Deliverable Phase 1 – Climate risk assessment

The risk prevention, management, climate change mitigation and adaptation improved in municipality Bijelo Polje (PREMMA) Montenegro, Municipality of Bijelo Polje

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HORIZON-MISS-2021-CLIMA-02-01 - Development of climate change risk assessments in European regions and communities based on a transparent and harmonised Climate Risk Assessment approach

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Document Information

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Abbreviations and acronyms

Insert here all acronyms appearing along the deliverable in alphabetical order. This text marked in green should be deleted before submitting the deliverable.

Abbreviation / acronym	Description
CRA	Climate-risk assessment
PRS	Protection and Rescue Service (Služba zaštite i spašavanja)
RCP	Representative Concentration Pathway (climate scenario)
JRC	Joint Research Centre of the European Commission
DEM	Digital Elevation Model
WMO	World Meteorological Organization
KPI	Key performance indicator
MUP	Ministry of the Interior of Montenegro

Executive summary

*The following text is a **generic guideline** for the authors to produce the Executive summary section. **The text marked in green should be deleted before submitting the deliverable.***

Please follow these guidelines:

- ***Length:** please limit it to 1 page (2 pages in exceptional cases).*
- *The executive summary must have conclusions.*
- ***Goal:** The Executive summary is not an "introduction" to the deliverable. The main goal of this section is to provide readers with a whole picture of the document, so that they can understand the content of the deliverable at once without further reading.*
- ***Self-contained:** If there is any input coming from other deliverables, it must be mentioned here.*
- *Motivation for the reader (Recommended: 1 –10 lines):*
  - *Why was this deliverable developed? Which does it address?*
  - *What will the reader learn from it?*
- *Main results and findings (Recommended: 5 to 50 lines):*
  - *What are the main actions undertaken during this phase?*
  - *What are the main results achieved?*
  - *How does it contribute to the overall project?*
- *Short conclusions (Recommended: 1 to 10 lines):*
  - *Key take-away messages*
- *Style:*
  - *Please use a formal and practical writing style without jargon.*
  - *Do not use "We" when writing the Executive summary.*

This deliverable presents the **Phase 1 climate-risk assessment (CRA)** for Bijelo Polje municipality under the CLIMAAX programme.

Motivation / problem addressed (why & who)

The Municipality of **Bijelo Polje** needs a **screening-level climate risk picture** for floods and wildfire to inform near-term planning and prepare Phase 3. The analysis targets municipal planners, civil protection and infrastructure owners.

Main actions undertaken (what we did)

- Built **Workflow #1 – River flooding (hazard)**: produced RP10/50/100/500 flood-depth maps for the AOI using the CLIMAAX flood workflow.
- Built **Workflow #2 – Flood risk to buildings & population**: combined flood hazard rasters with OSM buildings (incl. reclassification) and GHSL population to estimate exposure, displacement and economic damage.
- Built **Workflow #3 – Wildfire**: produced susceptibility & hazard layers and a screening-level risk using JRC vulnerability indices.
- Delivered **maps, graphs, CSV tables and GIS shapefiles**, plus a small HTML viewer for quick inspection of outputs

Main results & findings (what we learned)

- **Flooding** is concentrated along the **river corridor**; lateral expansion from RP10 to RP500 is **visible but limited**.

- **Buildings at risk** are a **minority** and cluster near the river; **counts and expected damage increase with RP**.
- **Population exposure/displacement** outside the river corridor remains **low** at screening resolution (GHSL 100 m), supporting a **corridor-first** mitigation focus.
- **Wildfire susceptibility** is **elevated on south-facing slopes and mid-elevation belts**; the **RCP4.5 2021–2040** scenario shows a **gradual increase** in susceptible area.
- **Road segments** intersect **medium to high wildfire risk** in the hills; these are candidates for **vegetation management and patrol priorities**.

Contribution to the overall project

- Delivers a **Phase-2 quantitative baseline** for floods using **reproducible workflows** and standardized outputs, ready for publication on **Zenodo** and for refinement in **Phase-3** (higher-resolution data, local hydraulics, defence scenarios).

Short conclusions / key take-aways

We now have a **coherent triad of workflows** (WF#1 hazard floods, WF#2 flood risk to assets & people, WF#3 wildfire) with **ready-to-use figures and tables**.

- Use **RP100** as the baseline design level for corridor assets; review **RP500** footprints where critical facilities are present.
- Prioritize **building-level measures** (flood-proofing, access) in riparian blocks and confirm damages
- For wildfire, plan **preventive fuel management** and **targeted protection** along identified **at-risk road sections**; engage forestry and PRS.
- The Phase-1 products are **fit for screening** and **ready for Phase-3 detail** (hydrodynamic refinement; exposure growth; multi-hazard).

1 Introduction

1.1 Background

Bijelo Polje lies in the Lim River basin in northern Montenegro and covers 924 km²; about **40 %** of the territory is forested. The local climate is temperate-continental with warm summers and cold winters. Recent decades have been characterized by climatic extremes: annual precipitation has ranged from **806 mm (2022)** to **1005 mm (2016)** with an extreme monthly event of **204 mm in January 2021**. Conversely, prolonged hot and dry spells have heightened the risk of **wildfires**. According to the 2023 census the municipality counts **38 662 residents**, most of whom live in the Lim valley and scattered rural settlements. A total of **8 300 households** and **865 businesses** are connected to the municipal water supply, and the area hosts critical infrastructure such as bridges, a main power substation, water-intake facilities and several industrial complexes (Franca Marketi, Meso-Promet, Put-Gross, Pelengić Trade, etc.).

Hazard overview. The hazards were examined in this assessment: **river floods and wildfires**. Flood risk is highest between **November and January** when snowmelt and intense rainfall cause the Lim and its tributaries to overflow; summer convective storms trigger flash floods on steep slopes. **Wildfire risk peaks in July–September** and is amplified by dry fuel accumulation and human negligence. Review of PRS records for 2009-2019 indicates **1 567 fire incidents**, of which **787 were forest fires** and **499 structural fires**. Landslides and rockfalls occur on steep slopes after heavy rainfall or seismic shaking; the Čokrlije landslide is an example of a large translational slide damaging roads and property. Earthquake hazard is moderate – no catastrophic events have occurred recently, but the built environment includes many unreinforced masonry buildings and is exposed to ground motions from regional fault zones.

Exposure and vulnerability. Settlements along the Lim (Bioča, Srđevac, Zaton, Patkova otoka) and hillside villages are highly exposed. Critical infrastructure includes bridges, water-supply and waste-water facilities, electric-power substations and telecommunication nodes. Vulnerability is heightened by socio-economic factors (low incomes, ageing population), inadequate building standards, dense coniferous forests and unstable slopes. The **Protection and Rescue Service (PRS)** has **24 staff** dedicated to flood and technical rescue and **22 staff** dedicated to firefighting. These numbers fall below international recommendations (about one rescuer per 1 000 residents), and the service lacks specialised equipment and training facilities. Support is provided by volunteer brigades, utility companies and specialised units (forest firefighters, mountaineers, kayakers) but overall capacity remains limited.

Key findings. Updated data from the municipal plans updated December 2024 show increasing variability in rainfall and a rising trend in fire incidents. The flood interventions log reveals a marked increase in responses from 2 interventions in 2011 to 58 interventions in 2023[1], underscoring escalating flood-related impacts. Exposure of people, assets and ecosystems is significant, while institutional and community capacity is insufficient. Data gaps remain in high-resolution hydrometeorological measurements, fuel-load assessments, building vulnerability surveys and socio-economic indicators at fine scales. Addressing these gaps is essential for quantitative modelling in Phase 2 and for designing effective adaptation measures. **Next steps.** Over the next six months the project will acquire high-resolution DEMs, hourly rainfall data, fuel-load and moisture indices and building inventories; conduct participatory workshops to map hazards and

[1] **Municipal Flood Protection and Rescue Plan for Bijelo Polje – updated December 2024** – rainfall statistics, flood-intervention records, asset inventories and updated data on infrastructure and demographics.

vulnerabilities; run CLIMAAX workflows for floods and wildfires under RCP4.5 and RCP8.5 scenarios; and begin identifying adaptation options (e.g., floodplain restoration, levee reinforcement, fuel breaks, slope stabilization). Capacity building for PRS staff and community volunteers will accompany these activities. A final multi-hazard risk assessment and adaptation plan will be developed in Phases 2 and 3.

1.2 Main objectives of the project

The PREMMA project's overarching goal is to develop a **comprehensive, multi-hazard climate-risk assessment** for Bijelo Polje that supports adaptation planning. Phase 1 objectives are to:

1. **Define the scope and priorities** of the CRA – identify key hazards (floods, wildfires, landslides & rockfalls, earthquakes) and determine which will be quantitatively modelled in Phase 2.
2. **Compile and harmonies' data** on hazard drivers (precipitation, snowmelt, drought indices, seismicity), exposure (population, infrastructure, economic assets) and vulnerability (socio-economic status, building typologies, land use) using municipal plans updated December 2024, hydrometeorological statistics, PRS logs and European datasets from the CLIMAAX toolbox.
3. **Map stakeholders and clarify risk ownership** – engage municipal departments, utility providers, national agencies, private sector, civil society and residents to ensure an inclusive process and to assign responsibilities for data provision, analysis and implementation.
4. **Develop a detailed work plan** for Phase 2, outlining data acquisition, workflow implementation, participatory activities, capacity building and interim deliverables.

1.3 Project team

The CRA is coordinated by the **Municipality of Bijelo Polje – Protection and Rescue Service (PRS)** with technical assistance from the **CLIMAAX consortium** and strategic guidance from the **Directorate for Protection and Rescue**. Key partners include:

- **Municipal departments** for urban planning, infrastructure, water management, agriculture, environment, health and education.
- **Utility companies** – JPKSD "Lim" (solid waste), "Vodovod Bistrica" (water supply), "Elektroprivreda Crne Gore" (electricity), telecommunications operators and road maintenance companies.
- **National institutes** – Hydrometeorological and Seismological Service, Forestry Administration, Institute for Public Health.
- **Private sector** – industrial facilities (Franca Marketi, Meso-Promet, Put-Gross, Pelengić Trade) and farmers' cooperatives.
- **Civil society and residents** – Red Cross, local NGOs, volunteer fire brigades, village councils, school boards and vulnerable groups (elderly, persons with disabilities, Roma community).

Figure 1 depicts these actors and their relationships. The Municipal Council and PRS coordinate risk governance; sectoral services manage assets in their domains; and communities provide local knowledge and support preparedness and response.

