Deliverable Phase 2 – Climate risk assessment

CLIMARCHEX

Italy, Marche Region

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Author(s)	• Gaia Galassi (MR – Environmantal Evaluation office) • Francesca Sini (MR- Civil Protection Department) • Natalino Barbizi (MR – Economic Department) • Marco Esposito , Sara Raggiunto (UNIVPM)
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Table of contents

List of figures

List of tables

Abbreviations and acronyms

CRA	Climate Risk Assessement
AWC	Available water capacity
DRMKC	Disaster Risk Management Knowledge Centre
EAFRD	European Agricultural Fund for Rural Development
ET0	Soil standard evapotranspiration
ETc	Evapotranspiration potential
ETa	Actual Crop evapotranspiration
ISPRA	Istituto Superiore per la Protezione e la Ricerca Ambientale
M2R	Marche to Resilience
OSM	Open Street Map
P2R	Pathway to Resilience
RCP	Representative Concentration Pathway
RP	Return Period
RPACC	Regional Plan for Adaptation to Climate Change
SECAP	Sustainable Energy and Climate Action Plan

Executive summary

Marche Region participate to CLIMAAX with the project CliMArcheX "Climate Risk Assessment in the Adriatic and Mediterranean Borders of the European Regions - the case of Marche Region in Italy". The following document represents the second output of the project and contains the climate risk analysis and results.

The document resumes a general overview of the climate hazards for Marche Region, from which it emerges increase in temperature, increase in length of dry period, increase in intensity and frequency of extreme precipitation events. This evidences the need to perform a risk analysis in terms of drought and flooding.

In the first phase of the project, the standard methodology for River Flood and Agricultural drought was applied. In this second phase, the methodology was refined with local information and further elaboration.

River floods were analysed in the pilot area of Foglia River with local maps presenting a better resolution and a more accurate distribution of flooded areas. To read information in terms of future scenarios, the relative increases in flood recurrence for different return periods have been analysed with the workflow of river discharge. Risk was assessed in terms of building damage and population exposed. Results shows that risk of flood is concentrated in some areas (within meander and in the river mouth), implying relevant cost in terms bot of damage and population exposed even for low return period. More intense events (i.e. with return period of 100 or 500 yrs), extend the areas damaged and, consequently, increase the risk. The discharge workflow confirms a future increase in extreme events and so a potential increase of flooded areas on Foglia territories

The agricultural drought workflow shows an increase in yield loss from precipitation deficit, corresponding to an increase in the revenue loss for 6 selected crops, especially maize and beans, whereas olive and wheat seem to better tolerate change in temperature and water availability.

The assessment of economic loss with the different scenarios, based on yield loss and data on current production, shows critical figures for maize and wheat, this latter for the relevant current production in the region.

A relevant outcome of the analysis is the evidence that main losses are expected for the near future (2026-2030): this makes urgent the action on adaptation.

The analysis performed here has set the basis for further action on adaptation measures. In particular, the outcome of the CRA will be shared with stakeholders and with decision makers to refine adaptation measures identified.

1 Introduction

1.1 Background

Marche Region is in central Italy on the Adriatic Sea; regional territory shifts from coastal area to the Appennino mountain chain. The territory include mountain, sea, hills, plains, river valleys, with a variety of environments and climatic conditions, and – therefore - a high vulnerability to climate change, which manifests with a wide range of effects. The gap between increasing impacts of climate change, and the limited capacity for responding with an adequate transformative climate adaptation, is at the root of the urgency of Marche Region to develop its own multi-risk analysis.

