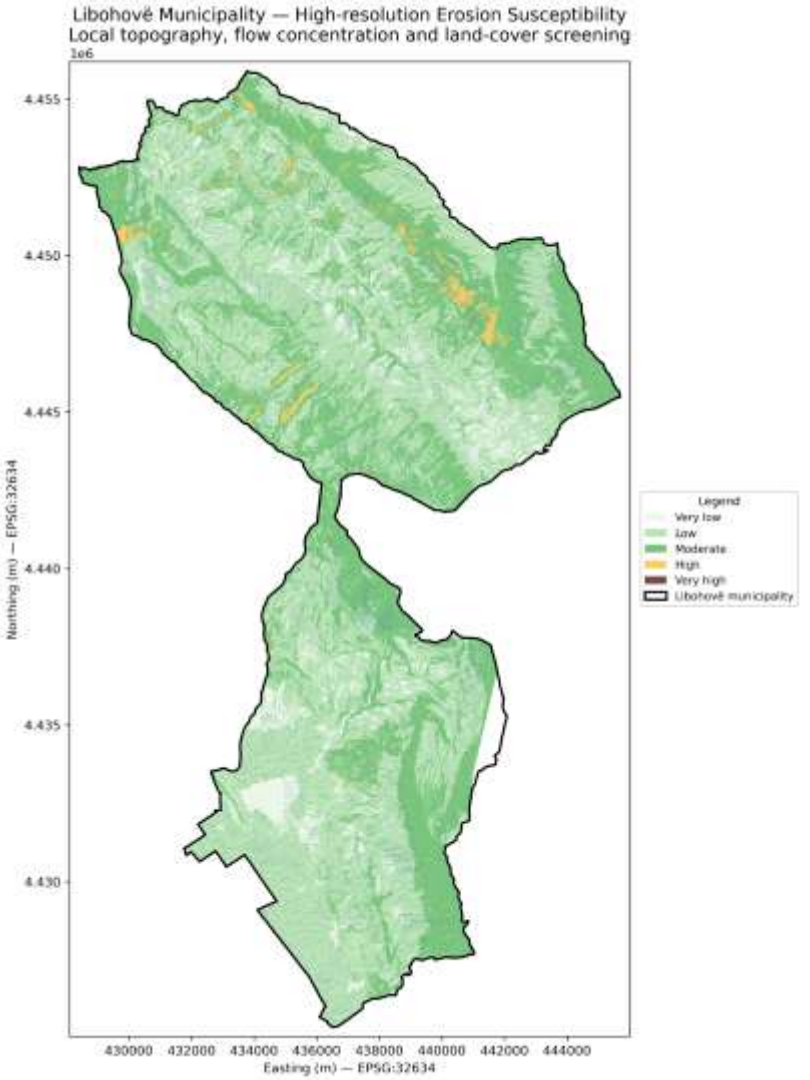


Figure 2-10 KPI Map 3 – High-resolution erosion susceptibility
Source: CLEAR-AL Phase 2; local topography, flow concentration and LUISA land-cover screening.

2.3.2.2 Risk assessment

Because calibrated erosion damage functions are not available, erosion risk is represented through exposure screening rather than monetary loss. Agricultural land, roads, settlements, and public/critical facilities are intersected with the areas classified as High or Very High erosion susceptibility.

Table 2-11 Erosion exposure indicators

Indicator	Value	Unit
High + Very High erosion susceptibility area	4.332	km²
Agricultural land	44.921	km²

Indicator	Value	Unit
Agricultural land in High + Very High erosion susceptibility	0.168	km²
Agricultural hotspot share	0.374	%
Municipal road length	267.870	km
Estimated road length in High + Very High erosion susceptibility	1.235	km
Settlements in High + Very High	0 of 18	count
Public/critical facilities in High + Very High	0 of 44	count

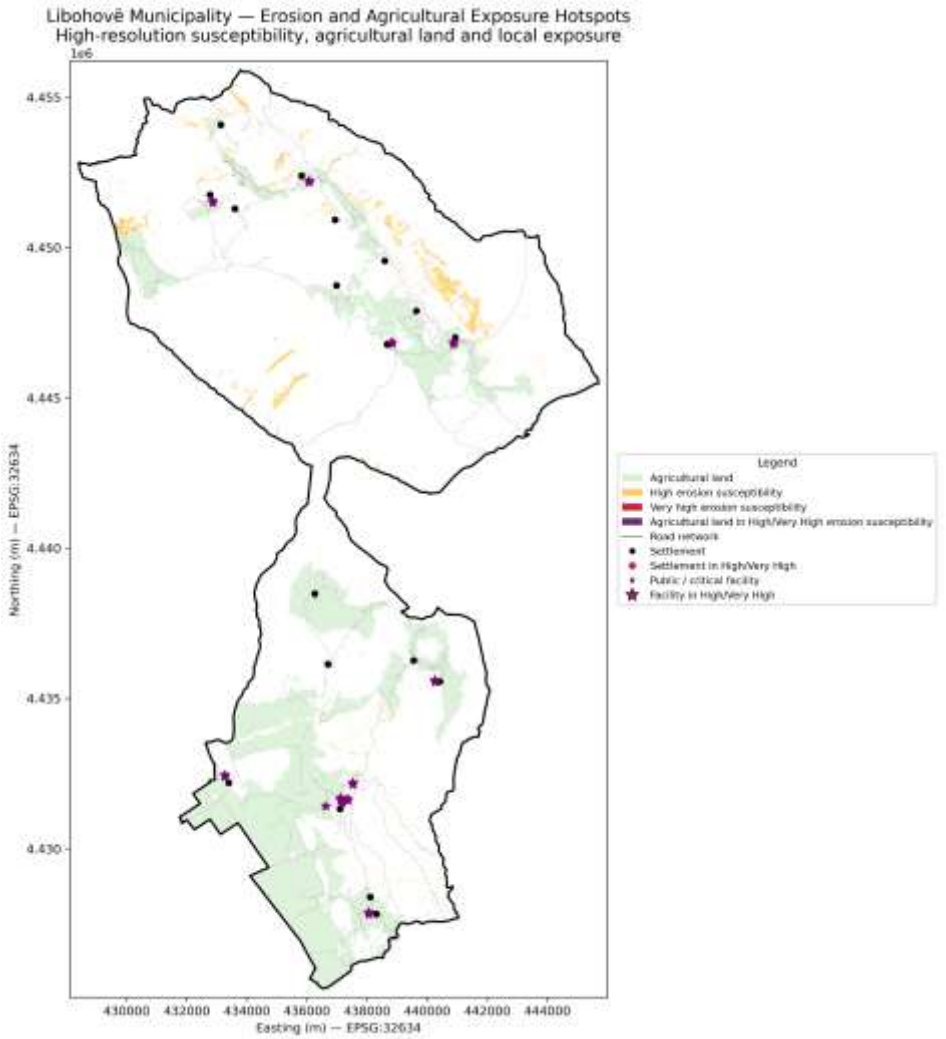


Figure 2-11 KPI Map 4 – Erosion and agricultural exposure hotspots
Source: CLEAR-AL Phase 2; erosion susceptibility, LUISA agricultural land and local exposure layers.

Among soil types, Calcaric Cambisol contains the largest High/Very High erosion hotspot area (3.398 km²), followed by Mollic Cambisol (0.461 km²) and Fluvic Cambisol (0.293 km²). These

absolute hotspot areas should not be interpreted as intrinsic soil erodibility, since each soil class covers different total areas. For this reason, the within-class hotspot share is reported alongside the absolute values.