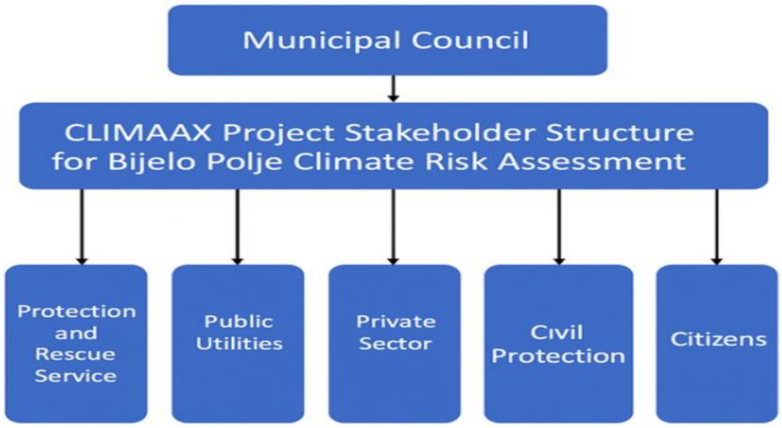


Figure 1 – Stakeholder organogram

1.4 Outline of the document's structure

The report is organised as follows:

- **Section 2** covers the Phase 1 CRA: scoping, risk exploration, preliminary risk analysis, key findings, monitoring and the Phase 2 work plan.
- **Section 3** summarises conclusions and recommendations for adaptation and policy.
- **Section 4** evaluates progress against KPIs and milestones.
- **Section 5** lists supporting documents and files to be uploaded to Zenodo.
- **Section 6** provides a list of sources used.

Citation notes. The precipitation statistics and flood-intervention records used in this report are drawn from the **Municipal Flood Protection and Rescue Plan for Bijelo Polje** 2024[2]. Wildfire incident statistics are taken from the **Municipal Fire Protection and Rescue Plan for Bijelo Polje** 2024[3]. Data on landslides and rockfalls come from the **Municipal Landslide and Rockfall Protection Plan for Bijelo Polje** 2024[4], and information on seismic hazards is based on the **Municipal Earthquake Protection Plan for Bijelo Polje** 2024[5]. Additional climate and seismic data are provided by the Hydrometeorological and Seismological Service of Montenegro[6], and intervention logs by the Municipal Protection and Rescue Service[7]. Methodological guidance follows the CLIMAAX CRA Handbook[8], and the legal context is provided by national protection and rescue legislation[9].

[2] **Municipal Flood Protection and Rescue Plan for Bijelo Polje 2024** – rainfall statistics, flood-intervention records, asset inventories and updated data on infrastructure and demographics.
[3] **Municipal Fire Protection and Rescue Plan for Bijelo Polje 2024** – wildfire incident statistics, causes and impacts, Protection and Rescue Service capacity, and updated demographic and infrastructural data.
[4] **Municipal Landslide and Rockfall Protection Plan for Bijelo Polje 2024** – descriptions of landslide triggers, affected areas, mitigation measures and updated inventories.
[5] **Municipal Earthquake Protection Plan for Bijelo Polje 2024**– seismic hazard context, critical infrastructure exposure and updated asset inventories.
[6] **Hydrometeorological and Seismological Service of Montenegro** – official precipitation, temperature and seismic data for Bijelo Polje for the period 2016–2024.
[7] **Municipal Protection and Rescue Service archives** – logs of interventions during floods and fires (e.g., 2009–2019 fire incidents and 2011–2024 flood interventions).
[8] **CLIMAAX CRA Handbook (2024)** – methodological guidance for scoping, risk exploration, analysis and adaptation planning.
[9] **Montenegrin laws and regulations on protection and rescue** – legal framework governing risk assessment and emergency management.

2 Climate risk assessment – phase 1

2.1 Scoping

2.1.1 Objectives

The Phase-1 CRA provides a **screening-level picture of priority hazards** for the Municipality of Bijelo Polje and sets the groundwork for detailed modelling in Phase 2/3. Based on stakeholder inputs and the municipal hazard plans updated in **December 2024**, the priority hazards are:

- River and flash floods – modelled in Phase 1 (hazard and risk).
- Wildfire – modelled in Phase 1 (hazard and risk).
- Landslides & rockfalls, earthquakes – scoped only in Phase 1; quantitative modelling is deferred to Phase 3 [in/out: leave this sentence if you indeed defer them].

The **spatial boundary** is the entire municipality of Bijelo Polje. The **time frame** spans **recent observations (≈ 2006–2024)** and **screening of near-term climate signals** where relevant to the selected workflows; detailed change-assessment is left to Phase 2/3 [in/out: if you do not want any mention of future signals here, replace this sentence with "The focus is present-day risk."]**.**

2.1.2 Context

Risk management is framed by national protection-and-rescue legislation and by **municipal single-hazard plans** (floods, fires, landslides, earthquakes). All plans were **updated in December 2024** with refreshed datasets (climate, demography, infrastructure, response units). The **Municipal Council** sponsors the CRA; the **Protection and Rescue Service (PRS)** coordinates operations; sector departments manage risks for their assets. Community representatives provide local knowledge and support warning dissemination. Early consultations highlighted three system needs: **(i)** better data sharing, **(ii)** clearer allocation of responsibilities across services, and **(iii)** stronger community participation.

2.1.3 Participation and risk ownership

A preliminary stakeholder mapping identified **20+ organisations and groups** engaged in risk management. Participants included municipal departments, utilities, national services, industrial operators, NGOs and village councils. They contributed information on **data availability, vulnerability hotspots and feasible measures**, and requested joint workshops to review maps. **Risk ownership** is as follows: the **Municipal Council** retains overall ownership; the **PRS** coordinates implementation; **sectoral services and industrial facilities** integrate findings into their plans; **community representatives** ensure inclusion of vulnerable groups and local knowledge.

2.2 Risk Exploration

Purpose. Risk exploration provides a first, municipality-wide scan of the main climate-related hazards, the people and assets exposed, and the data we can leverage in Phase 1. It also clarifies which hazards we analyze quantitatively now and which remain scoped for Phase 2.

2.2.1 Screen risks (selection of main hazards)

Which climate-related hazards and potential risks are relevant for your context?

The screening considered hazards that most affect people, assets and lifelines in the Municipality of Bijelo Polje: **river floods** (Lim and tributaries), **flash floods** (smaller catchments and steep urban sub-basins), **wildfires** (peri-urban hillslopes and rural–forest interface), and **geohazards** (landslides/rockfalls) together with **earthquakes** as background risk. The Phase-1 quantitative work focused on **river flooding** and **wildfire** because these combine (i) data availability, (ii) stakeholder priority for planning, and (iii) clear pathways to Phase-2 refinement.

What is the current situation? Where is the hazard occurring? Who is being affected?

- **River flooding**: Inundation is primarily confined to the river corridor; modelled RP10/50/100/500 depth maps show limited lateral spread away from the main channel, with exposure concentrated in riverside neighborhoods, low-lying industry parcels and transport links.
- **Flash flooding**: Observed in steep small basins and urbanized sub-catchments after intense rainfall; impacts include short-notice street flooding, culvert exceedance and local infrastructure disruption.
- **Wildfire**: The wildland–urban interface and rural slopes register recurrent summer-season susceptibility; risk is higher near vegetation, access tracks and scattered buildings.
- **Geohazards / earthquakes**: Recognised by municipal plans as relevant background risks; Phase-1 compiled evidence and entry points for later quantification.

Which hazards are observed/expected for the community/region? Explore the Copernicus Atlas (https://atlas.climate.copernicus.eu/atlas) and add a summary of the findings for your region

Regional assessments for South-Eastern Europe indicate **warmer conditions**, **more frequent heat extremes**, **longer dry spells** in summer and **intense precipitation** episodes, implying (i) pressure on **wildfire** conditions and (ii) **short-duration high-intensity rainfall** that may trigger **flash floods**. These signals support the municipality’s choice to start with **river flood** and **wildfire** mapping in Phase-1 and plan **flash-flood** refinements in Phase-2.

(Generic regional summary used here; detailed Atlas figures will be cross-checked in Phase-2 technical annex.)

Which hazards will you cover in this risk assessment? Why did your project decide to focus on these hazards?

Quantitatively in Phase 1:

- **Workflow #1 – River flooding (hazard).** We produce RP10/50/100/500 flood-depth maps over the AOI to provide a municipality-wide baseline and to support planning along the Lim corridor.
- **Workflow #2 – Flood impact on buildings & population (risk).** We overlay those hazard rasters with OSM buildings (with reclassification) and GHSL population to estimate exposed buildings, expected damage proxies and potentially displaced population at each RP.
- **Workflow #3 – Wildfire (hazard & risk).** We combine topography (DEM, slope/aspect), land cover (CLC), and historical fire evidence to map wildfire susceptibility for a baseline and a near-future climate (2021–2040, RCP4.5, CLMcom-CCLM) and translate it into risk classes using JRC vulnerability and exposure layers (population/buildings/roads).

Screened only in Phase 1 (to be modelled in Phase 2): Landslides & rockfalls and **earthquakes**—both are recognised as relevant, but require specialised datasets and local fragility information not yet available.

- *Which data or knowledge do you have on these hazards/impacts/risks? Which data, information or knowledge is further needed?*

Available in Phase-1 (used in this CRA):

- **Flood hazard**: tile-based RP10/50/100/500 depth rasters clipped to the AoI; quick-look figures and composite visuals (HTML).
- **Flood exposure & risk**: OSM buildings (with reclassification) and GHSL population; CSV tables and SHP/GeoPackage outputs with exposed/displaced/summary indicators; inspection graphs and maps exported for reporting.
- **Wildfire**: DEM-derived slope/aspect, land-cover (CLC) processing with non-burnable classes masked, historical fire footprints (rasterized), ECLIPS2.0 climate covariates; susceptibility/hazard maps and risk classes for population/economy/ecology; figures for present and one future realization.

Further needs (planned for Phase-2/3 – phrased constructively):

- **Hydraulic detail for flash floods** (sub-basin delineation, IDF curves, drainage inventories) to complement corridor-type river flooding.
- **Higher-resolution exposure** (authoritative building footprints, critical facilities, cadastre attributes) to refine damage modelling.
- **Local vulnerability curves** and replacement values for *damage monetisation* beyond screening-level summaries.
- **Multi-model climate signals** (ensemble of futures) for *change assessment* consistency across hazards.
- **Validation assets** (event photos, marks, PRS logs) for spot-checks and stakeholder calibration sessions.

2.2.2 Workflow selection

Considering your hazard selection, identify the risk workflows relevant to your climate risk assessment. Additionally, identify the relevant vulnerable groups or exposed areas for each of the risks. Describe this information for each of the selected workflows.

