Deliverable Phase 1 – Climate risk assessment

Climate change floods risk assessment for enhanced preparedness and resilience of vulnerable Putna river basin local communities in Romania (CARE-ROPutna)

Romania, Bucharest

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Abbreviations and acronyms

Abbreviation / acronym	Description
APSFR	Areas of Potential Significant Flood Risk
ATU	Administrative Territorial Units
CRA	Climate Risk Assessment
EAD	Expected Annual Damage
IDF	Intensity Duration Frequency
JRC	Joint Research Centre
FD	Floods Directive 2007/60/EC
GD	Government Decision
GDP	Gross Domestic Product
NIHWM	National Institute of Hydrology and Water Management
NSMFR	National Strategy for the Management of Flood Risk in the Medium and Long Term
ROFFG	Romania Flash Flood Guidance System
RP	Return Period

Executive summary

This Deliverable (Phase 1) – Climate risk assessment describes how the CLIMAAX Climate Risk Assessment (CRA) Framework and Toolbox have been tested and applied for Putna river basin, during the first phase of the project CARE-ROPutna.

The deliverable presents in the first part the background and the main objectives of the project, followed in the second one by describing the application of CRA workflows in the study area and the third one summarizing the conclusions of the analysis.

The main actions undertaken during this phase were testing the 3 selected workflows (River floods, Flood building damage and population exposed, and Extreme precipitation) and applying them to Putna river basin. The main outputs are maps, plots and data usefull for identifying and assessing potential hotspots of hazard anf risk that will be further analyze in the second phase of the project.

As main results achieved we could mention a general qualitative assessment of the potential climate change impact on the projected extreme river flooding, by analyzing the Aqueduct floods dataset, and a general quantitative assessment of extreme precipitation evolution under climate change, using an ensemble of climate models simulations, for different chains of GCM/RCM, RCP 4.5 and 8.5 scenario, and several future periods (2011-2040, 2041-2070, 2071-2100).

The results of this phase need to be considered as preliminary assessment, taking into account the limitations of the datasets used in the workflows, but they provide a basis for further refining the analysis in the next phase, by including local data at better resolutions, as well as existing local tools and models that will be used for a better estimation of the river flooding and flash floods hazard and associated risk.

1 Introduction

1.1 Background

Putna river basin (Figure 1-1) extends over most of the territory of Vrancea county (52% of the county area), which has a population of 335,312 inhabitants (population density of 69.0/km^2), 67% of whom live in rural areas and 33% in urban areas.

Putna River is a tributary of the Siret River and together with its network of tributary rivers drains a total area of 2487 km², with different characteristics imposed by the three major units of relief (mountains, hills, plains) and by the morphometric characteristics within each relief unit (altitude, slope, structural features of the drainage areas, the hydrographic convergence zones).

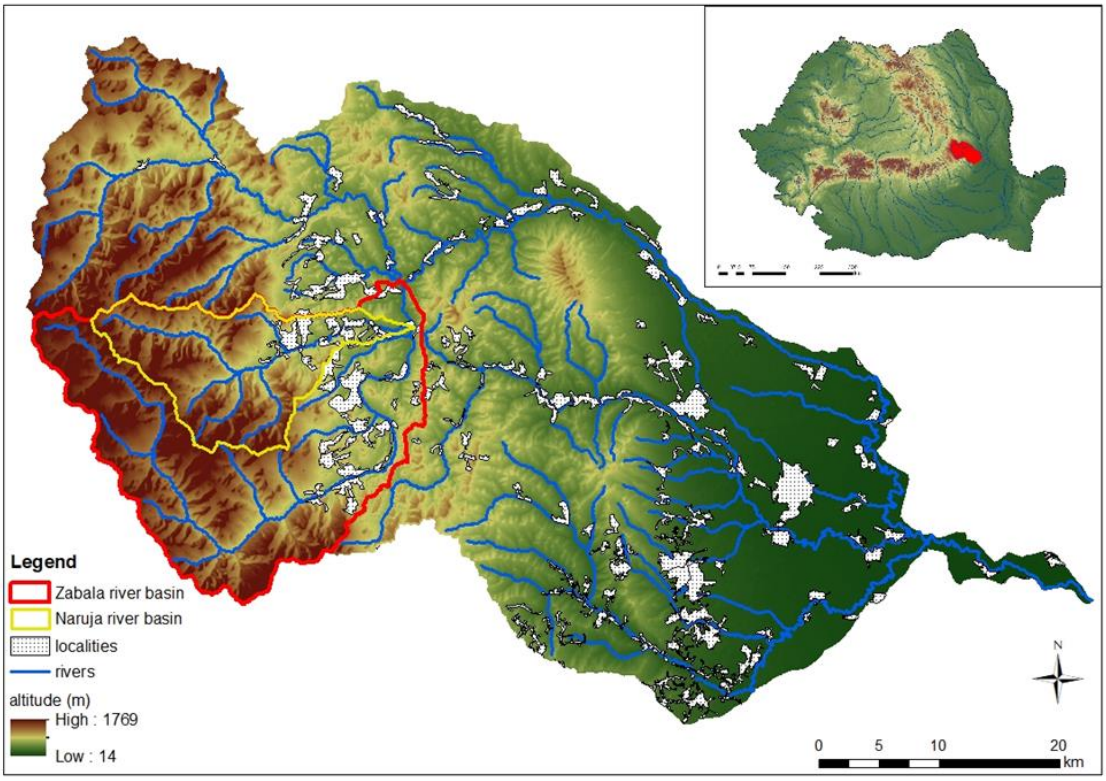

Figure 1-1 The location of Putna river basin and selected sub-basins Zabala and Naruja

The total length of permanent and torrential river bodies is approximately 2000 km, resulting to an average river network density of 1.24 km/km². Maximum flows are recorded in general from late spring (April-May), peaking in May-June often extending throughout the summer. Peak flows are caused by very high amounts of precipitation, generally with high intensity that could generate severe floods with significant damage.

The major climate-related risks that local communities in Putna river basin are facing are flooding and heavy rainfall as a major risk factor for flash floods. Intense rainfall events that occur in the region lead to flash floods and river flooding, particularly in small mountain basins, areas with poor drainage infrastructure or in low-lying areas. Flooding and flash floods damage property, infrastructure, and agriculture, disrupt transportation networks and threaten lives.

During 2005, 2012, 2016, 2021 and 2022 significant heavy rainfall and floods events in Putna river basin caused major damage and even loss of life. In 2005, local communities in Putna river basin experienced the largest flood ever recorded, with a peak flow value of 1,500 m^3/s, being considered the first in the chronological series of maximum flows with an exceedance probability of 2.5% (calculated for the period 1951-2022).

Zabala watershed (tributary of Putna river, with an area of 544 km²) and Naruja watershed (tributary of Zabala river, with an area of 174 km²), for which a detailed comparative analysis will be carried out in the second phase of the project, using high resolution local data, have been identified in the second cycle of implementation of the Floods Directive as areas of interest due to their high potential for floods (Zabala river) and flash floods (Naruja river).
Local communities in Putna river basin have limited resources to increase climate or disaster resilience because, in general, they do not have sufficient resources to implement proper emergency response, recovery and adaptation measures, have high exposure to natural hazards due to the geographical position, have a large number of vulnerable people (children or elderly people) existing within the communities.

1.2 Main objectives of the project

The main objective of the project is to reduce the vulnerability and to increase the adaptation of local communities in Putna river basin to the impact of climate change, by proposing supporting measures for the improvement of General Urban Plans and other urban plans and planning regulations.
Based on the improved assessment of the flood hazard and risk maps under climate change impact, for the areas of potential significative flood risk, several proposals will be made for updating the program of measures proposed in the study area in the Flood Risk Management Plan of the 3rd implementation Cycle of the Floods Directive. Also, the general knowledge and awareness of floods and flash floods risk at local and regional scale will increase. Stakeholders (e.g. local and regional administrative authorities) will be involved in the elaboration of new proposals for the program of measures which will include prevention, protection and preparedness measures for existing and future floods, taking into account the effects of climate change, as well as emergency response measures during floods and support for post-flood recovery.
Based on an improved comprehensive risk analysis carried out following the CLIMAAX framework and toolbox, NIHWM will be able to better support the communities in Putna river basin to assess climate-related risks, to inform the design of and improve local Risk Management Plans and Climate Adaptation Strategies to increase regional resilience. The results of the risk analysis will also help stakeholders understand the updated assessment of potential impacts of new climate change scenarios on various sectors, prioritize adaptation and mitigation measures, and allocate resources effectively to reduce vulnerability and enhance resilience. By understanding specific climate risks and their potential consequences, stakeholders can develop targeted strategies to address these challenges and build a more sustainable and resilient future for the region.

1.3 Project team

The project team is composed mostly of senior researchers PhDs, with experience and high skills in hydrological and hydraulic modelling, elaborating, managing and leading flood hazard and local climate risk assessments and Flood Risk Management Plans, acquired during the implementation of FD (Flood Directive 2007/60/CE) in Romania and national and international projects (e.g.: RO-RISK, ROFLOODS, JOINTISZA, DANUBE FLOODPLAIN, CLIMHYDEX).
During the 3 phases the project team will use their skills in working with Python, Jupyter Notebook and HTML and in hydrological and hydraulic modelling for the application of the CLIMAAX common methodology Framework, also for the refinement and improvement of the flood risk assessment as expert users of the Toolbox.
The team experts have also experience in providing technical support for the implementation of the FD for coordinating and participating in reporting to the EU on the results of the implementation of the FD.

1.4 Outline of the document’s structure

The deliverable is structured in 3 sections, the first one describing the background and the main objectives of the project, the second one describing the application of CRA workflows in the study area and the third one summarizing the conclusions of the analysis. The structure broadly follows the steps of the CRA as defined by the CRA Framework.

The report on the CRA is detailed in section 2, which is divided into 3 subsections, each for a selected workflow (River Flood, River Flood Building and Population Exposure and Extreme Precipitation).

The reports on the results of this first phase are followed by a Conclusion section, which reflects on the progress of the project and links this first phase to the second one.

2 Climate risk assessment – phase 1

2.1 Scoping

2.1.1 Objectives

The main objective of the CRA during the Phase 1 is to better understand the particularities and limitations of the toolbox and the data available in the workflows by applying CLIMAAX methodology to the study area for a first assessment of the hazard (river flooding, extreme precipitations), risk (river flooding, extreme precipitations) and potential impacts of climate change on river flood hazard and extreme precipitations characteristics.

The expected outcome of this first phase is an overall assessment of the hazard, risk and impacts of climate change mentioned above for the entire Putna river basin.

At the beginning of phase 2, this first assessment will form the basis for a comparative analysis with available local assessments that took mainly historical events and/or empirical methods into account and for the identification of new sectors that represent hotspots of hazard, risk and high climate change impact.

The results of the first two phases of the project will be translated into proposed measures for updating the program of measures for the study area in the Flood Risk Management Plan of the 3rd implementation Cycle of the Floods Directive.

Most limitations of the CRA in phase 1 are related to the availability and resolution of the default available datasets for Putna river basin. The lack of the following data for the study area was the main constraint of the CRA analysis in the first phase:

- buildings footprint and types;
- transport infrastructure layer;
- socio-economic development future scenarios;
- maximum discharges values and percent change in maximum discharges values for the present day and future scenarios;
- high resolution river flood maps for future climate scenarios;

Other limitations of the datasets used would include the unknown deviations of the flows underlying the JRC hazard maps from the available FD maps, the use of an averaged value for the model results included in the Aqueduct dataset.

During phase 2, by integrating local high resolution data sets (using the Toolbox package as expert users, in order to create a fully customized regional risk assessment package), and valuable information from local knowledge of the exposed areas (obtained through consultation with local communities in the first workshop planned in the study area) alternative methodologies and last generation hydraulic models, new hazard and risk maps will result that can help improving the local knowledge of these risks under climate change.