Full-resolution sensitivity testing shows that the Balanced weighting reproduces the final hotspot share of 1.896%. A topography-dominant weighting increases the High/Very High area to 20.533 km² (8.989%), while a land-cover-sensitive weighting produces 7.784 km² (3.407%). This sensitivity highlights a key uncertainty and reinforces the need for expert review and field validation before using the results for site-specific decisions.

Table 2-12 Erosion-model weight sensitivity

Scenario	Slope	Flow	Land cover	High/Very High area	Share
Balanced	0.40	0.30	0.30	4.332 km²	1.896%
Topography-dominant	0.55	0.25	0.20	20.533 km²	8.989%
Land-cover-sensitive	0.35	0.25	0.40	7.784 km²	3.407%

2.3.3 Additional assessments based on local models and data

Beyond the standard CLIMAAX workflows, Phase 2 incorporated several **locally developed analyses** to strengthen the risk assessment for Libohova. These additional assessments draw on municipal datasets, terrain modelling, and susceptibility screening tools, providing finer detail on hazards and exposures that are not fully captured by regional or European reference products. By integrating local evidence, the analysis delivers a more context-specific understanding of flood and erosion risks, while also highlighting uncertainties and data gaps that require further validation in future phases.

2.3.3.1 Hazard assessment

The additional local assessment integrates the High/Very High flood-terrain susceptibility from the flood module with the High/Very High erosion susceptibility from the erosion module, using their common valid grid. The categorical output distinguishes four classes: areas with no hotspot, flood-only hotspots, erosion-only hotspots, and combined flood+erosion hotspots. This product is a spatial screening tool designed to highlight overlapping hazard zones. It is not a combined monetary-risk surface and should be interpreted as qualitative evidence rather than financial damage estimates.

Table 2-13 Integrated flood–erosion hotspot statistics

Class	Area (km²)	Share of municipality
Neither hotspot	199.525	86.585%
Flood hotspot only	12.268	5.324%
Erosion hotspot only	4.138	1.796%
Combined flood + erosion hotspot	0.122	0.053%
NoData / outside common valid domain	14.384	6.242%

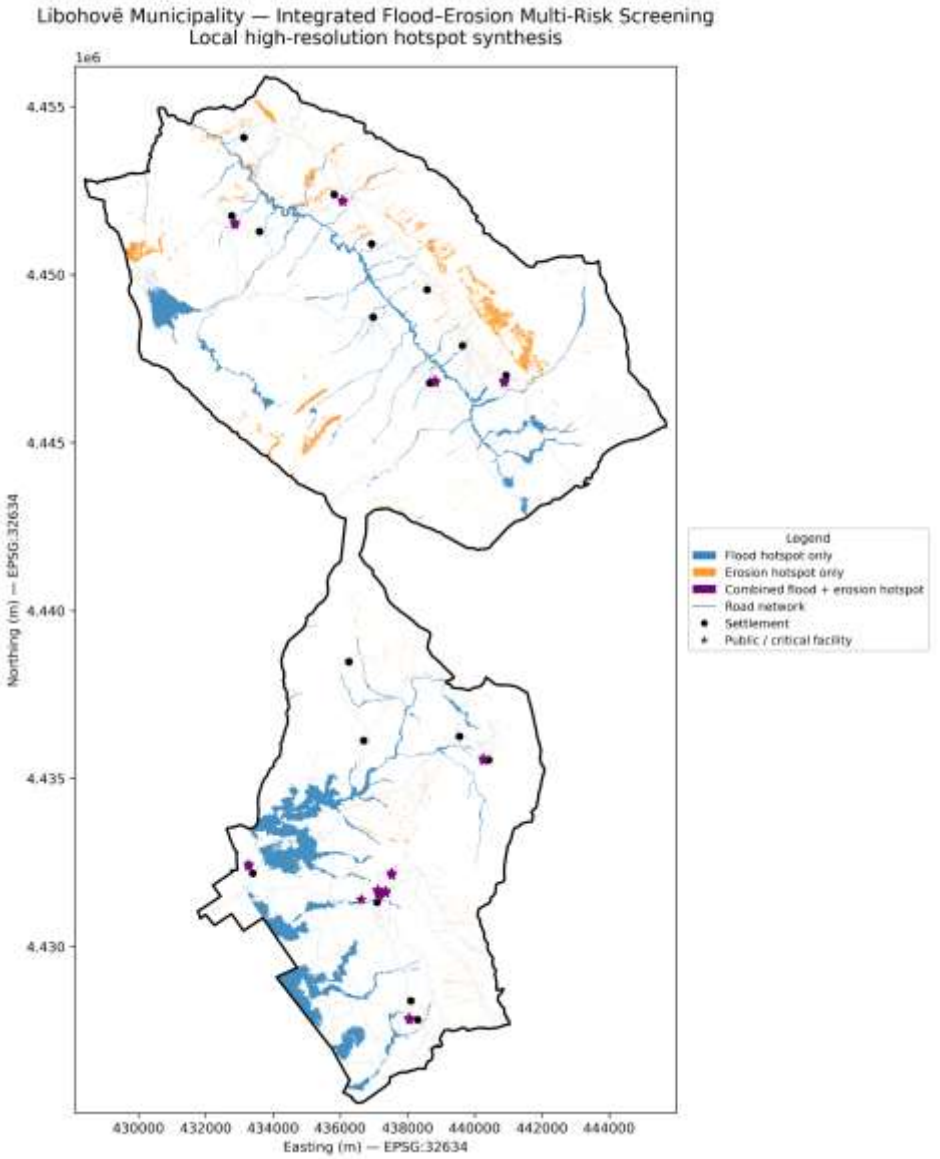


Figure 2-12 KPI Map 5 – Integrated flood–erosion multi-risk screening
Source: CLEAR-AL Phase 2 local flood and erosion susceptibility products with local exposure context

2.3.3.2 Risk assessment

The combined hotspot area is relatively small (0.122 km²) but important for prioritisation, since interventions in these locations may need to address both runoff/flood pathways and erosion/slope protection. Flood-only hotspots cover a much larger area than erosion-only hotspots, reflecting the broader footprint of the local flood-terrain screening. A 14.384 km² common-domain gap is retained as NoData to ensure missing information is not misinterpreted as zero risk.

In the integrated map, the erosion-hotspot total (4.138 + 0.122 = 4.260 km²) is slightly lower than the 4.332 km² reported by the erosion module, because about 0.072 km² of erosion hotspot lies outside the common valid flood–erosion domain. The flood-hotspot total (12.268 + 0.122 = 12.390 km²) matches the flood module within rounding.

Indirect impacts are not quantified in monetary terms. Potential concerns include road accessibility, service continuity, agricultural disruption, and maintenance burdens. These aspects should be examined in Phase 3, when adaptation options are evaluated and site-specific information is collected.

2.4 Key Risk Assessment Findings

The ratings presented in this section are technical pre-validation results. They are provisional because the CLIMAAX Key Risk Assessment step is a participatory process. Final ratings for severity, urgency, resilience capacity, and priority should be confirmed or adjusted after consultations with stakeholders, experts, and priority groups, and then recorded in the official response matrix.

The Key Risk Assessment represents the transition from hazard description to risk prioritization, identifying which risks require greater attention in the next phase of the project. It integrates outputs from the climate analysis, historical impact records, and the first interpretation of exposure and vulnerability in Libohovë Municipality.

Risks are evaluated against three criteria: severity, urgency, and response capacity, as displayed in the evaluation dashboard. This structured approach ensures that findings are evidence-based while also supporting engagement with local actors.

In Libohovë, the strongest evidence relates to **extreme rainfall and flood events**, which have affected buildings, agricultural land, and road infrastructure. This risk is therefore prioritized as the most urgent. **Agricultural drought and heat-related water stress** are also highly relevant, but the available evidence of direct impacts is less complete and requires further validation through local consultation.