2.2.2.1 Workflow #1 — River flooding (hazard)

- **Purpose / risk question.** Where does river flooding occur in Bijelo Polje and how does the *inundation depth* vary for different event severities (RP10/50/100/500)? This informs corridor zoning, maintenance priorities and first-order protection planning.
- **Primary outputs.** GeoTIFF depth rasters (RP10, RP50, RP100, RP500), overview maps (PNG/HTML), and a quicklook figure set for communication. These are bundled under **02_River_flooding/01_hazard**; a short README accompanies the set.
- **Method summary.** Event-based flood depth maps over the municipality's AOI using the workflow's standard hydrological layers; outputs are provided as gridded **water depth (m)** for each return period. No climate-change signal is applied in Phase 1 (present-day hydrology only).
- **Key inputs.** DEM derivatives and river network layers already included in the CLIMAAX workflow; AOI polygon; municipal basemap for context.
- **Exposed areas / vulnerable groups to keep in view.** Settlements and farmsteads along the **Lim river corridor** and tributary valleys; ground-floor households, older housing stock near riverbanks, and public facilities or utilities situated within the immediate floodplain (e.g., pumping stations, substations close to the corridor).
- **Why this workflow.** Screening and local knowledge highlight river flooding as a top priority for the municipality; WF#1 is the quickest way to obtain consistent depth products for multiple return periods.

2.2.2.2 Workflow #2 — Flood risk to buildings & population

- **Purpose / risk question.** Given the flood depths from WF#1, *how many* buildings and *how many people* are potentially affected, and *how does that scale with return period*? This supports emergency planning, critical-asset checks and quick benefit–cost scoping.
- **Primary outputs.**
    - **Exposure**: counts of exposed buildings and exposed / displaced population by RP; depth statistics per building class; summary CSVs and comparison graphs.
    - GIS layers: building footprints with joined depth attributes; RP-specific exposure shapefiles.
    - **Communications**: bar/line charts (PNG) showing *exposed* and *displaced* population vs RP, and building depth histograms.

  These are bundled under **03_Flood_damage_and_population_exposure** in two subfolders: **01_hazard** (intermediate maps, outline/OSM products) and **02_risk** (exposure tables, figures and vectors). See the package manifest/README for a quick index of files.

- **Method summary.** Overlay WF#1 rasters with **OSM building footprints** (reclassified into usage types) and **GHSL population** to compute exposure and simple displacement proxies (depth-based thresholds). All analyses use **present-day exposure** (2024 snapshots); no population-growth scenario is applied in Phase 1.
- **Key inputs.** WF#1 flood-depth rasters; OSM buildings (with basic reclassification); GHSL population raster; AOI outline.

- **Exposed areas / vulnerable groups to keep in view.** Residential clusters near the **Lim river** (especially ground floors), **public services** (schools, health facilities) in the valley floor, and **small industries/warehouses** adjacent to the river or low-lying access roads that can isolate communities during RP50–RP100 events.
- **Why this workflow.** Converts hazard maps into *people and asset* numbers needed by municipal planners and PRS. It also provides RP curves (exposure vs. severity) to support prioritization.

2.2.2.3 Workflow #3 — Wildfire (hazard & screening-level risk)

- **Purpose / risk question.** Where are *wildfire-susceptible* areas now and in the near future, and which communities and infrastructures might face increased exposure? (Phase 1 provides screening-level maps; detailed change modelling is deferred.)
- **Primary outputs.** Susceptibility maps for historical climate and a near-future scenario; classified hazard rasters ("very low" → "extreme"); illustrative risk overlays (e.g., roads × risk) and a compact figure set for reporting.
- **Method summary.** ML-based susceptibility using topography (DEM, slope/aspect), **CLC**-based fuels (non-burnable classes removed), historical fire points, and climate predictors; plus rasterised exposure layers for **population**, **buildings** and **roads proximity** to support risk articulation.
- **Key inputs.** DEM and derivatives; CLC; historical fire records; ECLIPS2.0 climate predictors (historic); one near-future climate realisation for illustration; GHSL population, OSM buildings, road network.
- **Exposed areas / vulnerable groups to keep in view.** Rural settlements in **forested hillslopes**, peri-urban fringes with shrub/grass fuels, **elderly households** in remote hamlets, linear infrastructure (roads/power lines) that can be disrupted by fire or smoke.
- **Why this workflow.** Stakeholders flagged wildfire as a growing concern after recent seasons; WF#3 provides a first map-based screening and a basis to plan Phase-2 improvements.

2.2.3 Choose Scenario

- **WF#1 River flooding.** Event-based **return periods RP10 / RP50 / RP100 / RP500** (present-day hydrology). No climate-change adjustment in Phase 1; outputs are used as common hazard inputs.

- **WF#2 Buildings & population.** Same **RP10/50/100/500** rasters; exposure and vulnerability are current-day (2024) snapshots; **no growth scenario** applied in Phase 1.

- **WF#3 Wildfire. HIST 1991–2010** and **near-future RCP4.5 2021–2040 (CLMcom_CCLM)**. Exposure/vulnerability are held constant (screening); outputs highlight relative change.

2.3 Risk Analysis

Describe how the selected risk workflows from the CLIMAAX Handbook were applied to your region. Which hazard, exposure and vulnerability data were used? Include the overview of the datasets in the tables below. For a broader overview of hazard, exposure and vulnerability datasets, consult the dedicated page in the Handbook: Datasets — CLIMAAX CRA Handbook[10]

[10] https://handbook.climaax.eu/CRA_steps/analysis/datasets.html
https://handbook.climaax.eu/CRA_steps/analysis/exposure_data.html

Note: We recommend that you include only the necessary visual material (maps, graphs) to support your climate risk assessment. Additional material can be shared through the Zenodo repository.

2.3.1 Workflow #1 – **River flooding (hazard & screening risk)**

Purpose. Produce screening flood-depth rasters for multiple return periods (RP10 / RP50 / RP100 / RP500) over the municipal AOI to support all downstream risk calculations.
Key inputs. Europe-wide flood-depth rasters (filled) clipped to the Bijelo Polje AOI; OSM basemap for context.
Outputs. Per-RP PNG maps; a 4-panel composite (RP10/50/100/500); an RP500–RP10 difference map; and a lightweight HTML figure viewer for quick inspection (packaged together with a short README and a file manifest). The flood hazard package itself also contains an HTML preview and MANIFEST that list all files clearly.
Exposed areas / vulnerable groups (screening view). Low-lying **riparian corridor** along the main river and tributaries; **settlements, local roads and small bridges** close to the channel; pockets of **agricultural land** on the floodplain. (No vulnerability model is applied in WF#1; this is the common hazard layer used by WF#2.)

Table 2-1 Data overview workflow #1

Hazard data	*Vulnerability data*	*Exposure data*	*Risk output*
Europe-wide flood-depth rasters for RP10/50/100/500 (filled), clipped to Bijelo Polje AOI	*– (screening only)*	*AOI polygon; OSM basemap for context*	*PNG maps per RP; 4-panel figure (RP10/50/100/500); **difference map** (RP500–RP10) and preview map; HTML quick viewer of figures*

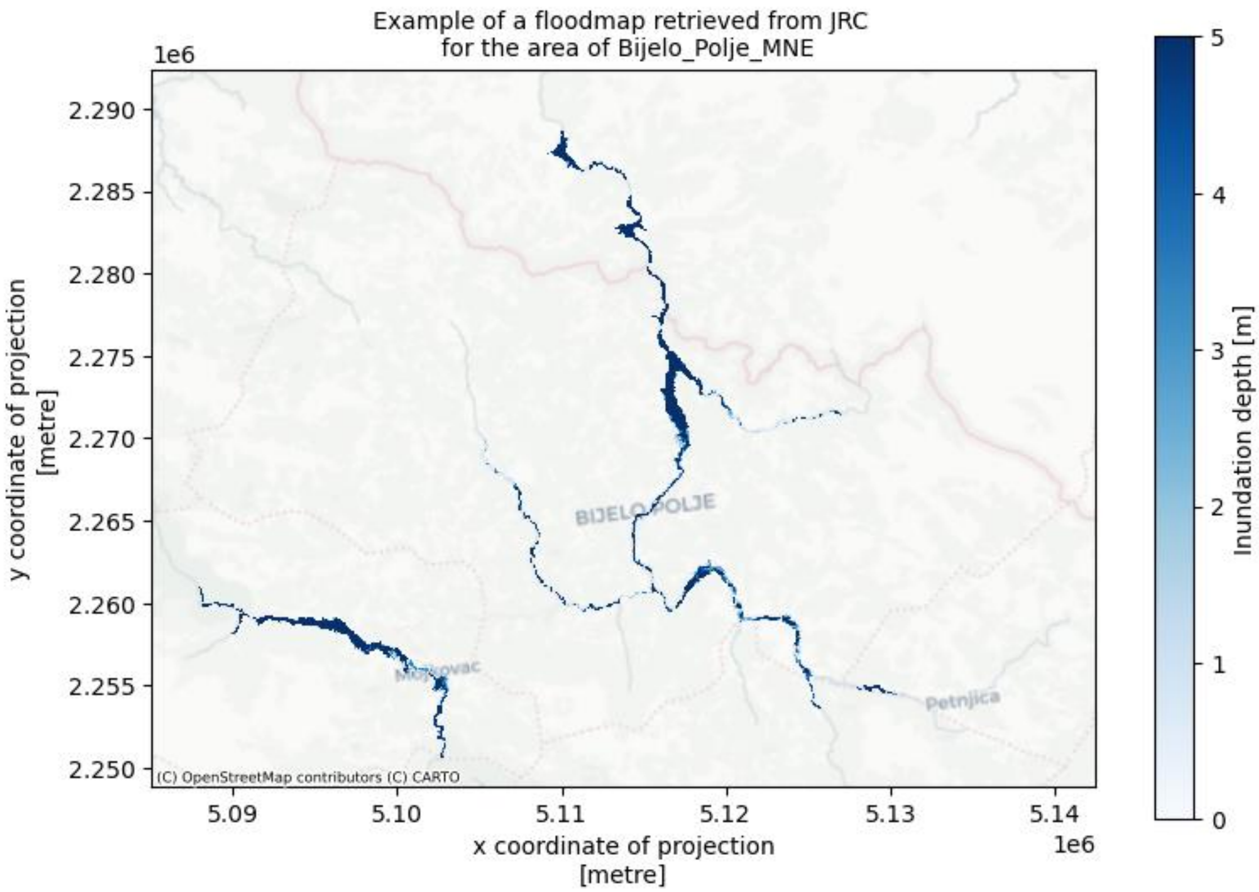
Notes for annex / filenames: flood_depth_rp10.tif, flood_depth_rp50.tif, flood_depth_rp100.tif, flood_depth_rp500.tif, preview_RP10_clip.png, 4-panel composite figure, etc.

2.3.1.1 Hazard assessment

Purpose & scope. Provide a screening-level depiction of fluvial flood **water depths** over the Bijelo Polje AOI for four return periods (RP10, RP50, RP100, RP500). No climate-change adjustment is applied in Phase 1; maps represent **present-day** hazard.

Inputs. Pan-European "filled depth" rasters for RP10/50/100/500 (GeoTIFF), clipped to the municipal AOI; OSM basemap only for context in figures.