2.1.2 Context

Climate hazards, impacts and risk were evaluated in Romania until now through the implementation of Flood Directive (2007/60/CE), whose 2nd Cycle was completed in 2023 together with developments of Flood Risk Management Plans. Based on the preliminary flood risk assessment which refers to the identification of significant floods events from 2010 – 2016 (54 significant historical flood events and 64 potential significant future floods identified) and delimitation of areas with potential significant flood risk (526 APSFR named), flood hazard and flood risk maps was created, at national level. For flood hazard maps was 5+1 (33%, 10%, 1%, 0,5%, 0,1%/0,2% and 1%+Climate Change) simulated probabilities. For flood risk maps a quantitative assessment was done. At the level of Putna river basin 2 APSFRs were identified, and flood risk mitigation measures were proposed for them. This data needs to be updated and reevaluated at every 6 years (National

Administration Romanian Waters of Ministry of the Environment, Waters and Forests: Flood Directive *(2007/60/CE)*. Romanian Government. Available at: https://rowater.ro/download/directiva-2007-60-ce-privind-evaluarea-si-gestionarea-riscului-la-inundatii/?wpdmdl=19319&refresh=67e67b9453dd41743158164, 2007.

Currently in the 3rd Cycle of Flood Directive respectively, flood events that occurred in 2017 – 2022 period are analyzed, and the result may lead to the identification of new APSFRs'.

Climate change may influence future floods because of changes in the maximum flow regime at the river basin level. The results of studies and research in Romania indicate that in the upper part of the river basins (generally at altitudes above 400 m) an increase in maximum flows is observed.

The major climate related risks that local communities in Putna river basin are facing, are flooding and heavy rainfall as a major risk factor for flash floods. Intense rainfall events that occur in the region lead to flash floods and river flooding, particularly in small mountain basins, areas with poor drainage infrastructure or in low-lying areas. Flooding and flash floods damage property, infrastructure, and agriculture, disrupt transportation networks and threaten lives. Based on the results of the climate risk assessment using CLIMAAX framework and toolbox, we aim to improve and complete the previous floods hazard and risk assessments, conducted within the implementation of Cycles I and II of FD (Floods Directive 2007/60/EC).

Romania has recently adopted a series of integrated national strategies and plans that substantiates the strategic framework for sustainable development and hazard and risk management (including flood risk): The National Strategy for Sustainable Development – 2030 aims, through its main objective to strengthen Romania's adaptive capacity and resilience to combat the dangers related to climate change and natural disasters by integrating mitigation and adaptation measures to climate change and natural disasters in both national strategies and policies and in planning and increasing education and awareness on climate change (Department for Sustainable Development: The National *Strategy for Sustainable Development of Romania 2030*. Romanian Government. Available at: https://dezvoltaredurabila.gov.ro/strategia-nationala-pentru-dezvoltarea-durabila-a-romaniei-2030-i, 2020.

The National Strategy on Adaptation to Climate Change 2024-2030, with a perspective to 2050, aims to strengthen Romania's resilience and capacity to adapt to risks associated with climate change and natural disasters, increasing the capacity to react rapidly to unexpected extreme weather events, improving education, awareness, and human and institutional capacity to mitigate, adapt and reduce the impact of climate change, as well as implementing early warning systems (Ministry of the Environment, Waters and Forests: The National *Strategy on Adaptation to Climate Change 2024-2030, with a perspective to 2050*. Romanian Government. Available at: https://mmediu.ro/app/webroot/uploads/files/Monitorul%20Oficial%20Partea%20I%20nr.%20823Bis.pdf, 2024.

In the National Recovery and Resilience Plan of Romania the issue of flooding is addressed in one of the pillars, where certain current problems are identified and the allocated amounts and approaches to various reforms and investments are presented (Ministry of Investments and European Projects: The National *Recovery and Resilience Plan of Romania*. Romanian Government. Available at: https://mfe.gov.ro/pnrr/, 2021.

The National Disaster Risk Management Plan (2020) promotes, among other things, the identification and development of disaster resilience measures that address natural, climate change or man-made risks. Floods constitute a major risk factor, with various mechanisms presented, as well as case studies highlighting the impact of climate change on floods and dam failure scenarios. Flood prevention, preparation and response measures are presented, along with the priorities established for the 2020 - 2027-time horizon (National Committee for Emergency Situations: The

National *Disaster Risk Management Plan*. General Inspectorate for Emergency Situations. Available at: https://igsu.ro/resources/d4084202-7e35-4edc-9172-216581ac8029.pdf, 2020.

Flood Risk Management National Strategy for medium and long term 2025 – 2035 aims to ensure the general framework for reducing flood risk for the population, economy, environment and cultural heritage, while contributing to the improvement/maintenance of the state of water bodies and biodiversity, through the synergy of prevention, protection, preparation, emergency management and post-event measures (reconstruction/recovery) (Ministry of the Environment, Waters and Forests: The Flood *Risk Management National Strategy for medium and long term 2025 – 2035*. Romanian Government. Available at: https://www.mmediu.ro/app/webroot/uploads/files/20230410_SNMRI_Draft%201_SEA%281%29%281%29.pdf, 2023.

The economy of the Putna Basin region is characterized by the variety of existing local resources that can be drawn into economic activities and the tradition of their processing. The main relevant sectors that could be affected by climate change are agriculture (in particular viticulture and forestry), tourism and transportation, food industry, residential construction.

An important contribution to supporting adaptation to the impacts of climate change is the development and improvement of the national hydrological forecasting systems, quantitative and qualitative monitoring systems and early warning systems.

Some possible adaptation interventions to meet the objectives for handling climate hazards, impacts and risk would be:

- Modernizing existing infrastructure to reduce flood risk.
- Promoting and implementing nature-based solutions and natural water retention measures (large-scale afforestation of torrential watersheds, ensuring space for watercourse mobility, watercourse restoration works, strengthening natural water retention areas, relocating some dam works at the watershed level).
- Reducing the risks generated by urban floods through urban spatial planning appropriate to the implementation of measures for the collection and temporary/permanent storage of rainwater.

2.1.3 Participation and risk ownership

The involvement of stakeholders is an essential component in the development of the local adaptation strategy and the improvement of the flood risk management plan at the level of the Putna river basin. This process will include 3 stages, starting with phase 2: information, involvement, and consultation of stakeholders. The relevant representatives of known vulnerable groups and exposed areas are the main stakeholders that will be involved starting with phase 2 of the project, according to the working plan.

The European Directive 2007/60/EC on the assessment and management of flood risks is transposed into Romanian legislation through the National Strategy for the Management of Flood Risk in the Medium and Long Term (N.S.M.F.R.) for the period 2025 – 2035 and approved by GD no. 1566/04.12.2025 and Water Law 107/1996 with subsequent amendments and additions. The implementation of this directive is carried out through the Flood Risk Management Plans developed at the level of the Water Basin Administration and the Danube River on the Romanian sector, approved by GD 886/2023. The main objective of these plans is to reduce the negative consequences of flooding for human health, economic activity, the environment, and cultural heritage through the proposed flood risk reduction measures.

In the Action Plan associated with the N.S.M.F.R. strategy, the action of approving spatial planning/land use norms and rules in flood zones and regulations regarding the construction regime in flood zones (exposed to flood risk) is foreseen. In the Methodological Norms regarding the

preparation method and content of flood hazard maps and flood risk maps, the flood risk map is a component part of the county territory planning documentation and is introduced in the general, zonal, and local town planning plans of the localities of each county. At the national level, through the Natural Disaster Insurance damage to homes as a result of natural disasters (floods, earthquakes and landslides) is covered, as a direct or indirect effect of them.
To ensure an adequate level of protection and flood resilience of the population, economic activity, the environment, and cultural heritage, through N.S.M.F.R. strategy standard protection values are proposed, expressed by probabilities of exceeding maximum flows, associated with different types of urban/rural developments, of which the Putna basin falls into the category of cities/municipalities with less than 50,000 inhabitants and of communes/villages, for which the annual probability of exceeding the protection standard is 1%. Another category within the study area is of agricultural area with high economic value where the annual probability of exceeding the protection standard is considered 10%. To reach the protection standard (target standard), individual measures or a package of combined measures (projects) are implemented to reduce the flood risk.
The main stakeholders and beneficiaries of the proposed study are the following: Ministry of Environment, Water and Forests, National Administration "Romanian Waters", Siret Water Basin Administration, local and regional authorities (mayors, County Councils), Civil Protection Authorities, community groups, agriculture/farmers, fisheries and aquaculture, NGOs, and nature protection.
Representatives of the main stakeholders and beneficiaries of the project will be invited to the 3 foreseen workshops in the study area (1 preparation meeting with stakeholders in the study area in September 2025, 2 stakeholder's consultation and project results dissemination workshops, in May and June 2026). During these workshops, they will be informed about the project and its implementation stage, directly involved in finalizing the new proposals for the program of measures which will include prevention, protection, and preparedness measures for existing and future floods, considering the effects of climate change. The results will be communicated with dissemination posts in social media (3 posts on the FB page of NIHWM and by preparing 2 notes for decision-makers) and awareness-raising brochure (will be distributed electronically and on paper) targeting the local communities will contribute to maximize the impact of the project results.

2.2 Risk Exploration

2.2.1 Screen risks (selection of main hazards)

The major climate-related hazards that local communities in Putna river basin are facing are flooding and heavy rainfall as a major risk factor for flash floods. These hazards were selected for analysis within the scope of the project. The risks derived from the selected hazards are loss of life, damage to properties, disruption of livelihoods and essential services.
During 2005, 2016, 2018 and 2021 significant extreme precipitation and floods events in Putna river basin caused major damage and even loss of life. In 2005, local communities in Putna river basin experienced the largest flood ever recorded, with a peak flow value of 1,500 m^3/s, being considered the first in the chronological series of maximum flows with a exceedance probability of 2.5% (calculated for the period 1951-2022).
The annual damage reports issued for Vrancea County territory, of which Putna river basin covers more than half, reveal values of damages caused by floods of more than 10 million euro, for the years with significant extreme precipitation and flooding events Figure 2-1.

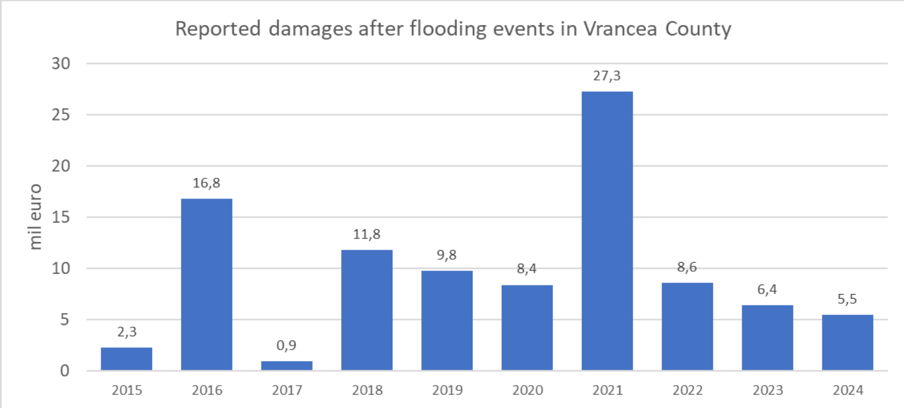

Figure 2-1 Annual reported damages after flooding events in Vrancea County

According to the damage reports for Vrancea County, the most significant impact as values of damages was on key sectors like the transport infrastructure (national and county roads, bridges), hydro-technical works for bank consolidation, water supply and sewerage networks and other damages (banks erosion and damage to supporting structures, households and annexes, treatment plants, economic units, agricultural land), Figure 2-2. Given the characteristics of the relief and location of human settlements in Putna river basin, the high impact of flooding and extreme precipitation on a major part of the traffic routes is of major importance for the local communities because the damage of roads leads to their isolation, having limited ability to recover by themselves. Along with flooded households, damages to water supply and sewerage networks and treatment plants have also a major impact on the local community living, Figure 1-1 (Zenodo Reported damages).