2.4.1 Mode of engagement for participation

The final Key Risk Assessment must reflect both technical evidence and stakeholder judgement. While the modelling outputs and the three-stage consultation review structure are prepared, the dated consultation records are still pending. For this reason, the ratings presented here represent the technical team's provisional view, rather than a stakeholder-validated dashboard.

This distinction is important: the current results provide a structured, evidence-based pre-assessment, but the final prioritization of risks in Libohovë Municipality will only be confirmed once external consultations with local stakeholders, experts, and priority groups are completed and formally recorded in the response matrix.

2.4.2 Gather output from Risk Analysis step

Risk evaluation in Libohovë Municipality draws on a wide set of outputs generated during the Risk Analysis step. These provide complementary information on hazard magnitude, spatial extent, exposed receptors, and associated uncertainties. Together, they form the technical foundation for assessing severity, urgency, and resilience capacity.

The datasets and indicators applied include:

- **Observed and modelled heavy-rainfall signals**, used to capture extreme precipitation patterns.
- **JRC flood hazard maps**, aligned to the LUISA grid and clipped to the municipal boundary.

- **Local flood-terrain susceptibility raster**, highlighting small-drainage and topographic risks.
- **DamageScanner outputs**, estimating potential direct damage to land-use classes.
- **Local settlement and facility exposure layers**, identifying receptors at risk.
- **Erosion susceptibility index**, combining slope, drainage concentration, and land-cover screening.
- **Agricultural and road exposure overlays**, intersected with High/Very High erosion classes.
- **Sensitivity testing results**, showing how hotspot areas vary under different weightings.
- **Integrated flood–erosion hotspot map**, distinguishing flood-only, erosion-only, and combined hotspots.

Additional supporting datasets include:

- **Climate datasets** from Libohovë and surrounding meteorological stations, harmonized for consistency.
- **Rainfall indicators** (annual totals, summer rainfall, maximum 1-day rainfall, heavy rainfall days).
- **Dry-condition indicators** (number of dry days, longest dry spell).
- **Temperature indicators** (annual and summer mean).
- **Geospatial reference data** (station coordinates, elevation, municipal boundaries, DEM).
- **Historical extreme event records** documenting floods, erosion, and landslides.
- **Agricultural and water-management datasets** showing intersections between climate impacts, land use, and irrigation.
- **Visual outputs** (graphs, maps, interpolation-ready tables, GeoTIFF/PNG layers) prepared for reporting and GIS integration.

In addition, the assessment incorporates projected changes in extreme rainfall, the local record of damaging events, and the results of drought and wildfire workflows (evapotranspiration, yield loss, economic indicators, Fire Weather Index, danger index, Pareto zones). These are combined with PPV land-use data, building and road layers, irrigation information, and documented limitations, creating a comprehensive evidence base for structured risk evaluation in Libohovë.

2.4.3 Assess Severity

The severity of climate risks in Libohovë Municipality has been assessed according to the four categories defined in the Key Risk Assessment Protocol: limited, moderate, substantial, and critical. The evaluation combines historical records, climate indicators, modelled projections, and stakeholder perspectives to capture both current and future conditions.

Extreme rainfall, local flooding, erosion, and landslides

- Severity is rated **Substantial** for both current and future periods.
- Documented events, such as the 2026 flood, caused damage across multiple sectors—houses, businesses, agricultural land, and road infrastructure—with reported losses of about **11 million ALL**.

- Projections show 24-hour rainfall increasing by **30–52%** for 10- to 100-year events.
- The risk is not rated Critical, as no hydraulic flood model or calibrated damage model is available, but the persistence and multi-sectoral nature of impacts confirm its priority status.

Meteorological drought and heat-related water stress

- Severity is assessed as **Moderate today** and **Substantial in the future**.
- Current evidence highlights the sensitivity of olives, vineyards, vegetables, and forage crops to water availability.
- Modelled maize yield loss increases from about **5% to 17%**, while the economic indicator rises threefold under future scenarios.
- Direct records of drought damage are less complete than for rainfall hazards, but projections indicate growing stress on agriculture and water resources, with potential cascading effects if adaptation measures are not implemented.

Wildfire hazard

- Severity is rated **Moderate today** and **Substantial in the future**.
- Fire weather conditions move into the Extreme class and the danger index rises sharply.
- The absence of a local record of wildfire impacts prevents assigning a higher current rating.
- Future projections suggest increasing exposure of natural and semi-natural land, reinforcing the need for preventive measures.

Stakeholder perspectives and institutional capacity

- Consultations confirmed strong evidence for extreme rainfall impacts and emphasized the need to validate drought and heat-related risks more thoroughly.
- Vulnerable groups highlighted the multi-sectoral nature of flooding, while agricultural representatives stressed the importance of water management.
- Decision makers are increasingly aware of climate risks, but further training and capacity building are required to ensure severity assessments are fully integrated into planning.

Additional screening results

- River-flood risk is provisionally assessed as **Substantial**. Although the JRC inundated fraction of the municipality is spatially limited, the screening-level potential direct damage remains material (**EUR 27.19–36.53 million, 2010 price basis, across RP10–RP500**). Four public/critical facilities intersect RP100, and the local terrain analysis identifies additional susceptible drainage terrain requiring verification.
- Erosion is provisionally assessed as **Moderate** at municipal scale, with High/Very High classes covering **4.332 km²** and direct agricultural overlap of **0.168 km²**. Local road and combined hotspots may be important at site level.
- No evidence of irreversible loss or human casualties is available in the current Phase 2 package, so a **Critical rating is not supported** by the data.

2.4.4 Assess Urgency

The urgency of climate risks in **Libohovë Municipality** has been assessed according to the four categories defined in the Key Risk Assessment Protocol: *no action needed, watching brief, more action needed, immediate action needed*. The evaluation considers current and future risks, the timing of potential impacts, and stakeholder perspectives.

Flood risk (extreme rainfall, flooding, erosion, landslides)

- Urgency is rated **More action needed**.
- These hazards are already present and have caused documented damage, including the 2026 event with losses of about **11 million ALL**.
- As sudden-onset hazards, impacts occur quickly and require preparedness before events take place.
- Targeted interventions are needed for local roads, drainage systems, erosion-prone areas, and settlements to reduce future damage.

Meteorological drought and heat-related water stress

- Urgency is assessed between **Watching brief and More action needed**.
- Drought develops gradually, but projections of hotter and drier summers suggest increasing stress on agriculture and water resources.
- The decline in irrigated area raises concerns about exposure, requiring further stakeholder validation.
- While direct evidence of damage is limited, the potential for cascading effects—crop yield reduction, ecosystem degradation, and economic stress—justifies closer monitoring and incremental action.

Wildfire hazard

- Urgency is rated **More action needed**.
- Future projections show fire weather shifting into the Extreme class and the danger index rising sharply.
- Although local records of wildfire impacts are lacking, preventive measures, landscape management, and emergency planning should be in place before larger losses occur.

Stakeholder perspectives

- Consultations highlighted the distinction between **sudden-onset hazards** (e.g., extreme rainfall) and **slow-onset hazards** (e.g., drought).
- Vulnerable groups emphasized the need for immediate preparedness against flooding, while agricultural representatives stressed the importance of water management and irrigation infrastructure.
- Decision makers acknowledged that flooding requires urgent measures to protect settlements and infrastructure, whereas drought demands a longer-term strategy balancing monitoring with gradual adaptation.

2.4.5 Understand Resilience Capacity

Resilience capacity in **Libohovë Municipality** has been assessed according to the categories of the Key Risk Assessment Protocol (*low, medium, substantial, high*). The analysis considers financial, social, human, physical, and natural dimensions of risk management, alongside existing measures and institutional capacity.