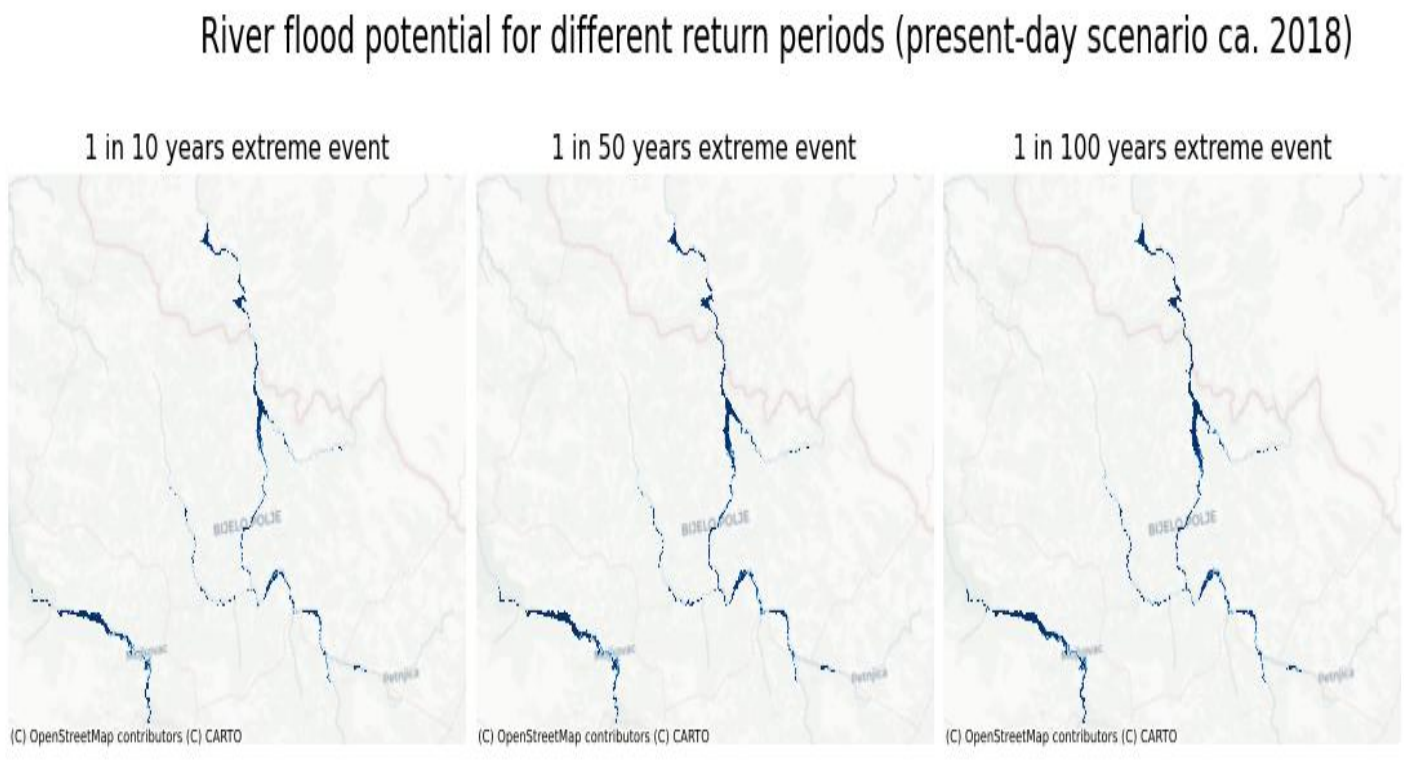
https://handbook.climaax.eu/CRA_steps/analysis/vulnerability_data.html#



Caption (EN): *Figure 2-1. Example JRC flood-depth raster for the Bijelo Polje AOI (present-day). OSM basemap shown; colour scale is inundation depth [m].*

Method.

- Reproject AOI to hazard rasters' CRS and **clip** each RP raster to AOI.
- Produce per-RP map figures (with consistent colour ramp and scale bar) and a **4-panel composite** (RP10/50/100/500) to allow side-by-side comparison.
- Compute a **difference map** (RP500−RP10) to visualize the marginal expansion of flooding toward higher RPs.
- Export a small **preview** map (RP10) to help reviewers quickly locate the study area.



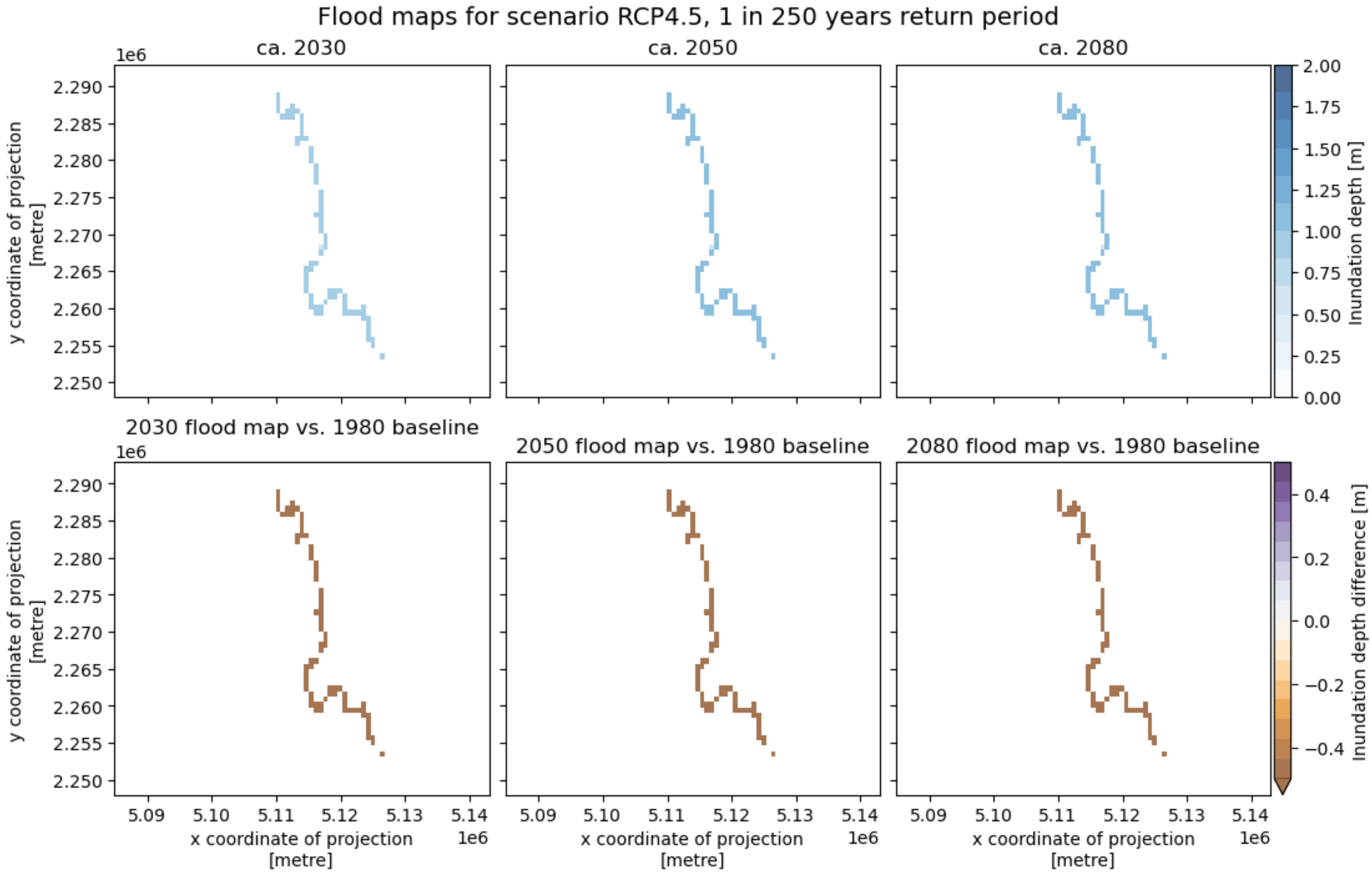
Caption (EN): *Figure 2-2. River flood potential – present-day return periods (RP10, RP50, RP100). Inundation depth [m].*

Key findings.

- Flooding is largely **confined to the river corridor**. Lateral expansion from RP10 to RP500 is visible but limited and mostly along known floodplain pockets.
- Deepest cells (river thalweg) do not imply building/people exposure on their own—these maps are **hazard only** and feed Workflow #2.

Limitations (screening level). European-scale rasters (coarse cell size) cannot represent local protection, small drains/bridges, or recent works; results should **not** be used for site-specific design without hydraulic refinement.

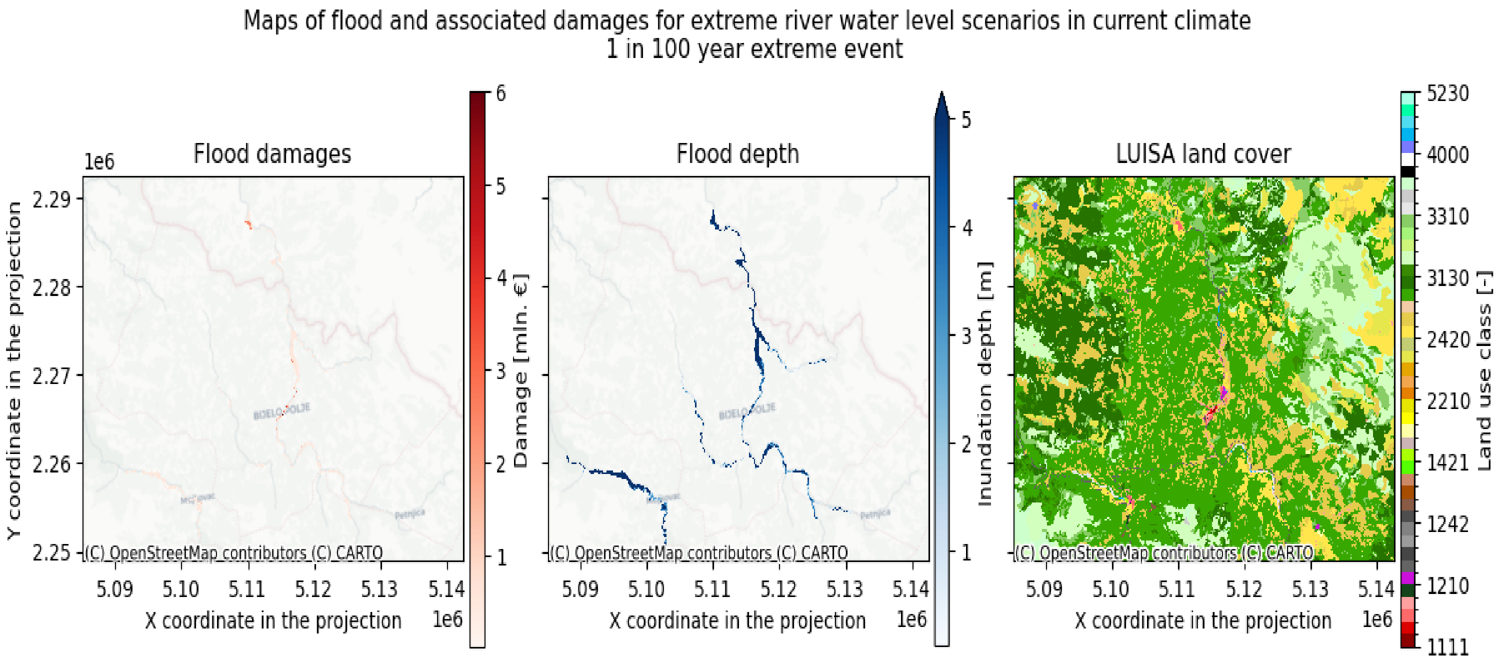
Outputs (see Annex). Per-RP PNG maps; **4-panel composite**; **difference map** (RP500−RP10); RP10 preview; clipped depth GeoTIFFs for RP10/50/100/500. (Package index and HTML quick viewer are also included.)