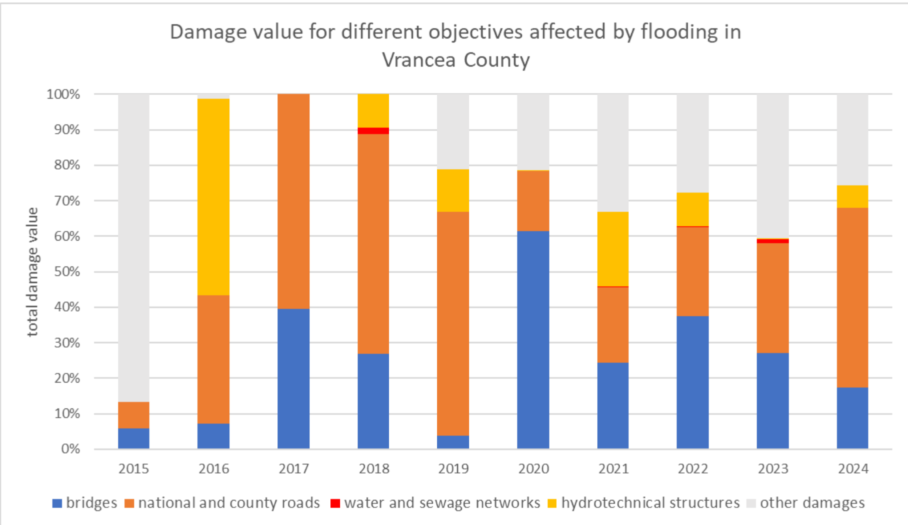

Figure 2-2 Percentage of affected objectives according to the amount of damage

The main hazards expected in Putna river basin are river flooding and heavy rainfall as a major risk factor for flash floods. According to the main climate-related hazards that Putna river basin communities are facing, our CRA will cover river flooding hazard and heavy rainfall (extreme precipitation) hazard. In the process of implementing Directive 2007/60/EC on flood risk assessment and management, the second stage was represented by the elaboration of flood hazard maps and flood risk maps. Flood hazard and risk maps have been drawn up for areas designated as having a potentially significant flood risk under the first phase of implementation of Directive 2007/60/EC – preliminary flood risk assessment due to reporting to the European Commission.

Flood hazard maps show the extension of the flooded area and water depth specific to flows with different probabilities of exceedance.
The flood risk map is the documentation indicating for floodplains, in various scenarios (at various probabilities of exceeding the maximum flow), the potential material and human damage, in accordance with the requirements of Directive 2007/60/EC, with reference to approximate number of potential inhabitants affected; vulnerable economic activities in the potentially affected area (including infrastructure); important sources of pollution, identified potentially affected protected areas, cultural objectives. The flood risk maps published at national level are made for each probability of exceeding the maximum flow of: 0.1% (low probability of exceeding), 1% (average probability of exceeding) and 10% (high probability of exceedance), according to the legislation. These maps were realized only for certain areas/sectors (APSFR - areas with potentially significant flood risk, within the meaning of Directive 2007/60/EC), and failure to cover an area does not lead to the conclusion that that area cannot be exposed to flood risk.
Since the area corresponding to the confluence of the Putna and Siret rivers, where the flood hazard values are high due to the backwater effect has been analyzed in detail in the 1st and 2nd cycle of the FD implementation, the CRA analysis will focus on the areas in the rest of the basin.
Considering that in Romania climate change impact was considered only for 1% probability floods (medium probability), taking into account only the A1B climate change scenarios, and the future period until 2050, a further analysis of the impact of climate change on flooding and heavy rainfall risk is needed. Also, in order to identify new areas with high risk values, a local detailed CRA is needed for Putna river basin.

2.2.2 Workflow selection

Considering that river flooding and heavy rainfall hazards were selected for analysis within the project, the risk workflows relevant to the CRA are River Flooding, Flood damage and population exposure and Extreme precipitation. Although in the initial work plan only the two main selected workflows are mentioned (River flood and Extreme precipitation) it was considered useful to include the Building and population exposure workflow that is related to the river floods workflow, being based on the same hazard.

2.2.2.1 River flooding #1

The main potentially vulnerable groups and exposed areas to river flooding risk are local communities that live in small mountain basins, areas with poor drainage infrastructure or in low-lying areas. Transport infrastructure between the localities, agricultural land and riverbed and bank consolidation hydrotechnical works are some of the most exposed objectives to the impact of river flooding.

2.2.2.2 Flood building damages and population exposed #2

In the case of flood building damage and population exposed workflow, the main potentially vulnerable groups and exposed areas are the majority of the areas occupied by municipalities in the middle and lower Putna basin and the communities within them. In the case of areas with tourist development in mountain and sub-mountainous areas, especially in resorts located at confluences, the risk values increase during the tourist season with the increase in population density.

2.2.2.3 Extreme precipitation #3

Extreme precipitation workflow - the main potentially vulnerable groups and exposed areas are represented by the different local communities, from the villages and cities areas, as well as all the transport infrastructure.

2.2.3 Choose Scenario

In the National Strategy for Adaptation to Climate Change, for future time horizons, regional climate model results are used, under scenarios with moderate and strong increases in global atmospheric greenhouse gas (GHG) emissions and concentrations until the end of this century. The global and regional climate models used succeed in simulating the general climate characteristics present in Romania, which provides an acceptable level of confidence for the results of future climate projections (Bojariu, R. et al.: Schimbările climatice – *de la bazele fizice la impact și adaptare*. Printech. Available at: https://www.meteoromania.ro/anm/images/clima/schimbari-climatice2021.pdf, 2021.

All three scenarios (short-term, medium-term and long-term) are considered relevant for the study area.

2.3 Risk Analysis

2.3.1 Workflow #1 River Floods

Table 2-1 Data overview workflow #1

Hazard data	*Vulnerability data*	*Exposure data*	*Risk output*
River flood hazard maps for Europe and the Mediterranean Basin region – Copernicus(depths over return periods 10, 100 and 500)	LUISA depth-damage curves for land use - JRC	Europe LUISA Land Cover basemap 2018 100m resolution JRC	River flood hazard maps for 10, 100, 500 years RP for preset day scenario Flood damage maps, expressed in economic value, for extreme events with different return periods based on available flood maps for the historical climate
Aqueduct Floods Hazard Maps (for RCP4.5, RCP8.5, 2030, 2050, 2080) – Aqueduct Floods data portal	…		Comparison plot of flood depth maps between the future and historical climates under two climate scenarios (RCP4.5 and RCP8.5) for the selected return periods

2.3.1.1 Hazard assessment

The Hazard assessment for river flooding was followed in order to map river flood hazard for Putna river basin for present day and future climate scenarios, using the default available European datasets. After defining the coordinates of Putna river basin, the "River flood hazard maps for Europe and the Mediterranean Basin region" dataset was downloaded. This dataset is created by the Joint Research Centre - Copernicus Emergency Management Service based on hydrodynamic simulations forced with past hydrological events, and available via Joint Research Centre at a 3 arc-seconds grid spacing for different return periods. According to the national methodology adopted for the implementation of the Floods Directive 2007/60/CE, which requires flood hazard mapping for 3 annual probabilities of exceedance (low, medium and high) the following probabilities of exceedance have been selected for the CRA in Putna river basin: 0.2% (500-years RP for low annual probability of exceedance); 1% (100-years RP for medium probability of exceedance) and 10% (10-years RP for high exceedance probability). Based on JRC dataset the flood hazard map for present day scenario was obtained for the return periods of interest. In order to compare the flood maps for different return periods a dataset for the combined flood maps is created (Zenodo W1H1).

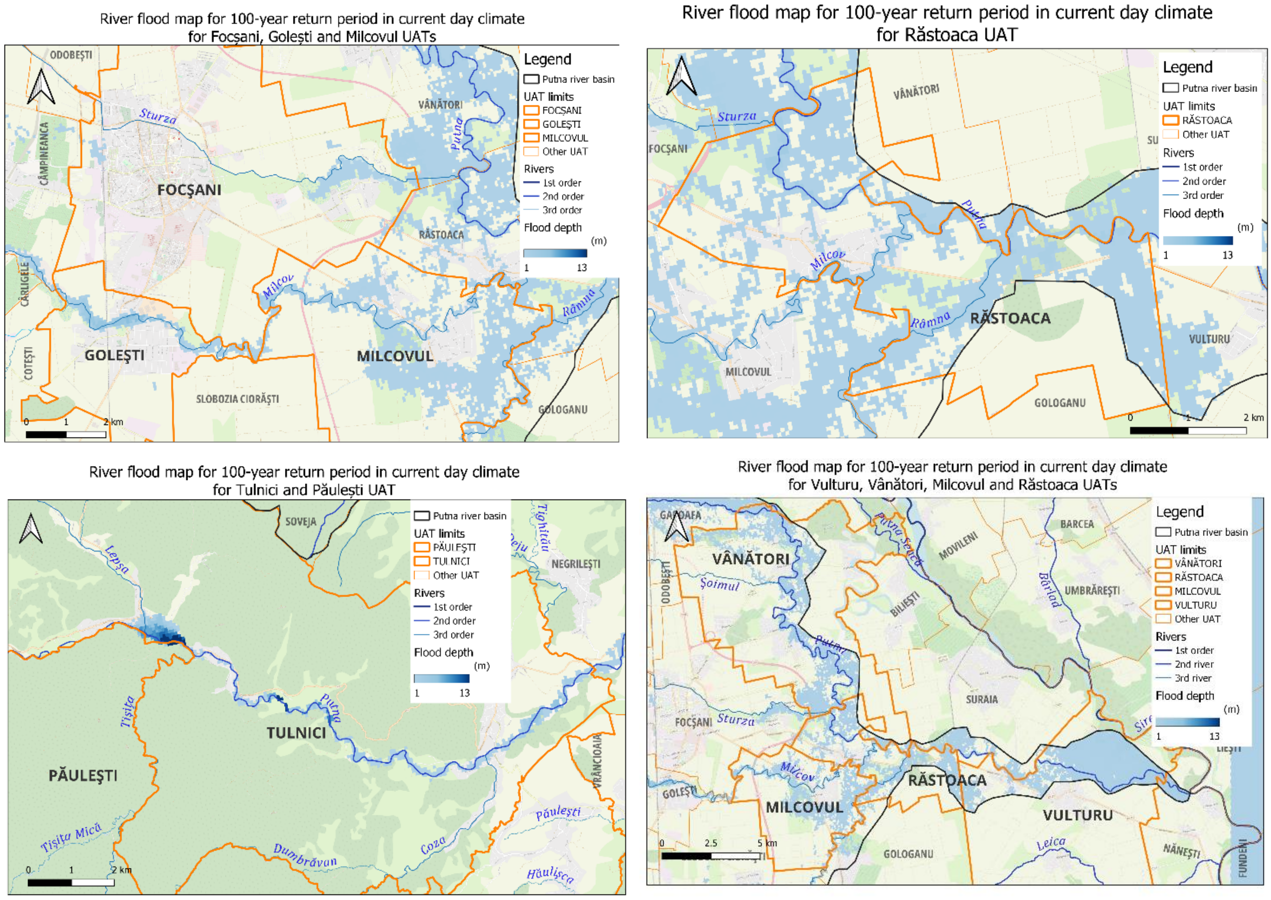

Figure 2-3 River flood hazard maps for relevant TAUs for 100-years RP flooding event

Due to the size of Putna river basin and the resolution of the resulted plots, the overall hazard maps are not very suggestive, therefore relevant details have been included following a GIS analysis on the TAUs (Territorial Administrative Units) with high values and extension of flood hazard with 100-years RP, Figure 2-3. For the other return periods analyzed, relevant outputs were loaded into Zenodo (W1H2).

For estimating the effect of climate scenarios on the river flood hazard in Putna river basin, the Aqueduct Floods river flood maps for both available scenarios (RCP4.5, RCP8.5 for years 2030, 2050, 2080) and for the selected return periods were downloaded from the Aqueduct Floods data portal and processed for Putna river basin. This dataset includes coarse resolution flood maps under the baseline climate (1980) and in future climates with global coverage and spatial resolution of 30 arc-seconds. To observe the effect of climate change on the projected river flood depths corresponding to the event with a given RP, the flood maps for different years (2030, 2050, 2080) were ploted next to each other, for both climate scenarios and against the baseline situation (1980) with the same return period (Zenodo W1H3).

Due to the characteristics and resolution of the Aqueduct dataset, the analysis captures some hazard areas only in the middle and lower Putna basin.