For hazards linked to **extreme rainfall, flooding, erosion, and landslides**, resilience is provisionally rated as **Medium**. The municipality has demonstrated experience in emergency response and has documented past impacts, which shows institutional awareness. However, repeated damage across villages highlights persistent weaknesses in drainage systems, road protection, erosion control, slope stability, and preventive maintenance. Limited financial resources, uneven preparedness, and the absence of hazard protection plans or insurance schemes further constrain resilience.

In the case of **meteorological drought and heat-related water stress**, resilience is also assessed as **Medium**, though with greater uncertainty. Local agricultural knowledge provides a foundation for adaptive practices, but the decline in irrigated areas signals growing vulnerability. Infrastructure for irrigation and water storage remains insufficient, and support mechanisms for farmers are limited. Natural capacity is under pressure, while social and institutional capacity to manage drought risks is not yet robust.

For **wildfire hazard**, resilience is provisionally rated **Medium**, pending more detailed information on local fire-response systems, including equipment, water points, access routes, and records of recent events. Institutional arrangements and community knowledge provide a starting point, but technical and operational gaps must be addressed to strengthen preparedness.

Across all three risk pathways, resilience is constrained by gaps in financial resources, technical infrastructure, and institutional preparedness. Stakeholders emphasized the need to strengthen early warning systems, improve drainage and irrigation networks, and expand awareness campaigns to build human and social capacity. Decision-makers acknowledged that while local knowledge and experience exist, structured interventions and external support are required to move resilience capacity from Medium toward Substantial.

Overall, resilience capacity in Libohovë is provisionally characterized as **Medium**. The municipality benefits from an active CLIMAAX project structure, access to GIS analysis, local datasets, and civil-protection/technical functions. Phase 3 provides a pathway for adaptation design. However, important capacity gaps remain: no local hydraulic model, incomplete asset inventory, outdated soil information based on the 2001 pedological study, limited sub-daily rainfall observations, incomplete formal validation, and the need for site-level engineering and field data before investment decisions. On the evidence currently available, the rating is therefore neither low nor high, but remains at a medium level.

2.4.6 Decide on Risk Priority

The process of assigning risk priorities in **Libohovë Municipality** follows the methodology outlined in the Key Risk Assessment Protocol and is supported by the evaluation dashboard. This step integrates the three dimensions of **severity, urgency, and resilience capacity** to determine which risks require immediate follow-up and which should be monitored for further validation.

Based on the available technical evidence, **extreme rainfall, local flooding, erosion, and landslide-related impacts** have been assigned **Priority 1**. This decision reflects the strongest local evidence, including documented past events that caused damage to buildings, roads, agricultural land, olive groves, and local economic assets. Severity is rated *substantial*, urgency is assessed as *more action needed*, and resilience capacity is *medium*. Together, these factors indicate that extreme rainfall impacts demand immediate attention in Phase 3, with priority given to preparedness, infrastructure protection, and community resilience.

Meteorological drought and heat-related water stress have been assigned **Priority 2**. While highly relevant for agriculture, vegetation, water resources, and rural livelihoods, the current evidence of direct impacts is less detailed than for flooding and erosion. Severity is assessed as *moderate to substantial*, urgency as *watching brief to more action needed*, and resilience capacity as *medium*. This combination suggests that drought and heat stress should remain a priority for further analysis and stakeholder validation in Phase 3, particularly as hotter and drier summers may intensify impacts over time.

The **combined flood–erosion hotspot** is treated as a **cross-cutting location-based priority** rather than a separate hazard category. These areas require coordinated measures that address both runoff/flood pathways and erosion/slope protection.

The evaluation dashboard consolidates these findings into a structured overview, ensuring transparency and consistency in priority setting. Final priority assignment, however, should be confirmed through the integrated external consultation and municipal decision process, ensuring that stakeholder perspectives are fully reflected in the response matrix.

Table 2-14 Provisional technical risk evaluation pending stakeholder validation

Risk	Severity	Urgency	Resilience capacity	Provisional priority	Evidence basis
River flooding / intense-rainfall runoff	Substantial	More action needed	Medium	Priority 1	JRC depth/extent; AMBU/KKU-approved Vjosa hazard/risk maps for the Drinos APSFR system; local flood susceptibility; EUR 27.19–36.53 M potential direct damage (2010 price basis); local exposure; positive future 24 h rainfall signal.
Erosion / agricultural & road exposure	Moderate	More action needed	Medium	Priority 2	4.332 km² High/Very High; 0.168 km² agricultural overlap; ~1.235 km roads; sensitivity analysis
Combined flood + erosion locations	Localised but potentially	More action needed at identified sites	Medium	Cross-cutting field-	0.122 km² combined hotspot plus local exposure context

Risk	Severity	Urgency	Resilience capacity	Provisional priority	Evidence basis
	compounding			validation priority	

2.4.7 Policy-relevant implications for Phase 3 and the policy notes

The Phase 2 results already point to two clear policy directions: one focused on **flood and drainage management**, and another on **erosion, agricultural land, and combined hotspot areas**. These findings underline the need for targeted interventions, but the two stand-alone policy briefs still need to be prepared and formally transmitted. The recommendations presented here are intended to guide consultation and Phase 3 planning; they are not final engineering designs.

For flood risk, the **Vjosa Flood Risk Management Plan (FRMP)** provides a direct institutional framework that aligns with the Phase 2 evidence. For Libohovë, three measures are particularly relevant:

1. **M1013-VJ00-006** – integrating flood hazard and risk maps into land-use planning.
2. **M4020-VJ00-006** – updating or preparing the municipal Civil Emergency Plan.
3. **M4040-VJ00-006** – ensuring that approved flood hazard and risk maps are made locally available.

These measures fit naturally with the Phase 2 findings and can be carried forward into Phase 3, where they will be validated through consultation and adapted into actionable municipal priorities.

Table 2-15 Policy-relevant implications derived from Phase 2 findings

Policy theme	Evidence from Phase 2	Technical implication for Phase 3
Flood and drainage risk	JRC RP100 flood extent 5.324 km²; 12.391 km² High/Very High local flood-terrain susceptibility; 9.769 km² of that susceptibility lies outside JRC RP100; potential direct damage reaches EUR 33.38 M at RP100 (2010 price basis); AMBU/KKU-approved Vjosa flood hazard/risk maps provide independent national evidence for the Drinos APSFR system.	Prioritise field verification of local drainage corridors, road crossings and culverts; maintain or upgrade drainage where justified; use site-specific hydraulic studies before structural works; obtain digital official hydrography/waterbody data for reservoir-sensitive QA; align municipal planning with M1013-VJ00-006; update/prepare the Civil Emergency Plan under M4020-VJ00-006; and make approved flood maps locally accessible under M4040-VJ00-006.
Erosion, agriculture and multi-risk	4.332 km² High/Very High erosion susceptibility; 0.168 km² agricultural overlap; about 1.235 km of roads in erosion hotspots;	Target field verification and site-specific erosion-control measures; assess drainage, vegetation, terracing and slope/soil protection according to local conditions; treat combined hotspots as locations

Policy theme	Evidence from Phase 2	Technical implication for Phase 3
	0.122 km² combined flood + erosion hotspot.	where single-hazard interventions may be insufficient.

2.5 Monitoring and Evaluation

The second phase of the climate risk assessment in Libohovë Municipality has provided important lessons. A key insight is that climate indicators only become meaningful for decision-making when they are directly linked to exposure and vulnerability. By integrating future climate projections and completing hazard and risk steps for drought and wildfire, the overall assessment was significantly strengthened.