Caption (EN): *Figure 2-3. Scenario RCP4.5 – RP250 flood-depth maps for ca. 2030, 2050, 2080 (top) and differences vs. baseline (bottom). Positive values indicate deeper water.*

2.3.1.2 Risk assessment

Status in Phase 1. No quantitative risk is computed inside WF#1. The WF#1 hazard layers are the **direct inputs** to WF#2 where exposure, vulnerability and damage are quantified for buildings and population. A qualitative read of WF#1 maps indicates that **potentially at-risk assets** cluster within the immediate floodplain; risk growth with RP is visible but spatially limited.



2.3.2. Workflow #2 – **Flood risk to buildings & population**

Purpose. Quantify how river flooding affects **buildings** (by depth and simple depth-damage classes) and **population** (exposed / potentially displaced) using WF#1 rasters.
Key inputs.

- **Hazard:** RP10 / RP50 / RP100 / RP500 flood-depth rasters (WF#1).
- **Exposure: OSM buildings** (reclassified to *residential / commercial / industrial*), **GHSL population** grid.
- **Vulnerability / functions:** depth-based thresholds and look-ups consistent with JRC practice for screening.
  Outputs.
- **Per-RP building depth shapefiles** (depth at each footprint).
- **Graphs** (building depth histograms per RP; **buildings exposed** vs RP; **population exposed** and **population potentially displaced** vs RP).
- **CSV tables** (e.g., *BuildingExposure_Summary.csv*; *ExposedPopulationTotal.csv*; *DisplacedPopulationTotal.csv*).
- **Quick HTML viewer** of the figures.
  Exposed areas / vulnerable groups (decision view). Built-up zones along the river corridor; ground-floor households and small commercial/industrial premises close to the channel; **public facilities** situated within the mapped floodplain. (Results indicate concentration of exposure near the corridor; expected increase of affected assets with higher RPs.)

Table 2-2 Data overview workflow #2

Hazard data	*Vulnerability data*	*Exposure data*	*Risk output*
RP10/50/100/500 depth rasters used in WF#1; AOI	**JRC flood depth–damage functions** by building class; displacement depth thresholds for population (screening)	**OSM buildings** (reclassified to residential / commercial / industrial); **GHSL population** (100 m); municipal outline	Per-RP **building-depth histograms** (…building_depth_hist_RP*.png); **buildings exposed** graph; **population exposed** and **population displaced** graphs; CSVs (…_BuildingExposure_Summary.csv, …_ExposedPopulationTotal.csv, …_DisplacedPopulationTotal.csv); per-RP **building-depth shapefiles** (…_Depths_Building_RP*.shp); packaged under `deliverables/BijeloPolje/risk/figures

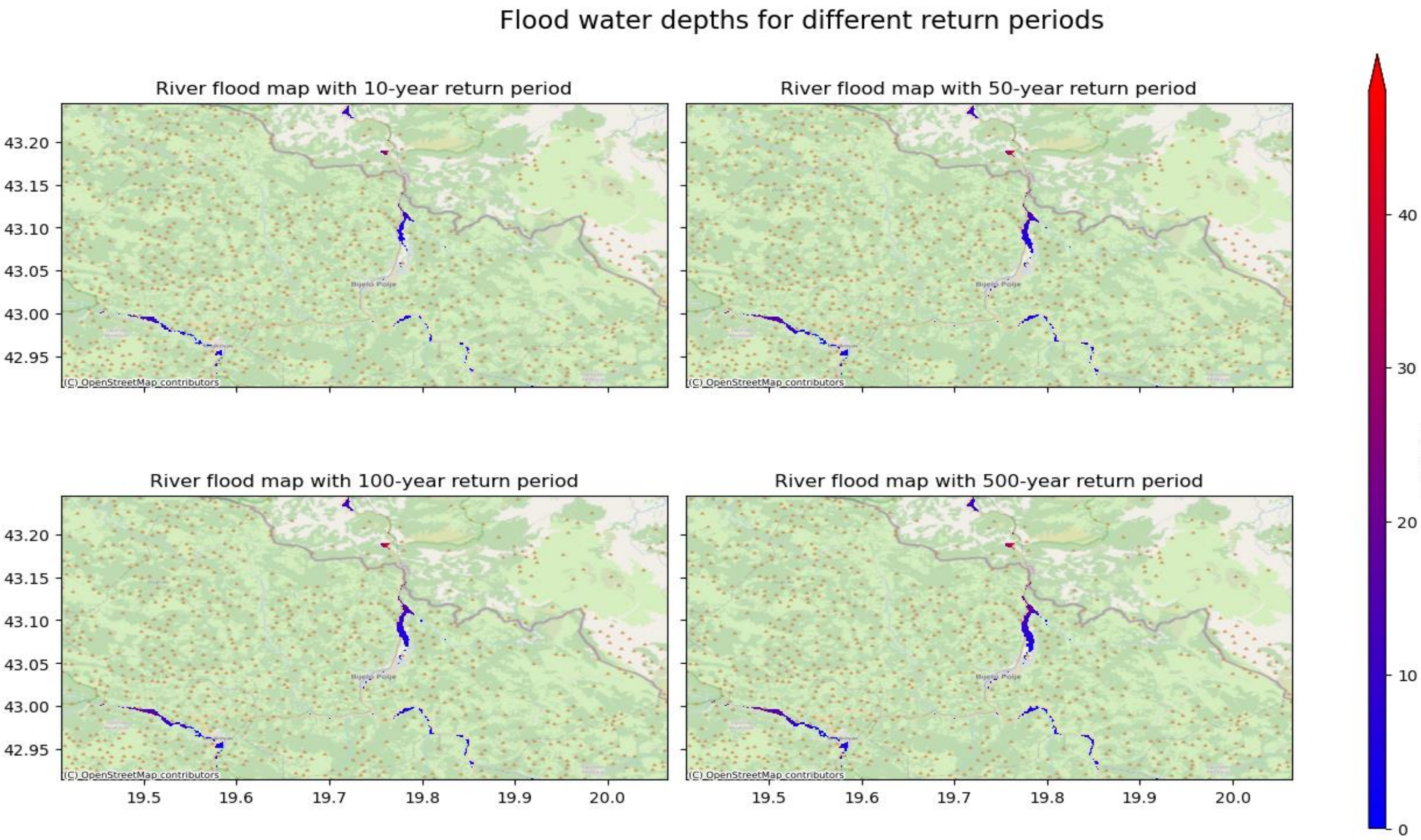
Notes for annex / filenames:
Bijelo_Polje_MNE_building_depth_hist_RP10.png|…|RP500.png,
Bijelo_Polje_MNE_buildings_exposed_graph.png,
Bijelo_Polje_MNE_popexposed_graph.png, Bijelo_Polje_MNE_popdisplaced_graph.png,
Bijelo_Polje_MNE_Depths_Building_RP10|50|100|500.shp,
…_BuildingExposure_Summary.csv, …_ExposedPopulationTotal.csv, …_DisplacedPopulationTotal.csv

2.3.2.1 Hazard assessment

Purpose. Bring the WF#1 depth rasters to the **asset scale**, extracting flood **depth at buildings** and **population grid cells** for RP10/50/100/500.

Inputs & pre-processing.

- **Hazard:** WF#1 clipped depth rasters (RP10/50/100/500).
- **Exposure:** OSM **building footprints** (unclassified) → **reclassified** into *residential / commercial / industrial*; GHS-POP 2025 global population grid (≈100 m) for people exposure.



- **Alignment:** All layers reprojected to the hazard CRS; OSM geometry validity fixed; AOI crop applied.

Method (hazard-to-asset linkage).

- **Buildings:** Sample raster depth under each building polygon (area-weighted mean depth), creating "Depths_Building_RP*.shp" layers; compute depth histograms per RP and by building class.
- **Population:** Summarize population in grid cells where modeled depth > 0 (exposed). For **potentially displaced people**, apply a configurable **depth threshold** (default **0.5 m**) as a proxy for loss of habitability/safety.

Outputs (see Annex).

- Shapefiles/GeoPackages: per-RP **building depths** (with building class).
- Figures: **building depth histograms** (RP10/50/100/500), **buildings exposed vs RP** graph, **population exposed vs RP** graph, **population potentially displaced vs RP** graph.
- CSVs: *BuildingExposure_Summary.csv*; *ExposedPopulationTotal.csv*; *DisplacedPopulationTotal.csv*.

Assumptions & limits. OSM coverage varies; occupancy class is approximate; GHS-POP is gridded (cannot represent vertical shelter). The **0.5 m** displacement threshold is generic and can be adjusted with local standards.

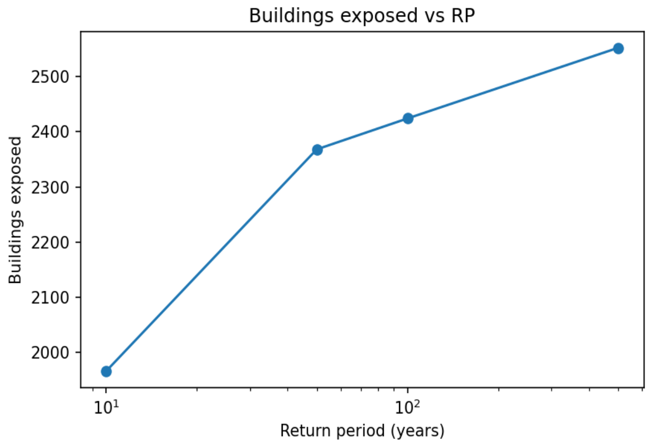
2.3.2.2 Risk assessment

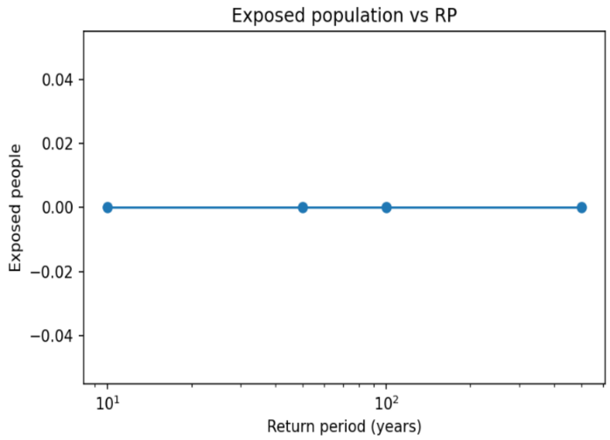
Buildings (direct damage).