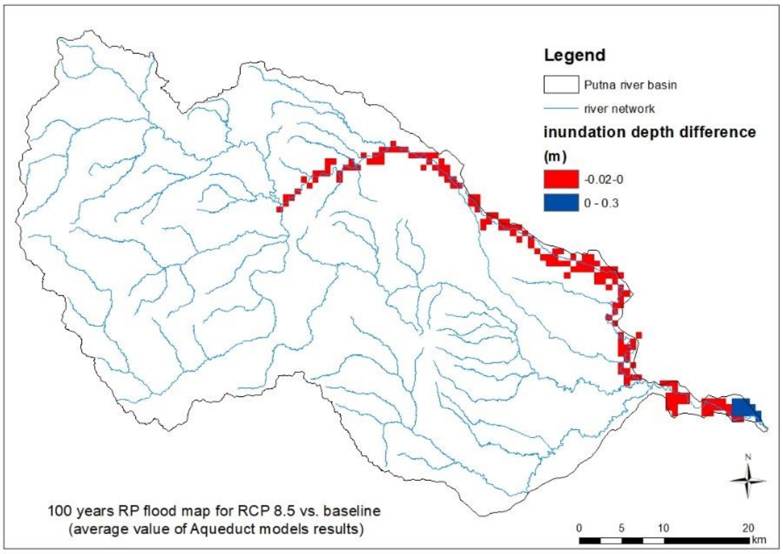

Figure 2-4 Inundation depth difference of 100 years RP flood map for RCP 8.5 scenario, 2080 from the baseline scenario 1980 (average value of Aqueduct models results)

The default analysis included in the workflow is based on an averaging of the results of the different models in Aqueduct dataset, that indicates for the RCP 8.5 scenario, for the flood event with 100-years RP, a slight decreasing trend in flood depth for most of the analyzed sector, Figure 2-4. (Zenodo W1H3). Considering that the Aqueduct flood maps carry a high degree of uncertainty and are treated as a first indication of the climate change impact on the river flood hazard, the worst case scenario has been selected for analysis, that indicates the increasing trend in water depth for RCP 8.5, year 2080 and a 1000 years RP Figure 2-5. To obtain the map corresponding to this scenario, the notebook code has been modified to take into account the maximum value of the results of the Aqueduct models.

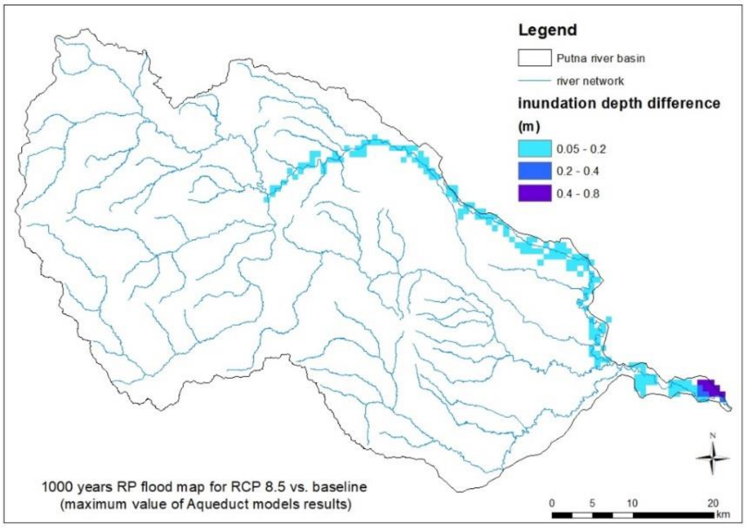

Figure 2-5 Inundation depth difference of worst case scenario (1000 years RP flood map for RCP 8.5 scenario, 2080, maximum value of Aqueduct models results)

2.3.1.2 Risk assessment

Following the river flood risk workflow for Putna river basin, the risk was assessed by combining maps of potential river flood extent with exposure and vulnerability data in the form of economic damage functions. The economic damage is mapped based on the flood depth maps linked with land use maps, damage curves, and country-specific economic parameters that approximate the economic value of different land use types (calculated based on Romania’s GDP).

River flood hazard maps for Putna river basin obtained in the hazard workflow were loaded to be used for the risk assessment.

The land use dataset used in this workflow as exposure data is Luisa land cover, at 100 sqm resolution, available at European level for 2018. This dataset was downloaded from the JRC portal and clipped to Putna river basin. Luisa damage curves were loaded and used to determine, for given land-use categories in the study area, what fraction (‘damage factor’) of the economic value is at risk given a particular flood depth.

To assess the potential total damage under a given scenario For Putna river basin, monetary value was assigned per land use category, expressed as the potential loss in €/m², scaled based on Romania’s GDP (Zenodo W1R1).

The outputs of the workflow were flood damage maps for Putna river basin in current day climate, in terms of economic damage, for extreme events with 10, 100 and 500 years RP (Zenodo W1R2) and aggregated data on damage within each land use category (Zenodo W1R1).

Maps of flood and associated damages, along with land use categories, for extreme flood scenarios of 100-year RP in current climate were also created (Zenodo W1R2).

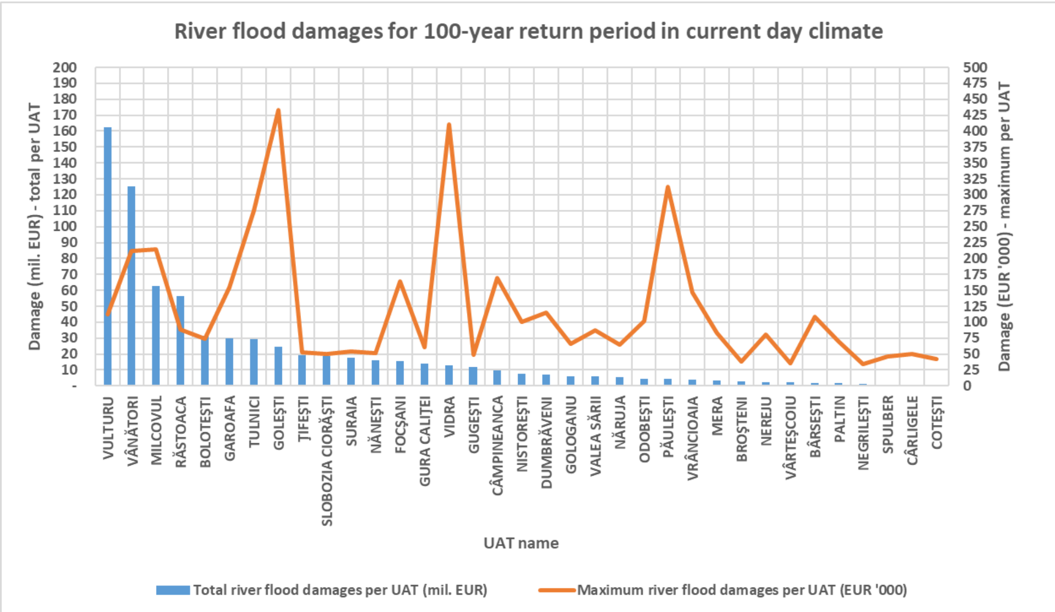

Figure 2-6 River flood damages for the main TAUs for 100 year RP

The resulting data and maps were usefull for identifying and assessing potential hotspots of economic damage due to river flooding for the RP of interest. A GIS analysis was conducted for identifying the main UATs (territorial administrative units) affected by damages of river flooding for the selected RP (Figure 2-6). Maps for this areas for flooding events with 100-years RP are presented in Figure 2-7 (Zenodo W1R2).

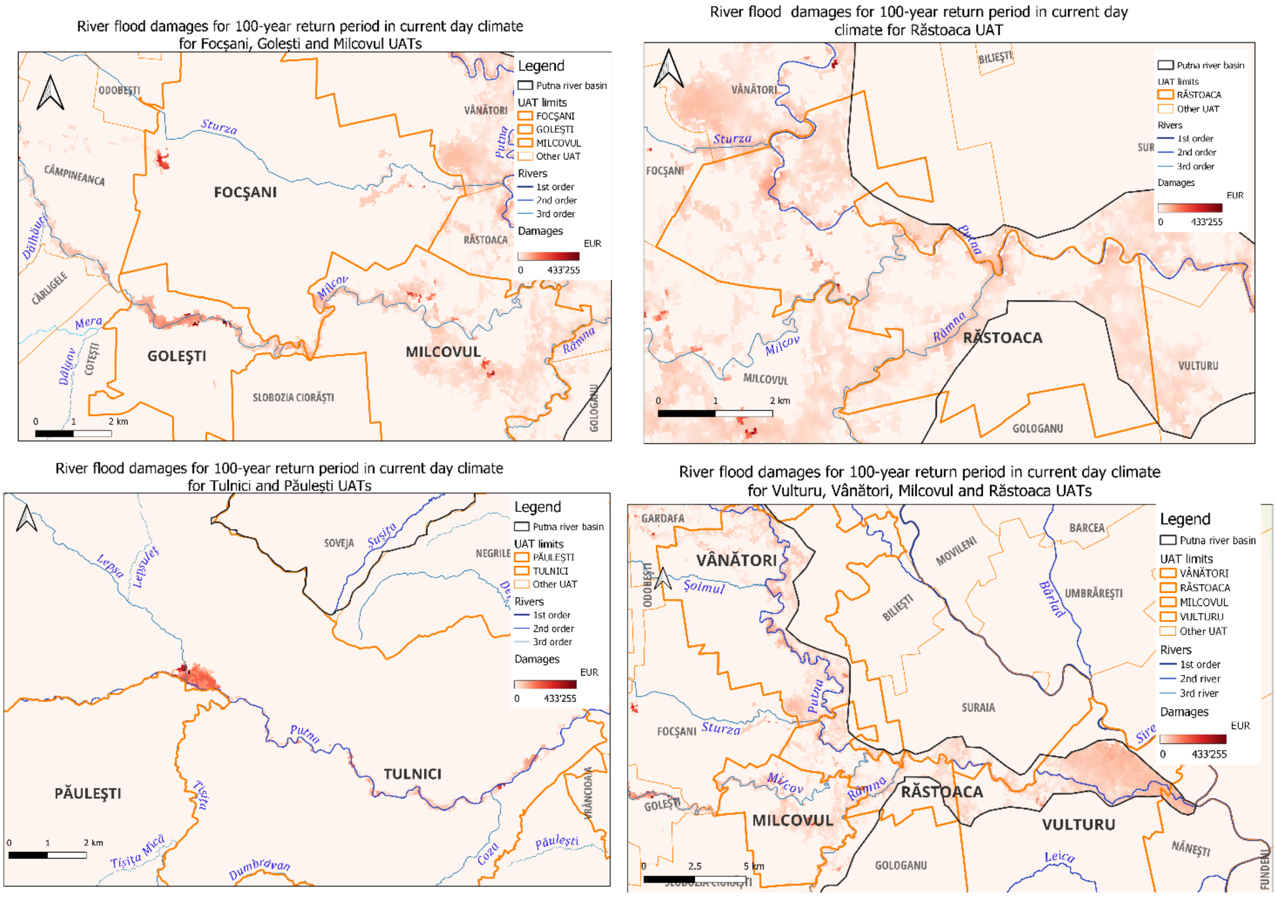

Figure 2-7 River flood damages maps for the main TAUs for 100 year RP

2.3.2 Workflow #2 Flood damage and population exposure

Table 2-2 Data overview workflow #2

Hazard data	*Vulnerability data*	*Exposure data*	*Risk output*
River flood hazard maps for Europe and the Mediterranean Basin region – Copernicus (depths over return periods 10, 100 and 500)	Inundation depth thresholds for population displacement	GHS-POP R2023A - GHS population grid multitemporal (1975-2030) Population density estimated for 2025- European Commission's Joint research Centre	Maps of exposed population Estimated annual exposed population graph Maps of displaced population Estimated annual displaced population graph
River flood hazard maps for Europe and the Mediterranean Basin region – Copernicus (depths over return periods 10, 100 and 500)	Damage curves for buildings-European Commission's Joint research Centre	Building data - OpenStreetMap	Building damage maps Estimated annual building damage graph

2.3.2.1 Hazard assessment

The Flood damage and population exposure workflow was applied for Putna river basin to analyse and identify areas with high density of exposed and displaced population and high estimated building damages. The river floods hazard for Putna river basin was obtained similarly to the river flood workflow, by retrieving the "River flood hazard maps for Europe and the Mediterranean Basin region" dataset after defining the geographical bounds of the area of interest.