Marche Region (NUTS 2) Vulnerability Index, produced by the JRC Disaster Risk Management Knowledge Centre (DRMKC), is 6.12 for year 2022, it appears a high Vulnerability Index in comparison with other Italian Regions, and in particular with the Region of Central Italy. Among all the dimensions considered for the Index definition, the Physical one is the most critical for the Region and it scores 8.29 VI. The social dimension (3.70 VI) is strongly related to the climate change issue in the regional context. A social aspect to consider in this context is the poverty-related one: a difficult economic situation prevents citizens from taking measures against the various climatic phenomena which are increasingly widespread, even at a regional level (excessive heat waves, excessive rainfall,...), through the redevelopment of homes or the purchase of suitable equipment. The economic dimension of the index (6.87 VI) scores significantly high in comparison to the previous one. Since post-disaster property loss and the effects of business disruption represent main constituents of the economic component, it is evident that the disasters that has strongly affected the regional territory and society during last years (earthquake, flooding, etc) have left their mark on the Region. Also, the political dimension scores quite high (6.20 VI) according to the average. In relation to the environmental dimension of the Index (5.53 VI), which considers the environmental and ecosystems-related aspects of vulnerability, the Region is subjected to the main common risks for the Mediterranean area, such as desertification or expansion of the adjacent arid and semi-arid systems. Climate change has strong impact on ecosystems and the regional vulnerability may be accentuated by the lack of specific analysis aimed at creating a specific assessment of climate change effects on the areas of particular naturalistic and ecological interest (Natura 2000 and other protected areas).

1.2 Main objectives of the project

The Regional Plan for Adaptation to Climate Change (RPACC) of Marche Region, has allowed a qualitative identification of potential risks and possible adaptation actions. The project allows introducing a multi-risk analysis combining climatic, social, environmental and territorial data in a quantitative way, which is essential for the implementation of adaptation measures.

This is of peculiar importance for risk of flooding (both riverine and coastal), for which the PRACC indicates measures dealing with the increasing of resilience, promoting adaptation options for existing and future structures and infrastructures. The delocalisation (displacement of existing buildings, settlements, infrastructures) is included between the adaptation measures, both as pilot action and cost benefit analysis to compare the convenience of defence interventions in respect to delocalisation. To do that, a more accurate analysis of risks, including an adequate definition of vulnerabilities and hazards, is essential.

The main objective of the project is hence to improve knowledge and awareness on addressed risks and in the implementation of specific adaptation measures of the RPACC. This, in turn will lead to better identify the population with priority needs of training to increase human being resilience.

The application of the CLIMAAX toolbox trough phases 1 and 2 allows data systematization of all climate-related data available in the regional context. The integrated analysis performed by the tool, allows to refine identified adaptation measures. The approach chosen for project implementation, based on exchange of experiences and stakeholder involvement, helps to capitalize experiences and to spread awareness. Specific objectives of the project are:

1. To obtain a regional multidisciplinary analysis addressed to climatic risks and vulnerabilities;
2. To create and consolidate a multiregional network for sharing and capitalizing experiences;
3. To refine adaptation measures identified in the RPACC, identifying path for adaptation.

The high vulnerability of the Marche Region's territory to the effect of climate change makes necessary to optimize the efforts of policies in increasing the system resilience. Even if the Regional administration has an adaptation plan, the possibility of an efficient implementation is hindered by the interference of multiple factors. Hence, a multi-risks analysis is a precondition to make the adaptation measures identified in the RPACC able to reduce vulnerability and increase resilience.

The CLIMAAX common methodology for multi-risk assessment is the first step and allows an identification of addressed risk, providing in the meantime indication for a further refinement of the analysis at local level.

The complete CRA (phase 1 and 2) will improve the risk assessment performed in the RPACC. The CRA performed in phase 2 with local data has supplied practical indication about adaptation measure (i.e. displacement). The involvement of stakeholders on specific risks (with increase in awareness and preparedness) also represents an adaptation measure of the RPACC. In this sense, the participation of Marche in Climaax became itself an action for the actuation of the RPACC.

1.3 Project team

The project team is internal to Marche regional administration and involves different offices with different competences. In particular, the team is led by the Economic Development Department with experts on economic development and on European project management. The Territorial and infrastructure department includes offices with different climate and environmental competences, such as the Energy and waste sector, participates with expert on sustainable development strategy. This, together with the Environmental Assessement Office, it is also responsible for the attuation of the RPACC, and participate with experts on climate change protection. The Civil protection direction participates with an expert on civil protection, hydrology and floods.