- Apply **depth–damage functions** (by building class) to per-building depths for each RP to estimate **direct reconstruction cost**; sum by class and RP (tables + plots).
- Results show that **buildings at risk are a minority** and concentrate along the river corridor; **expected damage increases monotonically** with RP, with commercial/industrial clusters near the river contributing the largest shares per event.

Population (exposure & potential displacement).

- **Exposed people** (depth > 0) remain low outside the corridor; **potentially displaced** (depth ≥ 0.5 m) are a subset and increase with RP.
- Outputs provide **absolute counts** and RP-wise curves to guide civil-protection planning (e.g., shelter capacity, evacuation triggers).





Interpretation for Phase 3.

- Focus detailed mitigation on **river-adjacent assets** where the curves and damage totals indicate the largest expected losses.
- Validate OSM classes for key facilities (schools, critical services) and refine local thresholds for displacement and damage as better data become available.

2.3.3. Workflow #3 – Wildfire hazard & risk (screening)

Purpose. Provide screening-level **wildfire susceptibility** and **risk** to support emergency planning and land-management dialogue.

Key inputs.

- **Hazard:** modelled **wildfire susceptibility** surfaces for **HIST 1991–2010** and **near-future RCP4.5 2021–2040 (CLMcom-CCLM)**.

- **Exposure: GHSL population**; **OSM roads** (for an ignition/evacuation overlay); land-cover layers used to mask non-burnable classes.
- **Vulnerability: JRC three-pillar** screening indices (**population, economic, ecological**), classed into Low → Very High.

Outputs.

- **Risk category maps** for *population*, *economic* and *ecological* pillars (present & near-future).
- **Roads × risk overlay** (present & future) to support operational planning.
- Figure set + short HTML viewer.
  Exposed areas / vulnerable groups. Rural and peri-urban WUI strips (forest–settlement interface), **road corridors** used for access/evacuation, and **ecologically sensitive patches** that register high susceptibility. (This is a **screening** product; no change-assessment beyond the near-future baseline is claimed in Phase 1.)

Hazard data	*Vulnerability data*	*Exposure data*	*Risk output*
DEM, slope, aspect; CLC (reclassified burnable classes); historical fires; climate drivers (ECLIPS2.0 / CLMcom-CCLM) — HIST & RCP4.5 (2021-2040)	**JRC vulnerability layers** (population, economic, ecological)	**Roads (vector),** built-up areas (context)	Susceptibility rasters (HIST & future); **hazard class maps**; **risk maps** (population/economic/ecological, present & future); **roads × risk** overlay; figure panels and HTML report (…FIRE_ML_outputs.html)

Wildfire figure set includes (examples): hazard_assessment_fire_ml_fig_06.png (HIST susceptibility), …_fig_08.png (future susceptibility), …_fig_09.png & …_fig_10.png (hazard classes / risk).

2.3.3.1 Hazard assessment

Purpose. Map **wildfire susceptibility** for the municipality under **historical climate** (1991–2010) and a **near-future** projection (RCP4.5, CLMcom_CCLM, 2021–2040), and convert susceptibility to categorical **hazard levels**.

Inputs.

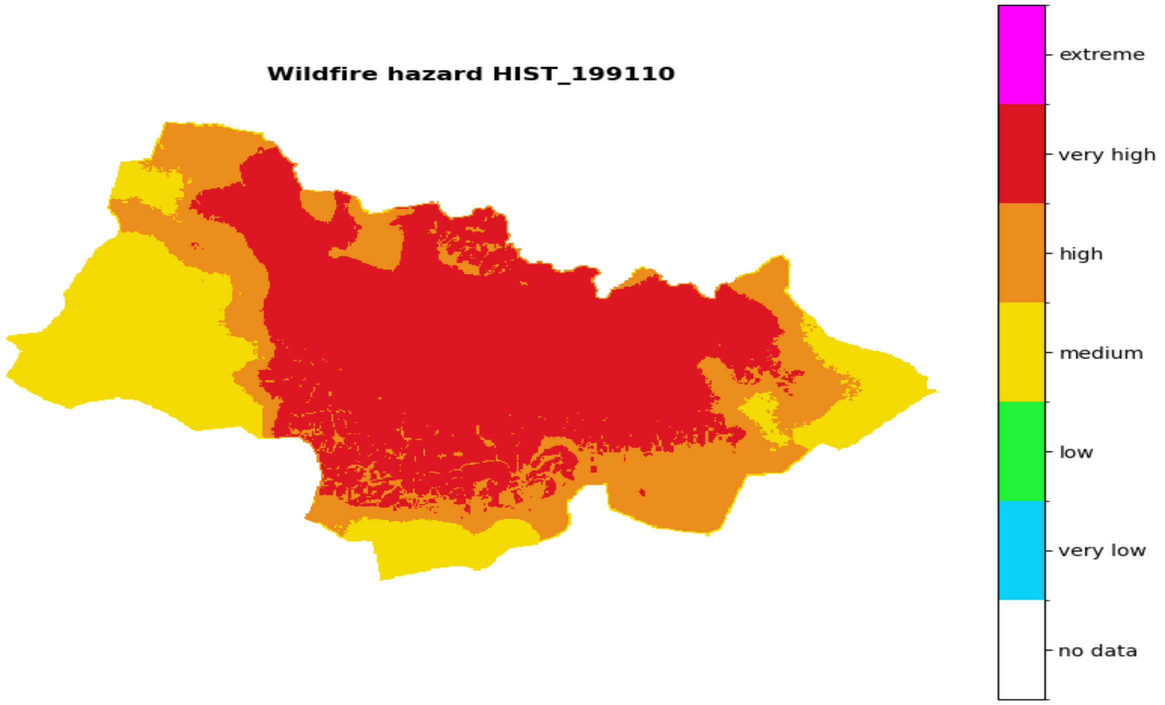
- **Topography:** municipal DEM; derived **aspect** (and slope if available).
- **Land cover: CLC** (original) with **non-burnable classes removed** for modelling.
- **Fire evidence:** rasterized **historical fire** points/footprints for calibration/context.
- **Climate driver:** ECLIPS2.0 wildfire susceptibility layers (historic and RCP4.5 near-future) used as the primary climatic signal.

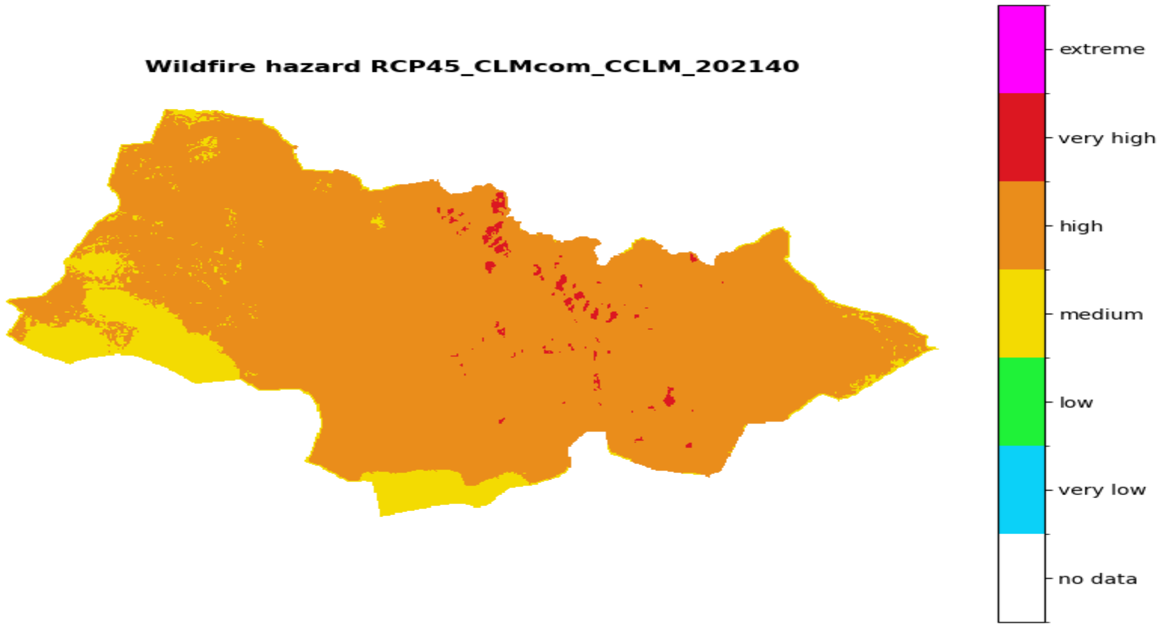
Method.

- Harmonize grids to a common CRS/extent and mask to burnable land.
- Use the ECLIPS2.0 susceptibility surfaces (historic, future) and classify them into **hazard classes** (*very low, low, medium, high, very high, extreme*).
- Produce maps for **HIST_1991-2010** and **RCP45_2021-2040**, and side-by-side panels to visualize spatial change.

Key findings.

- Under **historical climate**, **medium–high** susceptibility dominates many hilly tracts; the lowest values cluster along wetter valley bottoms.
- Under **RCP4.5 (2021–2040)**, **susceptibility increases** in several upland belts, enlarging continuous zones of *high* class.





Limitations (Phase 1). No local fuel-load mapping; wind and suppression are not explicitly modelled; susceptibility maps indicate **likelihood**, not spread/intensity.

Outputs (see Annex). DEM & **aspect** figures; **CLC original/modified** maps; **rasterized fires** map; **susceptibility** maps (historic & future) and **hazard category** maps for both periods; HTML preview of figures.