2.3.2.2 Risk assessment

The workflow for Risk assessment Flood Building Population was applied, at first for the entire Putna river basin. After a detailed analysis on the exposure data available in the workflow (building footprint from OpenStreetMap), it was found that only some of the localities within Putna river basin are covered by these exposure datasets. Due to this limitation in data sets it was decided to run this workflow for a relevant sector of Putna river, well covered by the exposure datasets and known as a flooding affected area by the most significant events. The sector of Putna river selected to run the workflow corresponds to Lepşa locality, situated in Vrancei Mountains, at the confluence of Putna river with Lepsa river, within a low-lying area (Lepsa depression basin), formed as a result of lateral erosion by the hydrographic network (Chiriac, S., Ivanof, N. and Dimulescu, R.: 'LIFE Nature LIFE02/NAT/RO/8576'. Available at: https://www.life8576.carnivoremari.ro/db83.html, 2004.

The analysis of fluvial flood risk and impact on buildings and population followed the Flood Building Population workflow that assesses the economic damage to buildings, using damage curves, EU level economic parameters and building geometry/type and the exposed and displaced population, using a population distribution map. After defining the geographical bounds of Lepsa area and the return periods of interest (10, 100, 500), river flood extent and water depth rasters for hazard were downloaded from the Copernicus Land Monitoring Service (Zenodo W2R1).

The river flood map with 100-year RP indicates that during a flood with a 1% probability of occurrence, the entire territory of Lepsa is strongly affected by flood depths up to 10 m (**Error! Reference source not found.**).

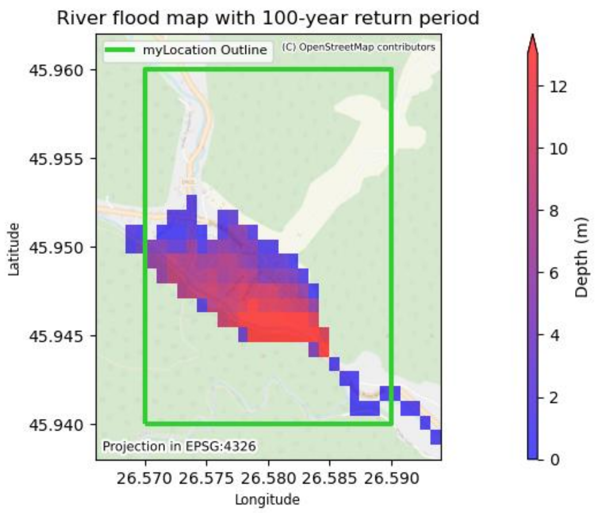

Figure 2-8 River flood hazard map with 100-year RP for Lepsa area

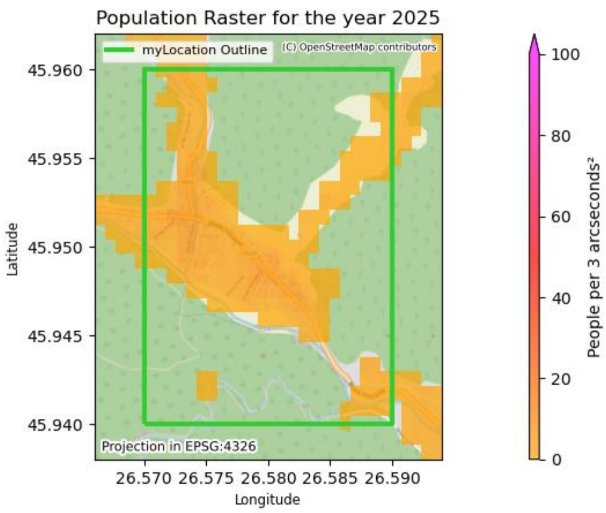

Figure 2-9 Population density map for Lepsa area

Data for estimated population density of Lepsa area was downloaded from the European Commission's Joint Research Centre, for year 2025 at 3 arc seconds resolution (GHS-POP R2023A - GHS population grid multitemporal 1975-2030), expressed as the number of people per cell (**Error! Reference source not found.**). Although it is a relatively small locality, the economic importance of Lepsa is given by the existence of a popular mountain tourist resort, which makes the number of the local population increase from 600 permanent inhabitants of the community to over 2000 during the tourist season.

Building data for Lepsa area was downloaded from OpenStreetMap, in terms of building locations/ geometry. Since building types are not available for this area in the dataset, all buidings have been considered to belong to the Universal class (Figure 2-12).

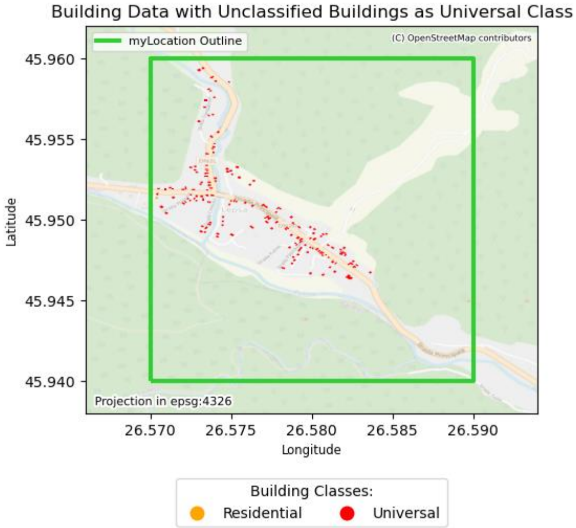

Figure 2-10 Building locations map for Lepsa area

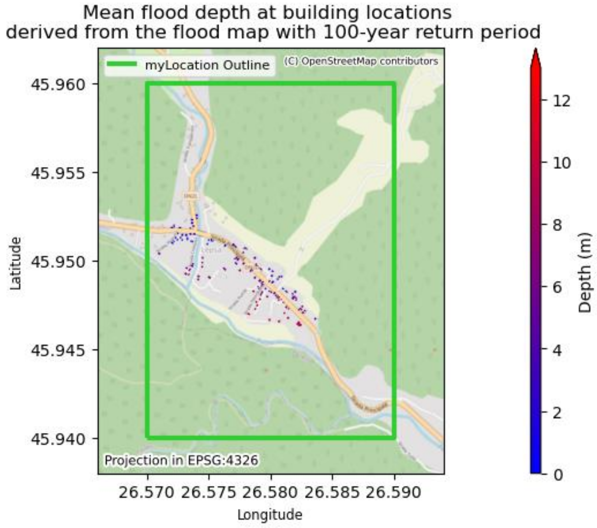

Figure 2-11 Mean flood depth at building locations map for Lepsa area for the event with 100-years RP

The next step in the workflow was obtaining the flood depths at building locations maps (Zenodo W2R2) derived from the flood depth maps for 10, 100 and 500 return periods and building location map. The map of mean flood depth at building locations for the flooding event with 1% probability of occurrence shows high values of flood depth for almost all the building locations in Lepsa. (**Error! Reference source not found.**). Based on the flood depth at the building locations, the economic damage to the buildings, as reconstruction costs are calculated in the next step of the workflow, applying the JRC damage function for Universal buildings (as an average curve of Residential, Commercial and Industrial ones), multiplied with the maximum damage value per square meter and the building footprint area in meters. Building damage maps and plots were computed for the selected return periods and the total building damage for Lepsa area was calculated (Zenodo W2R2).

The total estimated damage to buildings as reconstruction costs for Lepsa community (Figure 2-12) ranges from 7.2 mil euro in case of occurrence of a flooding event with 10-year RP to 15.5 mil euro for the ocurrence of the flood with 500-year RP (Zenodo W2R2).

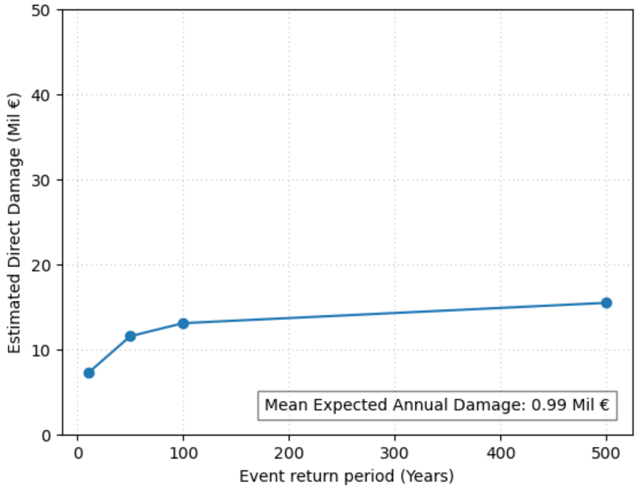

Figure 2-12 Estimated damage to buildings for Lepsa area on mean flood depth for different RP

These damages have a significant value considering that the local communities in Putna RB are considered to have limited resources to increase climate or disaster resilience because they do not have sufficient resources to implement emergency response and recovery measures.
Following the workflow steps, the dataset for population density in Lepsa area was loaded and intersected with the flood depths raster in order to obtain the map of exposed population (**Error! Reference source not found.**), (Zenodo W2R3) for the return periods of interest. The exposed population in Lepsa area is then plotted against the flood map return periods (**Error! Reference source not found.**) and expected annual exposed population is also calculated, representing the expected number of people exposed on average in any given year.

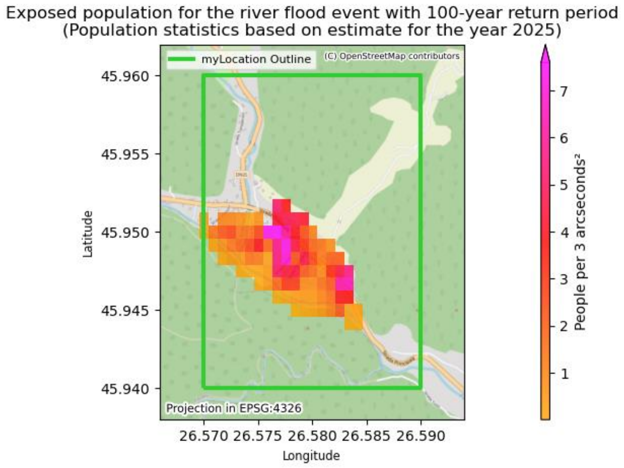

Figure 2-13 Map of exposed population in Lepsa area for the flood event with 100-years RP

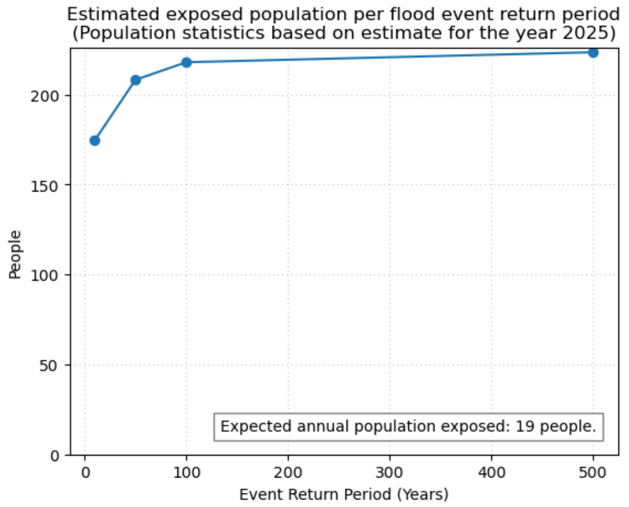

Figure 2-14 Estimated exposed population in Lepsa area for different RP of flooding event

Based on the flood depth and population density maps, the displaced population map is calculated, applying a given threshold of flood depth. The threshold for displaced population was set to >0.5m water depth (Zenodo W2R3). The plots of the exposed and displaced population on the selected return periods indicates similar values, ranging from 175 people for the flood with 10-years RP to 500 people for the one with 500 RP. The resulted maps and plots reflect the differences in building damage and exposure/population displacement depending on flood return period.
This workflow was applied also for another relevant sector of Putna river, located on the lower basin, at the confluence of Milcov and Putna rivers. Three river flood prone localities, Rastoaca, Milcovul and Lamotesti, where significant damages were reported after the main flood events in 2005 and 2021, were analysed based on this workflow to obtain maps and plots of exposed/displaced population. The building damage analysis was considered irelevant using the default available datasets in the notebook, due to the lack of information in OpenStreetMap for this area. The results are available in (Zenodo W2R4).