Together to the internal team, the University Polytechnical of Marche Region, engineering department, has contributed to the project (in the second phase) for the common research interest.

1.4 Outline of the document's structure

The document is organized as follow.

In section 2, the preliminary information for the risk analysis are presented. With the scoping (Sec. 2.1) the objectives are identified and a broad presentation of the climate situation in Marche Region is presented, together with the elements for participation. This section also includes results of the analysis performed for the RPACC. Then, a screening of relevant risk and the workflows selection is included (section 2.2). In this section are also included some of the results obtained within the P2R project. The regionalized risk analysis for phase 2 is then presented for the two workflows selected (sec. 2.3), were is also described the use of local models and data. A focus on additional assessment based on local models and data for the workflow river discharge is presented in section 2.3.4. The key risk assessment is shown in sec. 2.4 whereas the findings in terms of monitoring and evaluation is presented in sec. 2.5. Section 2.6 describes the steps planned in phase 3.

In Section 3 are summarized the conclusions for the second phase and in Section 4 is presented the progress evaluation. Supporting documentation and references are listed in Sections 5 and 6, respectively.

2 Climate risk assessment – phase 2

2.1 Scoping

The main objective of RPACC is to improve the resilience of key systems to make the critical systems resilient to current and future climate impacts. To achieve this goal, the RPACC has analysed the climate context and the related risk at regional level, using the impact chain methodology which combines information on climate framework with the analysis of critical issues for adaptation to obtain lines of action. These were developed through a participatory approach involving experts and stakeholders to represent the best knowledge and evidence available for the specific context of the Marche Region (specific risks on a specific scale). The impact chains mechanism allowed us to identify the key systems most exposed to climate change, along with the main related risks and the main challenges to be addressed.

In the second phase, the scoping analysis was integrated with the work done by Marche region in the project Pathways to Resilience (P2R), in which the impact chain has been revised according with the P2R approach.

The detailed risk analysis on specific key factors performed within the CLIMAAX project is needed to refine and to scale the analysis performed in the RPACC.

2.1.1 Objectives

The main objective of the CRA is to identify, between the risks explored in the RPACC, which are the most relevant: for these the CRA will explore in depth the connection with sectors and target group affected to find specific solutions in terms of adaptation. The RPACC has identified, for all the risks, possible adaptation measures. These measures refer to the administrative competences of the regional public administration. Nevertheless, it is necessary to refine the RPACC adaptation measures focusing on a more active and localized approach for specific risks.

Based on the analysis already performed, it has emerged that between the most relevant potential climate change impacts there are those directly linked to changes in precipitation, namely drought and floods. The purpose of the CRA is to investigate these impacts on different aspects of society and economy, in particular related to agriculture and urban planning.

The expected outcome is a set of practical indications for risk reduction.

As mentioned above, the RPACC has already identified possible adaptation measures. The RPACC is a policy instrument, in which the path for the implementation is defined in terms of decision-making process. This means that for all the adaptation measures, the RPACC has identified roles and responsibilities for the different actors involved in the adaptation process.

Concerning the limitation, for some risks, has emerged a lack of data for the whole regional territory or uncertainties concerning the level of information. In this case, the CRA is performed on pilot areas to test the approach, which could be replicated in others context in the region.

In other case, the lack of data is not a matter of distribution but of content of information. In this case, the development of the CRA should consider only the approach based on consistent information. This is peculiarly important since the outcome, as mentioned above, is a set of specific measure that will interact with different interests with economic implication. For examples, rules that deal with delocalization of settlements or infrastructures has to be based on reliable analysis and predictions.

2.1.2 Context

The climate hazards have been analysed for the preparation of the RPACC following the Impact Chains, an approach for conceptualizing climate risk and its components. In the approach, different impacts link together in a chain that describes a cascade effect. This approach in the RPACC has allowed identifying specific risks that deserve to be more specifically addressed here, namely drought and floods.