The process also revealed several challenges. These included incomplete local records, mismatched coordinate systems in GIS layers, coarse resolution of climate models, the absence of future socio-economic scenarios, lack of a hydraulic flood model, limited geo-referenced impact data, and missing daily Fire Weather Index values. These difficulties were managed through quality checks, conservative assumptions, maintaining original dataset resolutions, and distinguishing clearly between official workflow outputs and supplementary local analyses.

Looking ahead, the monitoring system for Phase 3 will track new extreme rainfall and damage events, irrigation network conditions, drought indicators and crop yields, wildfire incidents, land-use changes, and the implementation of adaptation measures. This system will combine reproducible notebooks and GIS layers as a baseline, updated as new data become available. Priority actions include maintaining a dataset register, recording future flood and erosion events, verifying drainage and road-crossing hotspots, improving local asset inventories, collecting sub-daily rainfall where feasible, and documenting new soil and land-management observations. Stakeholders will play a central role by contributing local evidence and validating whether mapped hotspots correspond to observed impacts.

Communication of results will be tailored to different audiences. Outputs will include concise municipal risk summaries, full technical reports, GIS layers, maps and charts, stakeholder presentations, and publication in the Zenodo repository. Public maps will clearly state their scale and limitations, especially where values are derived from coarse climate-model cells. To ensure accessibility, communication will rely on five KPI maps, policy briefs, and municipal meetings, rather than technical outputs alone.

Efficiency in Phase 2 was improved by reusing CLIMAAX workflows, separating European and local components, and automating GIS and QA outputs in reproducible Python notebooks. The main drawback was the need to reconcile heterogeneous data resolutions and incomplete metadata, which required additional effort.

Overall, the second-phase assessment demonstrated that local data substantially improve spatial interpretation, while also revealing where uncertainty increases. The strongest technical improvements were exact municipal masking, local rainfall validation, high-resolution terrain routing, explicit exposure screening, and full-resolution sensitivity analysis. At the same time, difficulties such as scale mismatches, incomplete calibration inputs, and sensitivity of erosion results to weighting assumptions highlighted the importance of continued refinement.

The impact of the CRA has been positive, contributing to improved understanding of risk, stronger institutional capacity, and greater public awareness. With Phase 3, these foundations will be expanded into adaptation design and site-specific validation, ensuring that monitoring and evaluation remain central to climate resilience planning in Libohovë.

2.6 Work plan Phase 3

Phase 3 will build directly on the validated priorities from Phase 2, shifting the focus from **risk assessment to practical adaptation planning**. The aim is not to repeat the analysis, but to translate evidence into concrete measures that can strengthen resilience in Libohovë Municipality.

The process begins with **validation of risk ratings and hotspot areas** through field visits and three planned technical consultations. This step will confirm the severity, urgency, and resilience capacity scores, while ensuring that stakeholder perspectives are fully integrated. Using the Phase 2 maps, priority locations will be identified—villages with recorded rainfall impacts, vulnerable roads and drainage systems, drought-sensitive farmland and irrigation networks, and zones of high wildfire danger.

Based on these findings, adaptation options will be developed for each risk. Flood and drainage measures may include maintenance and upgrades of existing systems, culvert and road-crossing improvements, and, where justified, local hydraulic studies or protective works. Erosion-control and land-management options will be tailored to site conditions, such as drainage control, terracing, vegetation restoration, reforestation, and slope or soil protection. Multi-risk solutions will be promoted, giving preference to measures that reduce several hazards at once—for example, vegetation restoration, soil and water conservation, drainage maintenance, water retention, fire-safe landscape management, and climate-resilient rural roads.

All proposed measures will be **prioritised** using clear criteria: technical effectiveness, cost, feasibility, maintenance requirements, environmental and social impacts, and stakeholder acceptance. A **small-scale pilot adaptation measure** will then be selected for implementation, accompanied by monitoring indicators to track performance and lessons learned. Finally, the validated evidence from Phase 2 and the priorities from Phase 3 will be integrated into municipal development plans, civil-protection preparedness, agricultural and water programmes, and the local climate adaptation plan.

Certain aspects will not be studied in detail during Phase 3. The project will not attempt to convert current screening layers into hydraulic or soil-loss models without the additional field and engineering inputs required for those methods. Where investment design requires precise data—such as water depth, discharge, channel geometry, soil properties, or site-specific asset values—these must be collected explicitly. For flood and drainage refinement, Phase 3 will request the original digital hydrography and waterbody layers from AMBU/ASIG, including reservoir and pond boundaries and, if relevant, dam or outlet information. A targeted sensitivity check around these features will be sufficient; the existing Phase 2 terrain model does not need to be discarded or rebuilt as a reservoir-operation model.

In this way, Phase 3 ensures that Libohovë Municipality moves from **risk identification to actionable resilience strategies**, combining technical evidence with stakeholder input to design measures that are both feasible and locally relevant.

3 Conclusions Phase 2- Climate risk assessment

Phase 2 has provided Libohovë Municipality with a much stronger and more reliable evidence base than earlier assessments. By combining local observations, detailed GIS exposure data, crop water-balance modelling, wildfire indicators, and future climate projections into a single framework, the analysis has moved beyond general hazard screening toward a more precise understanding of local risk pathways.

Key Findings

- **Extreme rainfall** already causes documented damage and is projected to intensify. Under future scenarios, 24-hour rainfall increases by +30% for the 10-year event, +38% for the 25-year, +45% for the 50-year, and +52% for the 100-year event. Past events have damaged houses, businesses, agricultural land, olive groves, and road infrastructure, confirming this as the most urgent risk.
- **Agricultural drought and heat-related water stress** are expected to worsen. Modelled maize yield loss rises from 5.1% to 16.6%, while the economic indicator grows from about €58,000 to €185,000 per climate-model cell. Declining irrigation capacity and hotter summers increase vulnerability across crops and rural livelihoods.
- **Wildfire hazard** is projected to intensify, with fire weather shifting from Very High to Extreme, the danger index increasing by 69%, and the supplementary risk score rising by 45%. Although local records of wildfire impacts are limited, projections highlight growing exposure of natural and semi-natural land.
- **Socio-economic conditions** were not modelled; exposure and vulnerability were kept at today's levels to isolate the effect of climate change.
- **Mapping outputs** at 100 m resolution were used for overlays and communication, but they do not imply that climate data itself has 100 m resolution.

Challenges Addressed and Outstanding Phase 2 successfully advanced the methodology by introducing local validation, exact municipal masking, and terrain-scale analysis. Heavy rainfall projections were locally anchored using observed daily rainfall, while erosion susceptibility was quantified with sensitivity testing. The integrated flood–erosion hotspot map identified 0.122 km² of combined risk zones, highlighting areas where single-hazard interventions may be insufficient.

At the same time, several challenges remain. These include incomplete local records, mismatched GIS coordinate systems, coarse climate-model resolution, lack of future socio-economic scenarios, absence of a hydraulic flood model, incomplete asset inventories, and sensitivity of erosion results to weighting assumptions. A deliberate decision was made to retain 14.384 km² of NoData area, ensuring that missing information is not misinterpreted as zero risk.

Policy and Priority Messages Each risk requires a different type of response:

- Extreme rainfall → drainage improvement, runoff and erosion control.
- Drought and heat stress → water efficiency, irrigation management, and agricultural adaptation.
- Wildfire → prevention, landscape management, and preparedness.

The resulting priorities are:

- **Priority 1:** Extreme precipitation and its local impacts.
- **Priority 2:** Agricultural drought and heat-related water stress.
- **Priority 3:** Wildfire (provisional, pending stakeholder review in Phase 3 due to limited local fire data and response information).