2.3.3 Workflow #3 Extreme precipitation

Table 2-3 Data overview workflow #3

Hazard data	*Vulnerability data*	*Exposure data*	*Risk output*
Annual maximum precipitation	Critical impact-based rainfall thresholds For 3h: 30, 50, 80 mm For 24h: 50, 80, 120 mm	Threshold Return Period map	Return period shift maps
Idf (Intensity Duration Frequency) maps			Precipitation shift maps

Hazard data	Vulnerability data	Exposure data	Risk output
Change over time Idf maps			Precipitation factor threshold maps

Flash floods due to extreme precipitation could be considered as the main hazard risk in the Putna River basin, and due to climate change impact we could expect that such events will become more frequent and more severe.
After analysing the extreme precipitation workflow, we choose to use it for a regional assessment, for the entire Putna River Basin, considering that this extended scope will provide insights into the overall impact of extreme precipitation across this basin.
EURO-CORDEX climate projections for precipitation flux at a 12km spatial resolution have been utilised for assessing future climate hazards, considering the timeframe from 1976-2005 as reference historical period, while the periods from 2011-2040, 2041-2070, 2071-2100 were used for climate projections.
As input climate data for this workflow we used the ready-to-go datasets for the European region, for different Global/Regional chains, that were prepared and made available by CRAHI-UPC.
To facilitate an ensemble analysis, of all the different combination of climate model chain, climate projections and future periods, and durations (Table 2-4), the workflow scripts were adapted to automaticaly iterate between the available options, by implementing processing loops, and they were run locally.

Table 2-4 Types of input data used in workflow #3

Attribute	Non-bias corrected datasets
Global and Regional Climate Model Chains	ichec-ec-earth/knmi-racmo22e mohc-hadgem2-es/knmi-racmo22e mpi-m-mpi-esm-lr/smhi-rca4
Representative Concentration Pathway (RCP)	RCP 4.5 RCP 8.5
Historical Time-frames	1976-2005
Future Time-frames	2011-2040 2041-2070 2071-2100
Durations	3h 24h

2.3.3.1 Hazard assessment

From the full spectrum workflow results, we concentrated on the non-bias corrected simulations, which provide simulations also for 3 h duration events, as our focus is represented by flash flood events, which in Putna River Basin are generated mainly by very intense and short duration torrential precipitation events.
One of the objective of results analysis was to identify from all the ensemble member, the most extreme change, for the 3h precipitation event with 100 year return period, for each of the future projection period (Figure 2-15, Figure 2-16, Figure 2-17), (Zenodo W3H1).
From this representative results for potential future changes of the extreme precipitation regime we could highlight the following preliminary conclusions:

- The biggest change for different future period is not indicated by the same model chain and RCP climate projections:
    - For the 2011 – 2040 future period, the most significant change is estimated using ichec-ec-earth_knmi-racmo22e model chain under RCP4.5.

- For the 2041 – 2070, and 2071-2100 future periods, the most significant change is estimated using using mohc-hadgem2-es_knmi-racmo22e model chain model chain under RCP8.5.

- The relative change in magnitude of these extreme precipitation events, is variable within the Putna River Basin, with the most important increase for the 2071-2100 future period.
- For all the future periods, we could expect in general an increase of these extreme precipitation events (3h and 100 year retur period), with the exception of 2041-2070 period, when for some part of the Putna basin we could expect a decrease, comparing with the reference historical period (1976-2005).

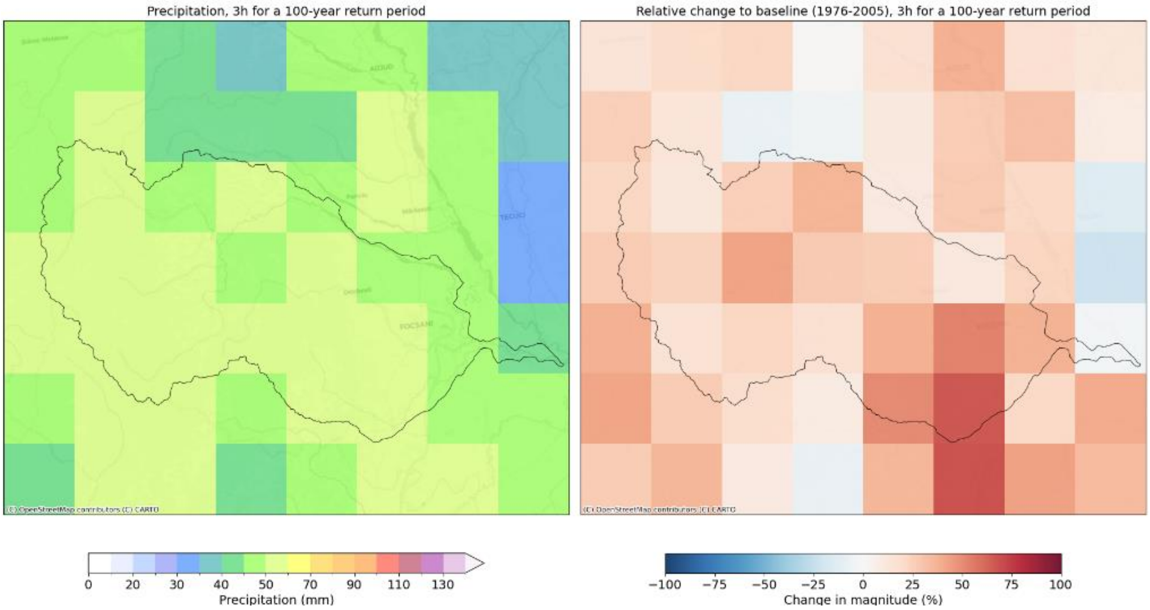

Figure 2-15 Extreme precipitation (3h – 100 year RP) for 2011-2040 under RCP4.5, estimated using ichec-ec-earth_knmi-racmo22e model chain

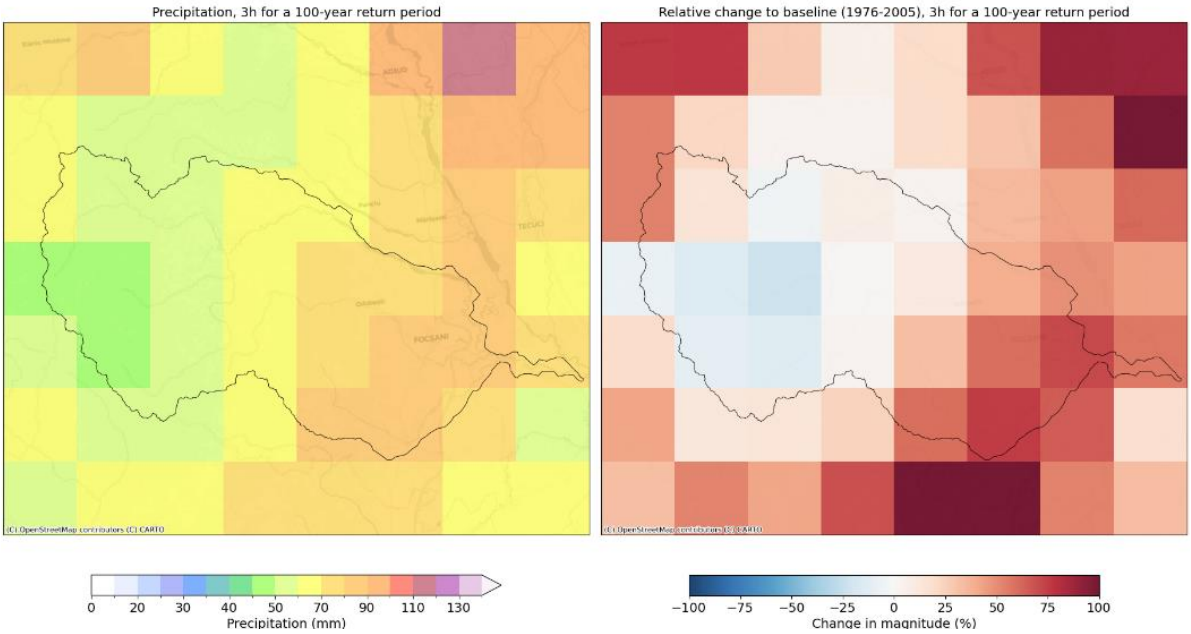

Figure 2-16 Extreme precipitation (3h – 100 year RP) for 2041-2070 under RCP8.5, estimated using mohc-hadgem2-es_knmi-racmo22e model chain

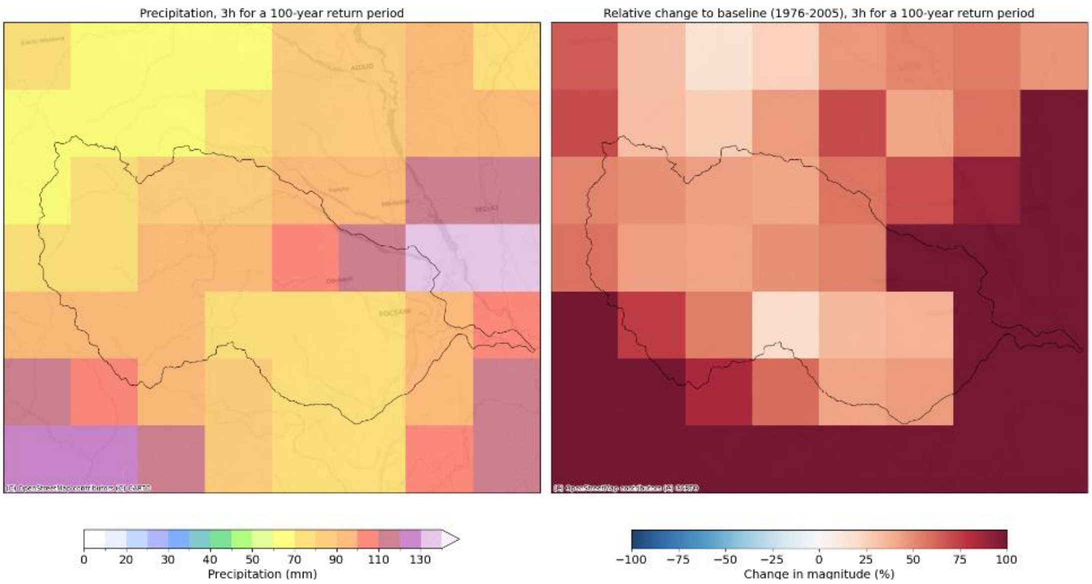

Figure 2-17 Extreme precipitation (3h – 100 year RP) for 2071-2100 under RCP8.5, estimated using mohc-hadgem2-es_knmi-racmo22e model chain

2.3.3.2 Risk assessment

Impact rainfall thresholds are defined as the precipitation required within a specific timeframe to trigger various impacts, such as flash flooding or urban flooding in vulnerable areas or sites (e.g., low-lying), serving as key indicators, linking local potential risk and its consequences to specific rainfall intensity values.

National Institute of Hydrology and Water Management (NIHWM) is in charge with the elaboration and dissemination of the official hydrological warnings (floods and flash floods) in Romania.

Based on our experience from the ellaboration in real-time of flash floods warnings, we defined the following rainfall thresholds:

- For 3 h rainfall events: 30 mm (Low impact); 50 mm (Medium impact); 80 mm (High impact);
- For 24 h rainfall events: 50 mm (Low impact); 80 mm (Medium impact); 120 mm (High impact);

For the next preparatory step, generation of the return period rasters corresponding to these rainfall thresholds, we use the existing regionalization of IDF curve, and the resulting Threshold Return Period maps were used as input in the extreme precipitation risk workflow, (Zenodo W3R3).

As in the case of hazard analysis, we adapted the scripts in order to produce more easy the graphical results for all the combination (model chain, climate projection, future period).

During the results analysis phase, we focus on the projected return period change for 80mm/3h events in Putna River Basin, analysing the side-by-side maps that compare the current return periods with the expected future return periods for the selected threshold across Putna River Basin. These maps indicate how frequently these events are projected to occur in a specific future period, allowing us to identify areas where the risk of extreme rainfall is expected to increase or to decrease.