Concerning the droughts, at national level, in line with the Water Framework Directive 2000/60/EC, the permanent district observatory for water use, are competent for the assessment of severe water shortage. The observatory pertains to the River Basin District Authority, a non-economic public body, of national relevance, controlled by the Ministry of Ecological Transition. Marche Region pertains to the Central Apennines River Basin District. The River Basin District Authority drafts and approves the Basin Plan and the related drafts, among which, the River Basin Management Plan and the Flood Risk Management Plan.

Beside the information on the hazards, it assumes increasing importance to have knowledge on how these hazards could affect the economic sector involved, such as the agriculture. As reported by Zhao et al, 2022, Mediterranean regions are facing different challenges in agricultural systems as consequences of climate change. It is the case for example of maize systems (Potop, 2011), where the warming and drought that occur between growing and final seed usage result in unintentionally shorter crop duration (earlier sowing and earlier harvests). Droughts and heatwaves affected crop production and drought conditions caused important yield reductions. The agricultural drought is defined as “a period with declining soil moisture and consequent crop failure” (*Villani et al., 2022*). An appropriate risk analysis has to consider economic loss to identify appropriate adaptation measures. The adaptation measure, intended as government responses to drought, refers to actions taken in advance of a drought that reduce potential drought-related impacts when the event occurs (*García-León et al., 2021*). These kinds of measures include climate services or early warning systems, preparedness plans, water demand reduction, etc.

Risk of floods is managed at national level in application of the Directive 2007/60/EC (“Floods Directive”), which established “a framework for the assessment and management of flood risks aimed at reducing the negative consequences for human health, the environment, cultural heritage and flood-related economic activities within the Community”. The responsibility for the preparation of preliminary risk assessments, the preparation of hazard and risk maps and the drafting of management plans is entrusted to the District Basin Authorities, in accordance with the preparation of the Hydrogeological Management Plans. The Regions, in coordination with each other and with the Civil Protection Departments, are responsible for preparing the part of the management plans for the hydrographic district of reference relating to the national and regional alert system for hydraulic risk for the purposes of civil protection.

Whereas climate change is increasing the hazard of river flooding (*Arnell & Gosling, 2016*), economic and territorial development are increasing exposure (people, properties, infrastructures, industrial activities, etc.) and vulnerability (the capability of the properties to withstand the forces due to the event). Adaptation measures need to reduce exposure and vulnerabilities, including displacement.

These aspects refer to urban planning and urbanization policies, managed by local administrations (municipalities) and affecting also private properties. The interaction between public and private interests is very strong, and potential risks need to be tackled carefully.

2.1.3 Participation and risk ownership

The definition of the RPACC was a collective process, made possible by identifying a multi-sector governance capable of combining all the dimensions involved in climate change. The RPACC is managed by the so-called "control room", composed of the top managers of the regional departments. Inside the control room, the referents identified by the Directors of Departments, form the executive development management team and follow the implementation of the Climate Adaptation Plan (including the risk analysis).

Marche Region also participate to Pathways2Resilience, with MARCHe2Resilience (M2R) project. Within M2R, Marche Region is working on the consolidation of a strong multi-level form of climate adaptation governance within the regional territory. The multi-level governance that Marche aims to achieve includes both internal and external aspects. Internally, it is necessary to ensure collaboration among regional structures, coordinated by the RPACC executive development management team. While, externally, Marche aims at implementing the coordination among different local Authorities (mainly regional Municipalities) through their SECAPs and the RPACC.