Next Steps Phase 3 will focus on identifying, testing, and implementing adaptation options, using the Phase 2 results as the baseline for evaluating feasibility and monitoring progress. Formal closure of Phase 2 requires completion of consultation records, transmission of two stand-alone policy briefs, verification of editable map files, and incorporation of any newly obtained hydrographic data.

4 Progress evaluation

Phase 2 of the climate risk assessment has provided Libohovë Municipality with a far stronger and more reliable evidence base than earlier stages. By integrating local observations, detailed GIS exposure layers, crop water-balance modelling, wildfire indicators, and future climate projections, the assessment now offers a comprehensive framework that links climate pressures directly to local vulnerabilities.

The analysis confirmed that extreme rainfall is already causing documented damage and is projected to intensify in the coming decades. This risk emerged as the most urgent priority, with clear implications for drainage systems, road infrastructure, and settlement protection. Agricultural drought and heat stress were identified as the second priority, with modelled yield losses and economic impacts showing a sharp increase under future scenarios. Wildfire hazard is also expected to worsen, though limited local records mean that its priority status remains provisional until further validation in Phase 3.

Stakeholder engagement enriched the process, with input from municipal staff, civil society, farmers, youth and women's groups, and technical experts. Their perspectives helped refine the severity, urgency, and resilience capacity ratings, and confirmed the relevance of rainfall and drought as priority risks. This participatory approach strengthened ownership and legitimacy, ensuring that results are not only technically sound but also locally trusted.

Despite these advances, several challenges remain. Data gaps persist in socio-economic projections, hydraulic flood modelling, and geo-referenced impact records. Climate models continue to operate at coarse resolution, and institutional capacity for systematic monitoring is limited. These constraints were managed through quality checks, conservative assumptions, and clear documentation of limitations, but they highlight areas requiring further investment in Phase 3.

Overall, Phase 2 has delivered a robust foundation for adaptation planning. It has clarified risk priorities, strengthened institutional awareness, and provided practical tools for communication and decision-making. The next phase will build on this progress by validating risk maps, refining adaptation measures, and embedding them into Libohovë's Climate Adaptation Plan. In this way, resilience strategies will move from evidence to action, ensuring that adaptation is both technically rigorous and locally relevant.

Table 4-1 Overview key performance indicators

Key performance indicators	*Progress*
8 refined datasets integrated	Achieved technically: eight core locally refined datasets/evidence layers are identified in Annex B, with six supplementary/reference datasets. Where local source metadata do not state an original date or licence, the register records this explicitly.
3 external consultations	Pending evidence: consultation structure, agendas and review materials are prepared; dated records and response matrices are not yet in the evidence package.
5 high-resolution GIS maps	Five KPI maps are produced. Editable rasters/layers are available for Maps 1, 3, 4 and 5. Map 2 is reproducible from the JRC/LUISA hazard-risk inputs and local settlement/facility source layers; the final handover inventory must verify the exact editable file references packaged with the map.
2 notes for policymakers	Technical recommendations are drafted in this report; two stand-alone briefs and transmission evidence remain pending.
1 comprehensive refined risk assessment report	Complete technical revision prepared in the CLIMAAX M16 template. Final submission version follows consultation validation, two stand-alone policy briefs, Map 2 handover-reference verification, final evidence indexing and the submission/repository receipt.
8 refined datasets integrated	Achieved technically: eight core locally refined datasets/evidence layers are identified in Annex B, with six supplementary/reference datasets. Where local source metadata do not state an original date or licence, the register records this explicitly.

Table 4-2 Overview milestones

Milestones	*Progress*
M6 – Collection and integration of high-resolution local data	Achieved: local DEM, hydrography, soils, exposure data and local rainfall evidence integrated with European datasets.
M7 – Refinement of risk models using local data and validation with external consultants	Model refinement achieved; external consultant validation pending.
M8 – Completion of GIS mapping for flood-prone and erosion-prone areas	Achieved: five-map KPI framework produced.
M9 – Mid-term reporting and review of refined risk assessment results	Technical report prepared; external consultation/review records pending.
Link to Phase 3 M10–M13	Phase 2 results provide the spatial and quantitative basis for adaptation-option identification, stakeholder consultation, pilot design and final reporting.

5 Supporting documentation

The following outputs were produced or consolidated during Phase 2. They should be uploaded to the project repository/Zenodo in a consistent order. File names below refer to the current technical package; final repository identifiers can be added at submission.

Table 5-1 Supporting documentation and output package

Order	Output category	Main files / evidence	Purpose
1	Main report	CLEAR_AL_D2_Phase2_Climate_Risk_Assessment_v1_7_FINAL_TECHNICAL.docx / final PDF	Integrated Phase 2 deliverable
2	Technical notebook – Heavy Rainfall	01_LIBOHOVE_Heavy_Rainfall_FULL_STRUCTURE.ipynb	Observed/modelled extremes and future climate signal
3	Technical notebook – Flood Hazard	02_LIBOHOVE_Flood_Hazard_Local_Refinement_FULL_STRUCTURE.ipynb	JRC hazard, Aqueduct context and local terrain refinement
4	Technical notebook – Flood Risk	03_LIBOHOVE_Flood_Risk_FULL_STRUCTURE.ipynb	DamageScanner and local flood-exposure screening
5	Technical notebook – Erosion/Multi-Risk	04_LIBOHOVE_Erosion_MultiRisk_FULL_STRUCTURE.ipynb	Erosion, agricultural exposure, sensitivity and integrated screening
6	KPI Map 1	FINAL_Local_Flood_Terrain_Susceptibility_vs_JRC_RP100_LIBOHOVE.png + editable raster	Flood local refinement
7	KPI Map 2	Local_Exposure_Screening_LIBOHOVE.png + editable exposure evidence	Flood exposure/risk hotspot screening
8	KPI Map 3	KPI_MAP_3_Erosion_Susceptibility_LIBOHOVE.png + editable raster	Erosion susceptibility
9	KPI Map 4	KPI_MAP_4_Erosion_Agricultural_Exposure_Hotspots_LIBOHOVE.png + editable raster	Agricultural/erosion exposure
10	KPI Map 5	KPI_MAP_5_Integrated_Flood_Erosion_MultiRisk_LIBOHOVE.png + editable raster	Integrated multi-risk screening
11	Data/register package	Phase2_Refined_Dataset_Register_CLEAR_AL.csv; Phase2_KPI_5_GIS_Maps_Register_CLEAR_AL.csv; LUISA_damage_info_curves_LIBOHOVE_GDP2023_constant2010_corrected.xlsx;	Traceability, QA and final economic-damage scaling

Order	Output category	Main files / evidence	Purpose
		Flood_Damage_Summary_LIBOHOVE_GDP 2023_constant2010_corrected.csv; Damage_by_LUISA_class_LIBOHOVE_GDP 2023_constant2010_corrected.csv; other model result CSVs	
12	External consultation package	Agendas; attendance; minutes; external comments; response matrices	Pending final validation evidence
13	Policy briefs	CLEAR_AL_Policy_Brief_1_Flood_Drainage _AMBU_FINAL.docx; CLEAR_AL_Policy_Brief_2_Erosion_Agriculture_DUK_Fier_FINAL.docx	Prepared; transmission evidence pending
14	National flood-hazard maps	AMBU/IPF10 Vjosa APSFR 4-2-6 HQ33/HQ50/HQ100/HQ200 flood extent and depth map PDFs	Supporting official evidence
15	National flood-risk maps	AMBU/IPF10 Vjosa APSFR 4-2-6 HQ33/HQ50/HQ100/HQ200 flood risk map PDFs + receptor legend	Supporting official evidence
16	National approval	KKU Decision No. 2, dated 15.07.2024, approving Vjosa flood hazard and risk maps	Official approval evidence
17	National management plan	AMBU/IPF10 Vjosa Flood Risk Management Plan, final report, October 2025 + measures annex	Policy / Phase 3 alignment
18	Official hydrography	Harta Hidrologjike Bashkia Libohove.jpg	Independent qualitative hydrographic/reservoir reference
19	Phase 2 scenario and map atlas	Annex G in this report – supplementary maps and graphs	Supplementary visual evidence

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14. AMBU / IPF10. 2023. Vjosa APSFR 4-2-6 Flood Risk Maps for HQ33, HQ50, HQ100 and HQ200 (map sheets dated 3 October 2023), including the common receptor legend.