Taking into account the uncertainty associated with the model climate simulations in general, for a robust estimation on this analysis step, we choose as representative the results from the ensemble mean of different model simulations, for each future scenario.

In Figure 2-18, Figure 2-19, Figure 2-20, (Zenodo W3R1), we present for each future period the most extrem results from the 2 future projections (RCP4.5 and RCP8.5), for each of the future period. We could observe, that for all the future period the highest differences are expected in case of the RCP8.5 projection, we could expect a general increase for the risk of extreme rainfall, and the highest increase risk is expected for the 2071-2100 period.

As the return period represents the average time in years between extreme events, if the value of the return period increases, it means the event will happen less frequently, and if the value of the return period decreases, the event will happen more frequently.
So as general conclusion on the climate change impact on extreme precipitation events, in particular for the event of 80mm/3h, we could expect a almost gradual increase in the frequency of these extreme events, for all the future periods.

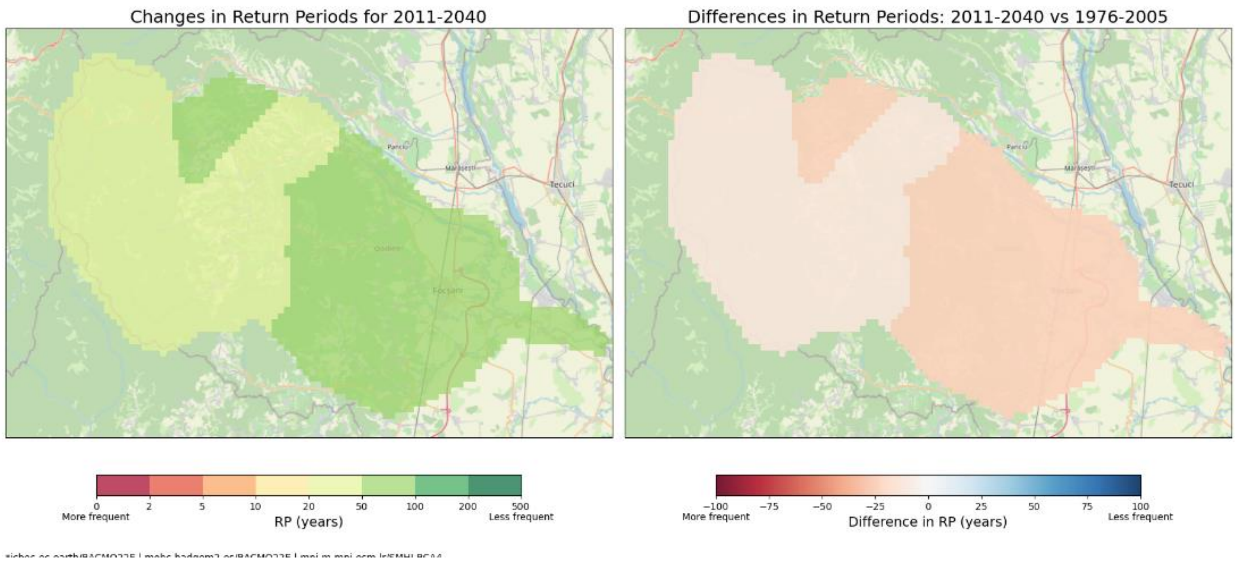

Figure 2-18 Projected return period for 80mm/3h events in Putna River Basin, Ensemble mean – scenario RCP8.5, future period 2011 - 2040

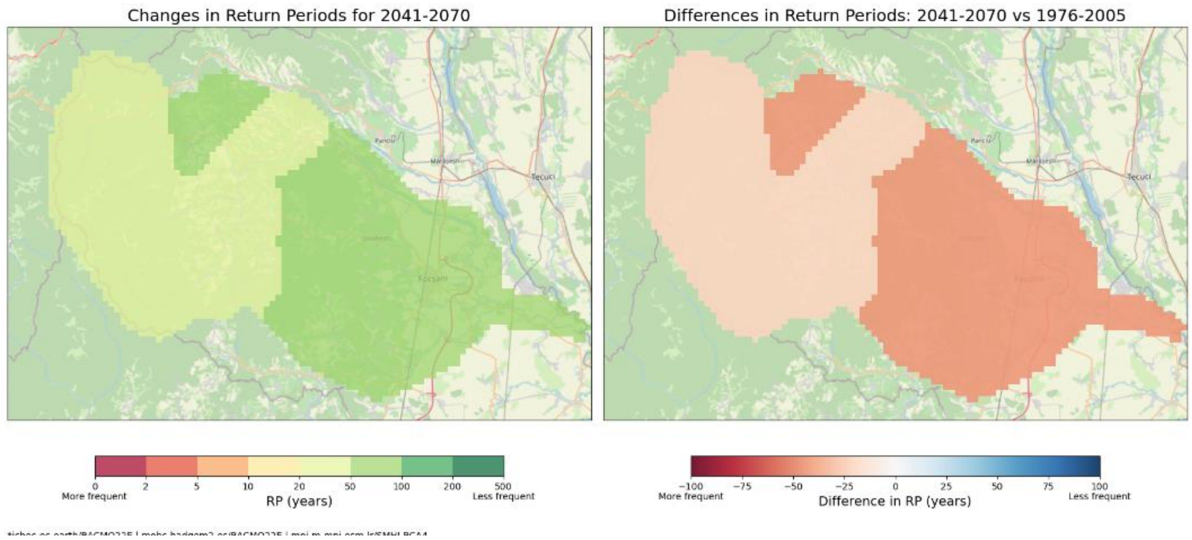

Figure 2-19 Projected return period for 80mm/3h events in Putna River Basin, Ensemble mean – scenario RCP8.5, future period 2041 - 2070

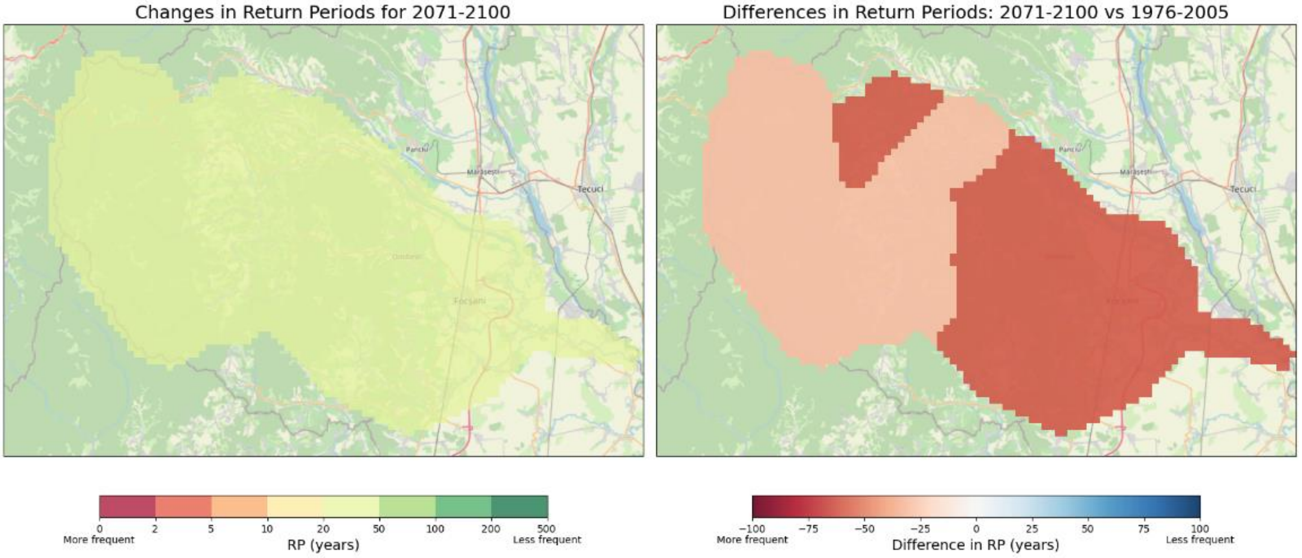

Figure 2-20 Projected return period for 80mm/3h events in Putna River Basin, Ensemble mean – scenario RCP8.5, future period 2071 - 2100

In the next analysis step, we analyse the shift in return periods for the 80mm/3h events, fro each of the avalibale climate model simulations, between RCP8.5 and RCP4.5, for all the future periods. The model chain that indicate the most important shift between the 2 climate projections, are presented for each future period in the Figure 2-18, (Zenodo W3R2).

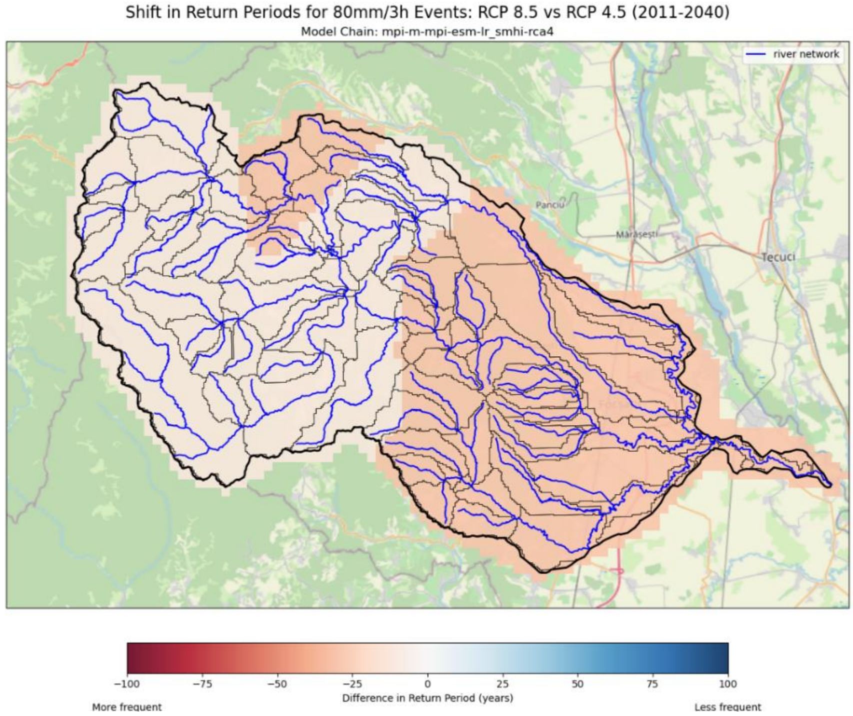

Figure 2-21 Shift in Return Periods for 80 mm/3h events, RCP 8.5 vs RCP 4.5 (2011 - 2040), using model chain mpi-m-mpi-esm-lr/smhi-rca4

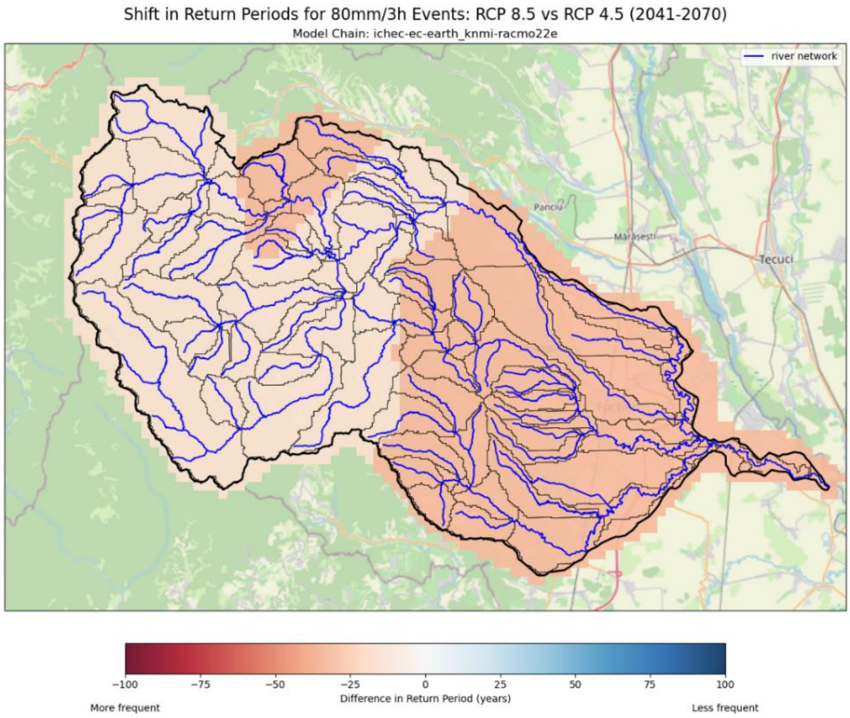

Figure 2-22 Shift in Return Periods for 80 mm/3h events, RCP 8.5 vs RCP 4.5 (2041 - 2070), using model chain ichec-ec-earth_knmi-racmo22e