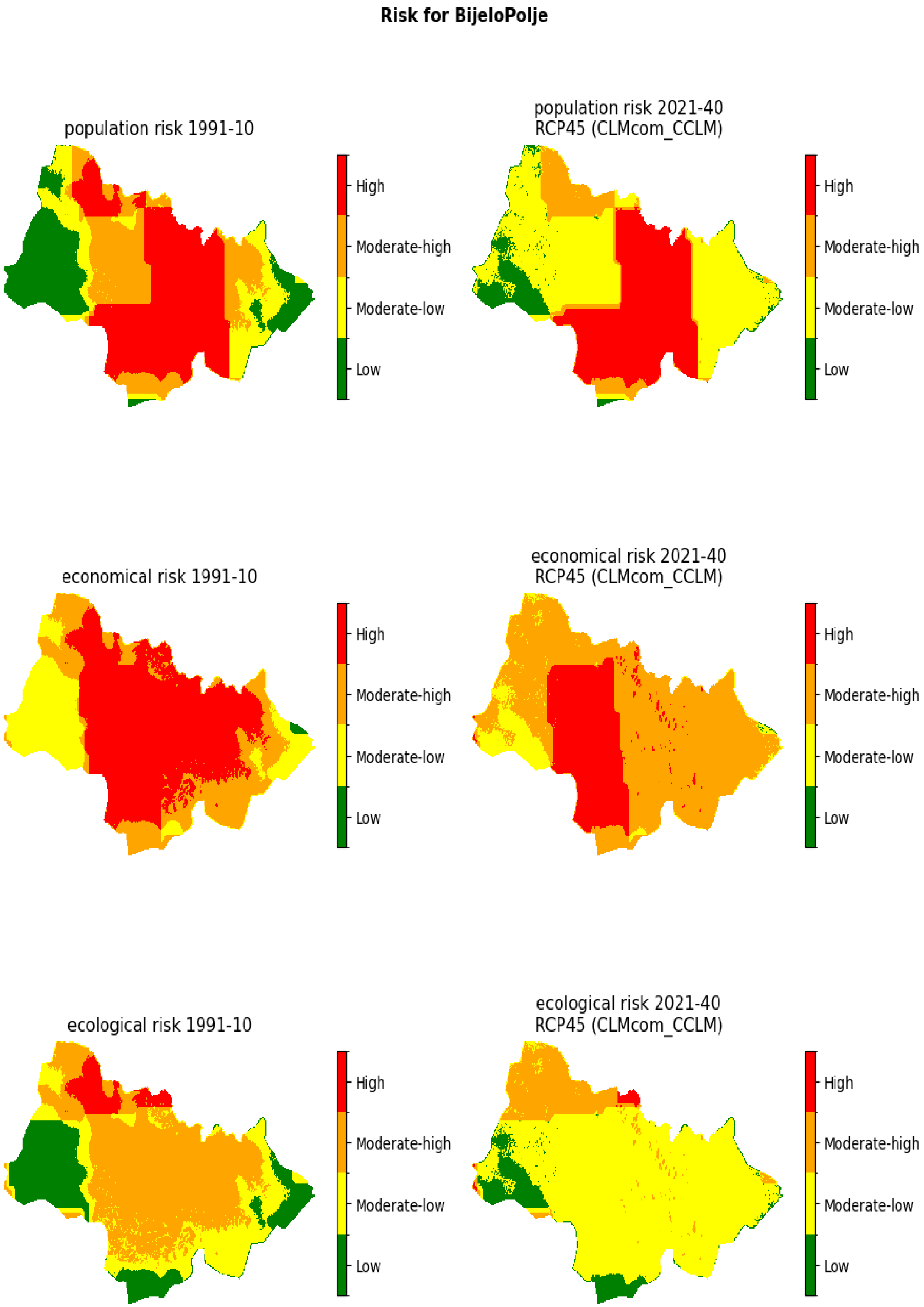
2.3.3.2 Risk assessment

Exposure & vulnerability.

- **Exposure:** GHSL **population**; a rasterized proxy for **buildings** (density) and **road-proximity** layer.
- **Vulnerability: JRC** vulnerability indices (three pillars: *population*, *economical*, *ecological*), normalized to [0–1] and **categorized into 3 classes** to match mapping scale.

Method (risk synthesis).

- Compute risk per theme as a standardized combination, e.g.
  Risk_theme = Hazard × Exposure × Vulnerability_theme (normalized)
  → classify to **Low / Moderate-low / Moderate-high / High**.
- Generate **present vs near-future** risk maps for all three themes.
- Derive a **roads risk** product by sampling the thematic risk fields along the **road centerlines**, classifying segments as *Medium/High/Very High* for prioritization.


Risk for BijeloPolje
population risk 1991-10
population risk 2021-40
RCP45 (CLMcom_CCLM)
economical risk 1991-10
economical risk 2021-40
RCP45 (CLMcom_CCLM)
ecological risk 1991-10
ecological risk 2021-40
RCP45 (CLMcom_CCLM)
High
Moderate-high
Moderate-low
Low

Key findings.

- **Population risk**: High-class areas are **localized**; most built-up valley bottoms remain in lower classes, but near-future maps show **growth of Moderate-high** patches on slopes above settlements.
- **Economic risk**: Mirrors the **commercial/industrial** footprint near the corridor; pockets of **High** appear in upland routes with limited redundancy (roads).
- **Ecological risk**: The most **spatially extensive**, highlighting forested belts; the near-future map shows **wider High zones** consistent with the susceptibility increase.
- **Roads**: Selected segments show **High/Very high** wildfire risk (present and future), suggesting candidates for fuel-breaks and roadside vegetation management.

Outputs (see Annex). Vulnerability **heatmaps** (continuous and 3-class), **exposure** rasters (population, buildings, road proximity), six **risk maps** (pop/eco/eco × present/future), and a **Roads × Risk** figure/table.

1.1 Preliminary Key Risk Assessment Findings

1.1.1 Severity

WF#1 & WF#2 – Flood (river flooding; risk to buildings & population)

- **Overall severity.** Modeled floodwater depths (RP10/50/100/500) are concentrated along the river corridor. Lateral expansion from RP10 to RP500 is visible but limited; the spatial footprint remains narrow, mainly affecting the immediate floodplain.
- **People & assets affected.** OSM building footprints show that the share of buildings exposed is a minority of the total stock, clustered close to the river; nevertheless, expected damage increases with return period (depth–damage functions). Coarse-resolution GHSL population grids indicate low population exposure and displacement outside the corridor; where exposure occurs, it is localized near the river.
- **Critical functions.** Risk is highest at river crossings and low-lying road sections, where inundation can block access, disrupt emergency response and supply chains.
- **Irreversibility/cascades.** Severe events may cause structural damage to small businesses and private housing, road closures, and temporary service disruption; widespread irreversible ecological loss is not expected at Phase-1 resolution.

WF#3 – Wildfire (hazard & risk)

- **Overall severity.** Susceptibility maps (historical climate) show moderate–high wildfire hazard across mid-slopes and south-facing aspects. The near-future scenario (RCP4.5, 2021–2040, CLMcom_CCLM) indicates persistence of moderate–high hazard, with local increases on drier slopes.

- **People & assets affected.** Settlements at the wildland–urban interface and linear infrastructure (roads, above-ground distribution lines) traverse areas of moderate to high risk. Population- and economy-oriented risk layers classify most inhabited zones as low to moderate, with pockets of moderate-high where vegetation meets built-up areas.

- **Irreversibility/cascades.** Potential for vegetation loss and smoke impacts; road closures during events; short-lived power outages possible where lines cross high-risk segments.

1.1.2 Urgency

WF#1 & WF#2 – Flood

- **When impacts occur.** Impacts occur during heavy rainfall and snowmelt pulses; even RP10–RP50 events can produce nuisance flooding in the corridor.

- **Short-term priority actions.** Before the next wet season: clear debris at culverts/bridges, inspect low-lying road sections and river crossings, update and disseminate detour and access plans, and verify siren/SMS warning dissemination for neighborhoods near the corridor.

- **Trend & persistence.** While Phase 1 applied present-day hydrology, flood exposure is expected to persist and likely intensify with future rainfall extremes (to be quantified in Phase 2). The narrow footprint supports targeted preparedness rather than broad restrictions.

WF#3 – Wildfire

- **When impacts occur.** Peak urgency in late spring–summer, during dry, windy spells.
- **Short-term priority actions.** Fuel management along roads and settlement edges, seasonal access control to high-risk tracks, public messaging on ignition prevention, and coordination with forestry for rapid initial attack.
- **Trend & persistence.** Near-future climate suggests continued moderate–high susceptibility; preparedness and prevention measures are time-critical ahead of each fire season.

1.1.3 Capacity

WF#1 & WF#2 – Flood

- **Existing measures.** The municipality operates under legally valid hazard-specific plans (updated 12/2024) and a Protection and Rescue Service (PRS) with operational units and inter-municipal cooperation. Detour networks exist along the corridor; bridge/culvert maintenance is routine.
- **Gaps.** Shelter infrastructure does not fully meet national standards; data sharing across services is fragmented; local cross-sections and hydraulics for detailed modeling are not yet compiled.
- **Feasible near-term reinforcements.** Establish a shared geodata folder for flood assets and events; tag and inspect the few recurrent inundation points (low-lying roads, crossings);

standardize citizen reporting (photos + coordinates) during events to build a Phase-2 evidence base.

WF#3 – Wildfire

- **Existing measures.** Firefighting capacity is present within PRS and forestry services; operational plans exist; public communication channels are in place (municipal website/SMS).
- **Gaps.** Systematic fuel-break mapping and upkeep around settlements and critical lines are incomplete; WUI (wildland–urban interface) inventory and road-access condition mapping are not yet standardized.
- **Feasible near-term reinforcements.** Prioritize fuel reduction within 50–100 m of settlement edges and along powerlines/roads in high-risk cells; create a simple WUI register (settlement edge polygons + contact points); pre-position water tanks and equipment at strategic road nodes.

1.2 Preliminary Monitoring and Evaluation

What did we learn from the first phase of the climate risk assessment? Where did we encounter the most difficulties?

- **WF#1 – River flooding (RP10/50/100/500, present-day):**
  - What we learned. Flooding in Bijelo Polje is largely confined to the **river corridor**. The step from RP10 to RP100 brings only **limited lateral expansion** of inundation, with RP500 adding depth primarily in the known low-lying areas. The four-panel overview (RP10/50/100/500) and the RP500–RP10 **difference map** clearly communicate this pattern.
  - Difficulties. Harmonising **CRS** across European flood-depth rasters and local AOI/OSM layers required careful reprojection. Given Phase-1's screening scope, we relied on pan-European rasters; fine-scale hydraulic effects (e.g., local embankments) are not captured at this stage and are flagged for Phase-2 hydrodynamic refinement.
- **WF#2 – Flood risk to buildings & population (present-day exposure/vulnerability):**
  - What we learned. **Buildings at risk** are a **minority** of the total stock and cluster next to the river; expected **damage increases with RP**, while affected counts remain modest outside the corridor. **Population exposure and displacement** are low when mapped with GHSL, which is suitable for screening but **coarse** for settlement-level analysis. Outputs (PNG figures, CSV summaries, GeoPackages) provide a solid **Phase-3 hand-off** for detailed planning.
  - Difficulties. Variable **OSM completeness** outside the urban core and the **resolution mismatch** between building polygons and hazard rasters required robust sampling and QA. We also needed to **reclassify OSM building use** to match damage functions—workable in Phase-1 but better supported by local asset registers in Phase-2.
- **WF#3 – Wildfire hazard & risk (historic and near-future susceptibility; categorical risk):**

- What we learned. Susceptibility surfaces (historic climate and **RCP4.5 2021–2040 – CLMcom_CCLM**) show **consistent spatial gradients** linked to slope/aspect and fuels, with several micro-areas transitioning from "moderate-low" to "moderate-high". Overlay with vulnerability categories and exposure (roads, settlements) highlights **priority segments** for prevention and patrols.
- Difficulties. Cleaning **CLC classes** to derive "burnable" fuels and aligning historical ignitions were the main data tasks. With Phase-1 intentionally light on calibration, we used a **transparent screening approach**; Phase-2 will benefit from local fire records (ignitions, burnt area per year) and finer-resolution fuels.