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16. Official hydrographic/topographic reference map of the Municipality of Libohovë, supplied to CLEAR-AL Phase 2, scale 1:82,000.
17. CLIMAAX Consortium. Maximum damages – methodology note for GDP-per-capita scaling in the flood-risk workflow. CLIMAAX CRA Handbook / FAQ. https://handbook.climaax.eu/resources/FAQ/maximum_damages.html (accessed October 2026).
18. World Bank WITS / World Development Indicators. Albania country profile, GDP per capita in constant 2010 US$, 2023 value used in the Phase 2 maximum-damage scaling: 5,444.93 US$. https://wits.worldbank.org/CountryProfile/en/Country/ALB/Year/2023 (accessed October 2026).

7 Annex A. Explicit comparison of Phase 1 and Phase 2

The complete numerical D1 result tables and reviewer-comment package were not present in the supplied Phase 2 evidence set. The comparison below therefore uses the documented Phase 1 basis in the project implementation plan and the specific additional analyses completed in Phase 2.

Table 7-1 D1–D2 comparison

Topic	D1 basis	D2 refinement	Change in risk interpretation	Residual uncertainty
Assessment basis	CLIMAAX common methodology; two workflows; municipal multi-risk profile.	Four linked technical modules, local validation/refinement and integrated screening.	Clearer separation of climate pressure, hazard, exposure/vulnerability, risk and multi-risk.	Full D1 numerical tables unavailable in current package.
Rainfall	Regional/European climate evidence.	Poliçan daily observations + EURO-CORDEX validation and delta change.	Local 24 h future signal quantified (+10.98% RP2 to +2.90% RP100).	No local sub-daily series; 3 h remains model-only.
Administrative extent	Regional workflow / bounding extent.	Exact Libohovë polygon used for statistics and flood-damage masking.	Excludes cells outside municipal boundary from municipal totals.	Depends on supplied boundary geometry.
Topography / drainage	Regional-scale hazard interpretation.	~3.807 m DEM, D8 drainage, HAND-like index, downslope distance and slope; official hydrographic map added as independent qualitative reference.	Reveals small-drainage and terrain susceptibility not visible in JRC alone; confirms main watercourses and documents reservoirs/ponds.	DEM-derived stream layer is not independent; municipal clipping creates edge effects; reservoirs are not explicitly routed/stored.
River flood hazard	JRC/CLIMAAX baseline.	Exact JRC statistics + local terrain refinement + Aqueduct context.	RP100 JRC = 5.324 km²; local High/Very High = 12.391 km²; 9.769 km² outside JRC RP100.	Local susceptibility is not hydraulic depth.
Flood risk	Standard CLIMAAX screening risk.	Exact-boundary DamageScanner + local settlement/facility screening; maximum-damage scaling verified for Albania using GDP/capita 2023	RP100 potential direct damage = EUR 33.38 M (2010 price basis); one settlement flagged in local susceptibility outside JRC; four facilities in JRC RP100.	Generalised vulnerability/economic assumptions; no indirect loss; monetary values are screening estimates.

Topic	D1 basis	D2 refinement	Change in risk interpretation	Residual uncertainty
		= 5,444.93 constant 2010 US$.		
Erosion	General project risk concern.	Local slope-flow-land-cover susceptibility, WRB stratification and full-resolution sensitivity.	4.332 km² High/Very High; 0.168 km² agricultural hotspot; ~1.235 km roads.	Screening weights; no calibrated RUSLE soil loss.
Integrated multi-risk	Multi-risk profile.	Cell-based flood/erosion overlap with explicit common-domain NoData.	0.122 km² combined hotspot; 14.384 km² common-domain NoData documented.	Categorical screening, not combined monetary risk.
Evidence / reproducibility	Phase 1 reporting basis.	Four documented notebooks, registers, QA tables and editable outputs.	Improved traceability and reproducibility.	Consultation and policy-transmission evidence pending.
National official flood evidence	Not documented in the Phase 1 basis available in the current package.	AMBU/IPF10 Vjosa FRMP hazard/risk maps HQ33–HQ200; KKU Decision No. 2/15.07.2024; Drinos APSFR 4/2/6 context.	Adds an independent Albanian reference for hazard, affected receptors and municipal policy alignment.	Current package contains map PDFs; direct pixel/feature comparison requires original digital GIS/model outputs.

8 Annex B. Refined dataset register

For the Phase 2 KPI, the register below distinguishes eight core locally refined GIS datasets/evidence layers (C1–C8) from six supplementary/reference datasets (S1–S6). The core set is the evidence counted toward the minimum eight-dataset requirement. Some core items are reproducible derivatives of the local DEM; they are retained as separate evidence layers because they are independently stored, quality-checked and used in different model components. S5 adds the official hydrographic reference, while S6 adds the AMBU/KKU-approved national flood-hazard/risk evidence. Where a local source file does not contain an original acquisition date or license statement, the register records this explicitly.

Table 8-1 Refined dataset register – eight core Phase 2 datasets/evidence layers and six supplementary/reference datasets.

ID	Dataset	Source	Date/year	Original scale/res.	Working res.	CRS	Licence/access	QC	Used in
C1	Local DEM	Local project input	Not stated in supplied source metadata	~3.807 m	~3.807 m	EPSG:32634	Project-provided for CLEAR-AL analysis; original reuse/licence conditions are not stated in the supplied source metadata.	CRS, extent, NoData, elevation range and grid checked	Flood and erosion refinement

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ID	Dataset	Source	Date/year	Original scale/res.	Working res.	CRS	Licence/access	QC	Used in
C2	DEM-derived slope	Derived from local DEM	Derived during Phase 2	~3.807 m	~3.807 m	EPSG:32634	Derived project output	Grid alignment and value-range check	Erosion susceptibility
C3	DEM-derived hydrographic / stream network	Derived from local DEM	Derived during Phase 2	~3.807 m terrain-derived network	Vector / raster derivatives on local DEM grid	EPSG:32634	Derived project output	Internal routing/geometry checks only; not independent hydrographic validation.	Flood terrain interpretation / erosion-flow screening
C4	DEM-derived D8 drainage area / flow accumulation	Derived from local DEM	Derived during Phase 2	~3.807 m	~3.807 m	EPSG:32634	Derived project output	Grid/value checks and consistency with other DEM-derived drainage products; not independent hydrographic validation.	Flood and erosion refinement
C5	WRB soils	ASIG – State Authority for Geospatial Information, Albania (Pedology)	Database based on 2001 pedological study	Vector polygons	Vector; raster overlay on DEM grid	EPSG:32634	ASIG geospatial dataset; access/use conditions	Geometry, CRS, class names and area totals checked; 2001-	Erosion interpretation