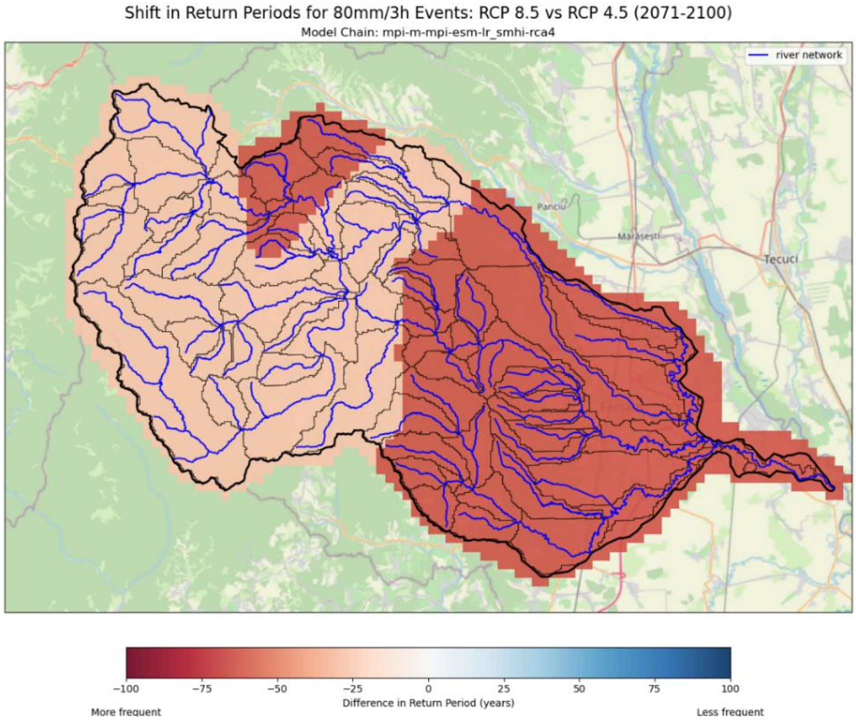

Figure 2-23 Shift in Return Periods for 80 mm/3h events, RCP 8.5 vs RCP 4.5 (2071 - 2100), using model chain mpi-m-mpi-esm-lr/smhi-rca4

As supplemental spatial information, in these figures we added also the river network layer, and the boundary of the small catchment layer from the Romania Flash Flood Guidance System (ROFFG), one of the operational flash flood forecasting system curently used by NIHWM (Zenodo W3R3).

2.4 Preliminary Key Risk Assessment Findings

2.4.1 Severity

The main key results from phase 1 of the CRA are related to the identification and localization of hotspots with high hazard and risk values over the entire Putna basin territory and especially to obtaining an indication of the effects of climate change on the future evolution of selected hazards and risks. These results will provide the basis for the local detailed CRA in phase 2 of the project.

The major climate related risks that Putna river basin are experiencing are heavy rainfall, river flooding and flash flooding.

Taking into account the limitations of the datasets used, most of the outputs of the CRA in phase 1 indicate numerous areas with high hazard and risk values for the selected RP events and an increasing trend for these in the future climate change scenarios.

2.4.2 Urgency

In real time, floods and flash floods events estimated severity/potential severity in the study area is expressed by the hydrological warnings color codes:

- Yellow code: Risk of floods or fast rises of water level requiring increased vigilance when carrying activities near or in the flood-prone area. Significant slope runoff, torrents and flash floods on small rivers with possible local flooding effects. In the hydrometric monitoring sections this code is associated with the possible exceedance of First Defense Water Level/Attention Level;
- Orange code: Risk of major floods, which may lead to the flooding of households and social - economic objectives. There may also be significant runoff on slopes, torrent and flash floods on small rivers with possible severe local flooding effects. In the hydrometric monitoring sections, this code is associated with possible significant exceedance (> 20 – 30 cm) of the Second Defense Water Level/Flooding Level. Due to the severe intensity of the expected dangerous hydrological phenomena, significant economic damage may be recorded and human life may be endangered;
- Red code: Risk of major floods which may require the adoption of special measures to evacuate people and property, imposes restrictions on the use of bridges and transportation routes, operation of hydro-technical constructions and others. In hydrometric monitoring sections this code is associated with the possible significant exceedance (> 20 – 30 cm) of the Third Defense Water Level/Danger Level. Due to the severe intensity of the hydrological phenomena predicted to be dangerous, there may be significant economic damage and significant risk to human life.

Flooding and flash flooding risk can be considered as being a sudden hazard, for the upper Putna river basin, on small tributaries and for torrential runoff on slopes, and a slower one for the flooding on the lower sector of Putna River.

Based on the results from the first Phase, for the climate change impact on extreme precipitation events, we consider that the primary urgency is represented by flash flood events.

2.4.3 Capacity

The present program of measures for the study area in the Flood Risk Management Plan of the 2rd implementation Cycle of the Floods Directive, mentions the following proposed measures for different sectors of the APSFRs in Putna river basin:

- Floodplain and riparian forest management.
- Local river bed regularization works (including river bed stabilization).
- Reinforcement of streams with small-scale hydrotechnical works.
- Improvement / Rehabilitation of sewerage systems, dewatering and drainage systems, pumping stations.

- Analysis of the technical and economic possibilities of relocating buildings in flood-prone areas.
- Damming works in the area of the localities.

2.5 Preliminary Monitoring and Evaluation

Going through the steps of the first phase of the CRA we learned how to apply the framework and how to use the toolbox to obtain relevant results in the study area. The particularities of the study area required some modifications to adapt the notebooks. In interpreting the results obtained it was necessary to take into account the characteristics and limitations of the datasets available in the CRA.

Some difficulties were encountered working with the extreme precipitation workflow, in order to understand the details of different processing steps. To facilitate this understanding we consider that it will be useful to prepare for each workflow also a schematic representation (data processing diagram). Also we were not able to understand the details/correct geographical projection associated with the bias-corrected datasets, we will analyse again in more details during Phase II.

According to the project workplan representatives of the main stakeholders and beneficiaries of the project will be invited to the 3 foreseen workshops in the study area (1 preparation meeting with stakeholders in the study area in September 2025 during phase 2 and 2 stakeholder's consultation and project results dissemination workshops, in May and June 2026, during phase 3).). During these workshops, they will be informed about the project and its implementation stage, directly consulted and involved in finalizing the new proposals for the program of measures which will include prevention, protection, and preparedness measures for existing and future floods, considering the effects of climate change

The most important data needed for better estimate the impact of climate change on the hazard and risk of river flooding and flash flooding is the dataset with maximum discharges values and percent change in maximum discharges values for the present day and future scenarios.

3 Conclusions Phase 1- Climate risk assessment

The testing and application of the toolbox for Putna river basin and the challenges for adapting each different workflow to obtain relevant results for the first phase provide a good basis for the knowledge of its use in order to configure the local package planned in phase 2.
As a summary of main key findings and challenges, from the selected workflows, we could mention the following:

- We consider that all the used workflow are well designed, proved to be quite stable, and they really support the general assessment of different hazard and risk, facilitating the integration and processing of relevant global and/or regional data.
- Due to the size of Putna river basin and the resolution of the resulted plots, the overall flood hazard maps are not very suggestive, therefore a local GIS analysis on the Territorial Administrative Units was applied.
- It is difficult to assess the quality of available flood hazard products, without knowing the values of maximum discharges that were used to produce these hazard estimates, this is valid both for the JRC and the Aqueduct datasets.
- There is a need to improve the assessment of potential climate change impact on fluvial floods, as the use of Aqueduct datasets allow now to perform only a qualitative one.
- The extreme precipitation workflow, together with the provided ready-to-go hazard datasets allow for a quite detailed hazard and risk assessment. We consider this is a good practice example for such kind of application.
- As general conclusion on the climate change impact on extreme precipitation events, in particular for the event of 80mm/3h, we could expect a almost gradual increase in the frequency of these extreme events, for all the future periods.

The main outputs resulting from the application of the toolbox indicate high values of the selected hazards and risks for most of the selected RPs and generally increasing trends for future scenarios. Taking into account the limitations of the datasets used in this phase, and the uncertainty associated with the assessment of climate change impact, most of the results could be considered as preliminary findings.
These first outputs limitation highlight the need to perform a more detailed local assessment by integrating in the toolbox high resolution datasets, new assessment methods and local hydraulic models for a more reliable CRA in Putna river basin.

4 Progress evaluation and contribution to future phases

The outputs of the analysis carried out in phase 1 of the project will help us to identify new areas at significant risk (APSFR - Areas of Potential Significant Flood Risk) within the basin and to validate the areas that were identified in the previous Cycles of FD based mainly on historical events and/or empirical methods.

The experience gained in working with the toolbox in the first phase of the project will allow us to use the Toolbox package as expert users, in order to create a fully customized regional risk assessment package for Putna river basin, by integrating local high resolution data sets, alternative methodologies and last generation hydraulic models.

This local customized risk assessment package for Putna river basin will be main tool for the refinement and improvement of the CRA carried out in phase 1, planned for the second phase of the project in order to obtain new hazard and risk maps will result that can help improving the local knowledge of these risks under climate change.

Table 4-1 Overview key performance indicators

Key performance indicators	*Progress*
3 workflows successfully applied on Deliverable 1 (fluvial floods, Flood damage and population exposure, Extreme precipitation)	The workflows for River Flooding and Heavy Rainfall/Extreme Precipitation were successfully adapted for Putna river basin and applied for the relevant return periods and scenarios. The Flood Damage and Population Exposure workflow was included in the plan and successfully applied. All outputs were analyzed.

Table 4-2 Overview milestones

Milestones	*Progress*
M1: Tests of the workflows for fluvial floods and heavy rainfall made	Testing of the River Flooding and Extreme Precipitation workflows was done in the CLIMAAX JupyterHub based on the default hazard and risk notebooks. The Flood Damage and Population Exposure workflow was tested and included in the plan, as it is based on the same hazard as the river flooding workflow.
M2: Workflows for fluvial floods and heavy rainfall for Putna river basin successfully applied	The workflows for River Flooding, Heavy Rainfall/Extreme Precipitation and Flood Damage and Population Exposure were successfully adapted for Putna river basin and applied for the relevant return periods and scenarios. The outputs were analyzed and processed taking into account the limitations of the datasets used.

5 Supporting documentation

Zenodo:

10.5281/zenodo.15112941

Main report Word

- ***Outputs of Workflow 1 River Flooding:***

W1H – Outputs of Workflow 1 Hazard
Reported damages
W1H1_Floodmap_overview_JRC_PresentScenario_Putna
W1H2_River_flood_hazard_maps_TAUs (12maps)
W1H3_River_flood_maps_Aqueduct_Putna
W1R - Outputs of Workflow 1 Risk
W1R1_Luisa_info_damages_tables
W1R2_Damage_maps

- ***Outputs of Workflow 2 Buildings and population exposure:***

W2R - Outputs of Workflow 2 Risk
W2R1_Hazard_maps_Lepsa
W2R2_Building_damage_maps_graphics_Lepsa
W2R3_Population_exposure_maps_graphics_Lepsa
W2R4_Population_exposure_Rastoaca

- ***Outputs of Workflow 3 Extreme precipitation:***

W3H – Outputs of Workflow 3 Hazard
W3H1_Extreme precipitation_3h_100yearRP (3 maps)
W3R - Outputs of Workflow 3 Risk
W3R1_ProjectedRP_80mm3h_events_Ensemble mean (3 maps)
W3R2_Shift in Return Periods_80mm3h_events_RCP 8.5 vs RCP 4.5 (3 maps)
W3RD – Other data Workflow 3
W3R3_LocalSupportData

6 References

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