- ***Cross-cutting lessons.***
    - A screening pipeline works: each workflow now outputs a compact CLIMAAX package (HTML quick viewer, figures, CSVs, GeoPackages, MANIFEST), ready for Zenodo and stakeholder use.
    - The largest productivity gains came from standardising naming/CRS and automating export (maps + tables).
    - Limitations are known and acceptable for Phase-1: we used pan-European hazard rasters (flood) and screening-level fuels/vulnerability (wildfire); climate-change adjustment of flood hazard and socio-economic growth scenarios were intentionally out of scope for this phase.

What feedback did we receive from stakeholders? Do other stakeholders need to be involved in the next iteration of the analysis?

- **Municipal departments (planning, PRS, utilities).** Appreciated the PNG maps and HTML viewers for non-GIS staff. Requested clearer priority lists (e.g., top N buildings/road links at risk by RP; wildfire-risk road segments) and map packages they can open offline.
- **Civil protection / emergency services.** Asked for actionable layers (access/egress routes, staging areas) and simple risk classes to set patrol priorities during heatwaves and high-wind days.
- **Water management & forestry agencies** (to involve more closely in Phase-2). Interest in sharing gauge data, cross-sections and maintenance plans (flood), and forest compartment data (wildfire).
- **Community reps/industry.** Supported the approach; requested the inclusion of schools, health facilities and key industries in the risk summaries.

1.3 Work plan

Key activities planned for the next six months include:

1. **Data acquisition** – Obtain high-resolution DEMs (1–5 m) and LiDAR; secure hourly rainfall data; collect fuel-load and moisture indices; compile building age and structural type; map critical infrastructure; gather socio-economic data at settlement level.
2. **Participatory mapping** – Organise workshops with municipal departments, utilities, industrial facilities and community leaders to validate hazard maps, identify vulnerable groups and discuss adaptation options.
3. **Workflow implementation** – Run CLIMAAX flood and wildfire workflows using compiled datasets and RCP4.5/8.5 climate scenarios; generate hazard maps, risk metrics and impact estimates; cross-validate with local observations.

4. **Preliminary adaptation options** – Identify structural and non-structural measures: floodplain restoration, levee reinforcement, retention basins, fuel-break establishment, controlled burning, slope stabilization, seismic retrofitting.
5. **Capacity building** – Provide training to PRS and sectoral services on CLIMAAX tools, modelling techniques and emergency planning; strengthen volunteer networks and community education programs.
6. **Reporting** – Document technical results, update the CRA deliverable and prepare communication materials for policy-makers and the public.

Activities outside the scope of Phase 2 include detailed economic analysis, design of structural measures and integration into municipal budgets; these will be addressed in Phase 3.

2 Conclusions Phase 1- Climate risk assessment

The Phase 1 CRA indicates that **floods and wildfires are the most pressing climate-related hazards** in Bijelo Polje, while landslides and earthquakes pose additional risks that require further investigation. Updated rainfall and fire-incident data reveal increasing variability and extremes. Exposure is high along river valleys and forested areas; vulnerability is amplified by socio-economic factors and ageing infrastructure. Institutional and community capacities lag behind the evolving risk landscape.

To enhance resilience, the following actions are recommended:

1. **Strengthen data collection** – Expand hydrometeorological and geotechnical monitoring networks; conduct building-vulnerability surveys; develop fuel-load and moisture maps; establish data-sharing protocols among institutions.
2. **Improve early warning** – Upgrade flood forecasting with real-time river and rainfall measurements; establish wildfire danger indices and lightning detection; disseminate warnings through multiple channels (sirens, SMS, radio, web).
3. **Upgrade infrastructure** – Reinforce levees and drainage systems; construct retention basins; maintain and widen firebreaks; stabilize slopes; retrofit critical buildings; ensure redundancy in power and water supply.
4. **Enhance human capacity** – Increase PRS staffing and equipment; develop specialised units (swift-water rescue, aerial firefighting); train volunteers; integrate civil protection units more effectively.
5. **Engage communities** – Conduct awareness campaigns on fire prevention and flood preparedness; involve residents in mapping exercises; support vulnerable households with adaptation resources; promote community-based forest management.
6. **Mainstream risk into planning** – Integrate CRA results into spatial planning, building codes, infrastructure design and sectoral plans; coordinate with national adaptation strategies and the EU Mission on Adaptation.

3 Progress evaluation and contribution to future phases

- *Describe the connection between this deliverable, its outputs and the planned activities for the following phases of the project.*
- *Include the **Key Performance Indicators** and **Milestones** achieved in this phase and the actions executed to achieve these as per the Individual Following Plan. Please use the summary tables below to give an overview of the progress.*

Table 4-1 Overview key performance indicators

Key performance indicators	*Progress*
Delivery of flood hazard & risk outputs (WF#1 River flooding; WF#2 Buildings & population): HTML quick viewers, PNG figures, CSVs, GIS layers, README/manifest	***Completed** — files produced and structured; ready for archiving and review*
Delivery of wildfire hazard & risk outputs: HTML viewer, figures, risk maps (present & near-future), exposure layers	***Completed** — package assembled and quality-checked*
M6 documentation: Sections 2.1–2.4 drafted; Annex (manifest + file list); reproducibility notes (data sources, CRS, naming)	***Completed***
Engagement & capacity building: 1 municipal working meeting (prep, agenda, notes); participation in CLIMAAX Academy workshop (Spain)	***Completed —** attendance confirmed; key learnings integrated into the work plan*
Data stewardship: Prepare Zenodo deposits (wildfire + flood) with metadata and licence	***In progress —** archives prepared; links to be added after municipal sign-off*
Stakeholder engagement (Phase1) - mapped actor network, agreement on priorities (flood/fire), confirmed inputs for phase 2	***Completed:** initial screening and collection of feedback; followed by local data detailing workshops in phase 2*

Table 4-2 Overview milestones

Milestones	*Progress*
M1. Scope & AOI agreed with municipality; roles/contact points confirmed	***Done***

Milestones	*Progress*
M2. Hazard data retrieved & pre-processed (flood depth rasters RP10/50/100/500; wildfire drivers)	***Done***
M3. Exposure & vulnerability prepared (OSM buildings reclassified; GHSL population; road subset; JRC vulnerability)	***Done***
M4. Run workflows (WF#1 flood, WF#2 buildings & population, WF#3 wildfire); internal QC; hot-fixes	***Done***
M5. Package results (HTML viewers, figures, CSVs, GIS) + README/MANIFEST	***Done** (flood packaged as CLIMAAX M6 bundle)*
M6. Draft deliverable (Sections 2.1–2.4 + Annex) integrating wildfire & flood	***Done***
M9. Phase-2 plan (data upgrades, co-design workshops, modelling roadmap)	***Open** — see Section 1.3 Work plan*
Milestones (iz SGA) Progress / Evidence *M10: Attend the CLIMAAX workshop – Barcelona (Spain)*	***Done***
M11: Draft local adaptation strategy and action plan	***Not due (Phase 3)***
M12: Presentation of results to policy/decision makers	***Not due (Phase 3)***
M13: Attend the CLIMAAX workshop – Brussels (final)	***Not due (Phase 3)***
Procurement/subcontracting for all three phases	***In progress***

4 Supporting documentation

Description	*Filename*
Main Report	CLIMAAX_Report_Phase1.docx
Dataset	CLIMAAX_M6_FIRE_outputs Bijelo Polje.zip
Dataset	CLIMAAX_M6_FLOOD_outputs Bijelo Polje.zip
Reference to Annex (MANIFEST))	

5 References

Please use the typical paper referencing, that is for example: (Buskop et al., 2024)

Buskop, F., Sperna Weiland, F., and van den Hurk, B.: Amplifying Exploration of Regional Climate Risks: Clustering Future Projections on Regionally Relevant Impact Drivers Not Emission Scenarios, https://doi.org/10.1088/2752-5295/ad9f8f, 2024

1. *Go to the Reference section and add your reference following the provided model and style.*
2. *Place your cursor in the main text where the cross-reference should be inserted.*
3. *Click **Insert | Cross-reference**. A Cross-reference dialog box will appear.*
4. *Click the **Reference type**: drop down and select the type of object you want to provide a cross-reference to.*
5. *Click the **Insert reference to**: drop down and select the information to be displayed in the cross-reference field.*
6. *Available headings, captions or footnotes will appear. Select the item you wish to reference.*
7. *Click **Insert.***

6 Managing the formats of the template- Title Styles

Add your text here.

6.1 Heading level 2

Add your text here.

6.1.1 Heading level 3

Add your text here.

6.1.1.1 Heading Level 4

Add your text here.

6.1.1.1.1 Heading Level 5

Add your text here.

This is an example of text (font Roboto, size 11): CLIMAAX is a 4-year Horizon Europe project that will provide financial, analytical, and practical support to improve regional climate and emergency risk management plans. CLIMAAX is designed to contribute to the harmonization and consolidation of the practice of climate risk assessment, leaving a legacy for upcoming European initiatives. The project started in January 2023 and runs until December 2026.

This section includes format examples to follow. Project color palette:

Figure 7-1 CLIMAAX palette.

6.2 How to manage tables

This is an example for a table:

- *Captions always at the top.*

- *Check that the table header repeats at the top of each page if the page breaks across pages.*
- *Update the list of tables at the beginning of the document. Check that the numbering sequence is correct.*

Table 7-1 Name of the table

Column name	*Column name*	*Column name*
...	...	...
...	...	...

6.3 How to manage figures

This is an example for a figure:

- *Captions always at the bottom.*
- *Update the list of figures at the beginning of the document. Check that the numbering sequence is correct.*
- *Always use the automatic numbering format for figures as provided in the caption of the figure below.*

Figure 7-2 Title of the figure

Figure source: Please include cross-reference here of the external image source in case of copyrighted images