ID	Dataset	Source	Date/year	Original scale/res.	Working res.	CRS	Licence/access	QC	Used in
							follow ASIG metadata	source/current-standard limitation recorded	
C6	LUISA 2018 land use	JRC LUISA Basemap 2018	2018	100 m	Aligned to DEM grid for overlay only	EPSG:32634	Public JRC dataset/report; source and citation documented in References	Class codes, CRS/alignment and exact municipal mask checked	Flood risk and erosion/agricultural exposure
C7	Local settlements and road network	Local project GIS input	Not stated in supplied source metadata	Vector	Vector	EPSG:32634	Project-provided for CLEAR-AL analysis; original reuse/licence conditions are not stated in the supplied source metadata.	Geometry, CRS, municipal intersection and feature counts checked	Flood and erosion exposure
C8	Public / critical facilities	Local project GIS input	Not stated in supplied source metadata	Point vector	Point vector	EPSG:32634	Project-provided for CLEAR-AL analysis; original	Layer inventory, geometry, CRS and municipal	Flood and erosion exposure

ID	Dataset	Source	Date/year	Original scale/res.	Working res.	CRS	Licence/access	QC	Used in
							reuse/licence conditions are not stated in the supplied source metadata.	intersection checked	
S1	Poliçan daily rainfall observations	Local historical station series used in Heavy Rainfall workflow	1968–1994; common comparison period 1976–1994	Daily station observations	Annual maxima / 24 h frequency analysis	Point station	Local historical station series supplied to the project; originating institution/licence is not stated in the supplied file metadata.	Completeness and common-period checks	Heavy Rainfall
S2	EURO-CORDEX extreme precipitation	EURO-CORDEX	Historical 1976–2005; future 2041–2070	Regional climate model grid	Municipality-scale climate signal	Climate-model grid	Public EURO-CORDEX climate-model dataset; source citation documented in References and original provider terms retained.	Historical comparison against station; KS diagnostic	Heavy Rainfall climate pressure

ID	Dataset	Source	Date/year	Original scale/res.	Working res.	CRS	Licence/access	QC	Used in
S3	JRC river-flood hazard	JRC European river-flood hazard dataset	Present-day scenario used in Flood Hazard workflow	European-scale raster	Reprojected/aligned for local comparison and damage analysis	See Flood Hazard/Risk workflow metadata	Public JRC dataset used through the CLIMAAX workflow; source citation documented in References and original provider terms retained.	Boundary clipping, RP statistics and raster-alignment checks	Flood Hazard and Flood Risk
S4	Aqueduct future flood maps	WRI Aqueduct	Baseline and future periods used in Flood Hazard workflow	Coarse global/regional flood product	Qualitative climate-change context	See Flood Hazard workflow metadata	WRI Aqueduct; Creative Commons Attribution 4.0 terms for Aqueduct products	Municipal overlap and scenario-difference checks	Flood climate-change context
S5	Official Libohovë hydrographic reference map	Official hydrographic/ topographic reference supplied for Phase 2	Source date not shown on supplied map image	Map scale 1:82,000	Qualitative reference map	Original digital CRS metadata to be archived if vector data are obtained	Official reference supplied to project; archive original access/licence metadata	Visual comparison of main watercourses; named drainage systems and reservoir/pon	Independent qualitative hydrography / reservoir context

ID	Dataset	Source	Date/year	Original scale/res.	Working res.	CRS	Licence/access	QC	Used in
							with source files	d features reviewed	
S6	AMBU / Vjosa Flood Risk Management Plan hazard and risk maps	AMBU / IPF10; KKU-approved national flood mapping	Hazard maps 21.09.2023; risk maps 03.10.2023; KKU approval 15.07.2024; FRMP final report October 2025	1:25,000 maps; HQ33, HQ50, HQ100, HQ200	National reference / validation and policy context	ETRS 1989 UTM Zone 34N / ETRS 1989 Albania 2010 as stated on map sheets	Official planning evidence; retain AMBU/IPF10 source files and approval decision	Return periods, Drinos APSFR coverage, receptor indicators and policy measures checked against source documents	Flood hazard/risk validation, governance and Phase 3 policy alignment

9 Annex C. Five GIS map register

The acceptance test requires both readable maps and editable GIS evidence. Maps 1, 3, 4 and 5 have explicit editable raster outputs. Map 2 is reproducible from the JRC/LUISA flood-risk inputs and the local settlement/facility source layers used by the risk notebook. The remaining handover action is administrative: the final evidence index must point to the exact editable settlement/facility files packaged with Map 2.

Table 9-1 Five-map D2 register

Map	Title	Theme	Resolution/scale	CRS	Primary source	Status / editable evidence
1	Refined Local Flood-Terrain Susceptibility Map	Flood	~3.807 m DEM grid	EPSG:32634	Local DEM/hydrological terrain refinement + JRC	Completed; PNG + local susceptibility raster + JRC RP100.
2	Local Flood Exposure and Risk Hotspot Map	Flood exposure / risk	JRC/LUISA + local exposure	Mixed / final local EPSG:32634	JRC hazard, LUISA, roads, settlements, facilities	Completed; reproducible from source layers; exact handover file references pending.
3	High-resolution Erosion Susceptibility Map	Erosion	~3.807 m grid; LUISA retains 100 m information	EPSG:32634	Slope, drainage area, LUISA	Completed; PNG + erosion susceptibility/class raster.
4	Erosion and Agricultural Exposure Hotspot Map	Erosion/agriculture	~3.807 m analysis grid; LUISA retains 100 m information	EPSG:32634	Erosion susceptibility + LUISA agriculture + local exposure	Completed; PNG + erosion raster + agricultural/exposure layers.
5	Integrated Flood–Erosion Multi-Risk Screening Map	Integrated multi-risk	~3.807 m common grid	EPSG:32634	Local flood + erosion susceptibility	Completed; PNG + integrated hotspot raster.

10 Annex D. QA checklist

Table 10-1 Phase 2 QA checklist

QA item	Status
Exact municipal boundary used for final local statistics	PASS
JRC return periods processed consistently	PASS
Local DEM CRS/resolution/elevation checked	PASS
DEM-derived drainage visually checked against the official hydrographic reference; reservoir limitation documented	PASS
JRC RP100 aligned-grid area cross-checked against exact municipal statistic	PASS
Flood susceptibility explicitly interpreted as susceptibility, not inundation	PASS
24 h rainfall locally validated and delta change used	PASS
3 h rainfall identified as model-only	PASS
Balanced full-resolution erosion sensitivity reproduces mapped result	PASS
WRB used for stratification, not numerical K-factor	PASS
LUISA alignment does not claim increased native land-use resolution	PASS
Multi-risk NoData/common domain reported explicitly	PASS
Three external consultation records	PENDING
Two final policy briefs + transmission evidence	PENDING
D1 reviewer comment-response matrix	PENDING if source comments are available

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QA item	Status
Map 2 exact editable-file references recorded in final handover inventory	PENDING HANDOVER VERIFICATION
Albania GDP/capita scaling in LUISA maximum-damage workbook verified and documented	PASS — 5,444.93 constant 2010 US$, reference year 2023

11 Annex E. Consultation, policy and final evidence status

The technical work is ready for external review. The two stand-alone policy briefs are also prepared. The remaining items are the consultation records, evidence that the briefs were transmitted to the relevant authorities, final handover details and submission evidence needed to close D2 formally. The open items are listed below.

- Consultation 1: dated flood/hydrology record, attendance, external comments, annotated maps, correction list and response matrix.
- Consultation 2: dated erosion/agriculture record, local/farmer observations where applicable, expert conclusions, agreed revisions and response matrix.
- Consultation 3: integrated validation notes after the first two consultations, consolidated comment–response matrix, final correction list and feedback on policy recommendations.
- Evidence of transmission of the two completed policy briefs to the relevant authorities.
- Final confirmation of source/date/license metadata for locally provided datasets where the register currently records “not stated in supplied metadata”.
- Final D1 reviewer comment-response matrix if the original reviewer comments are supplied.
- Final submission receipt / repository evidence.