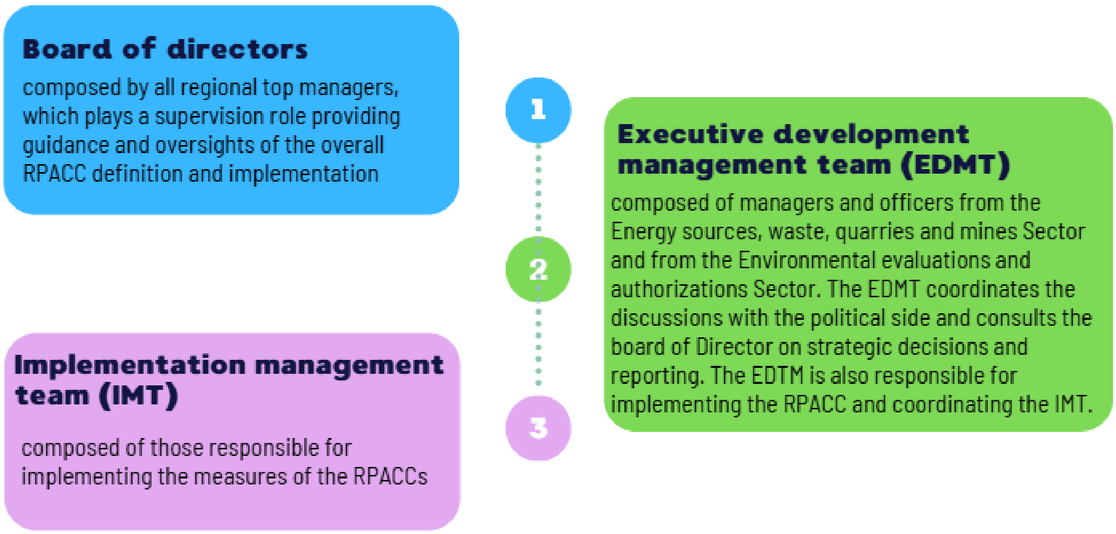


Figure 2-1- RPACC internal governance and Key systems and regional structures involved (department, direction, sector) Figure source: Project Marche2Resilience (in P2R)

Table 2-1- Key systems and regional structures involved (department, direction, sector) for internal governance. Figure source: Project Marche2Resilience (in P2R)

Key systems	Implementation management teams	Key systems	Implementation management teams
Water quality	Environment and water resources (EWR)	**Soil**	ARD
	Agriculture and rural development (ARD)		FHP
Water availability	EWR	**Ecosystems**	EWR

	ARD		Environmental assessments and authorization (EAA)
	Forestry and hunting policies (FHP)		FHP
Climate risks (hydraulic/hydrogeological, forest fire, warning and awareness)	Civil Protection and Territorial Security (CPTS)	**Coast**	EWR
	Civil engineering (CE)	**Agriculture**	ARD FHP
	EWR	**Tourism**	Tourism, European Territorial Cooperation, and Development Cooperation (TEC)
	ARD		Infrastructures and territory (IT)
Urban planning	Urban planning, landscape and public housing (ULH)	**Fishing**	Trade, fishing and consumer protection (TFP)
	Energy sources, waste, quarries and mines (EWQ)	**Health**	Regional health company (RHS)
	EAA	**Sustainability culture Vector**	EWQ
Energy	EWQ		EAA
	EAA		EWR
	Healthcare, hospital and school buildings (HHS)		ARD
Policy coherence Vector	EWQ		CPTS
	EAA		Economic development (ED)
Participation for sustainable development Vector	EWQ		
	EAA		

The mapping and the involvement of stakeholder is started with the preliminary analysis of the RPACC. This has allowed to identify and involve, from the very preliminary phase of risk analysis, all the actors potentially interested by the different topics of climate change adaptation. Internal stakeholders (see table 2-1) were involved in a series of technical meetings aimed to (i) define current situation and trends for economic, social and territorial issues affected by climate change; (ii) discuss in more detail the possible impact dynamics induced directly or indirectly by climate change, and to engage, sometimes for the first time, with professionals from other sectors connected by these impacts; (iii) investigate the "adaptation capacity" for the regional administration.

External stakeholders (such as local administrations, civil society, universities and research centres, etc.) have been involved in specific consultation both on the analysis and on the adaptation measure identified.

Within the CLIMAAX activities, the specific risks addressed in the CRA requires the involvement of regional offices, namely Water management, Civil protection and Agriculture (internal stakeholders), and of further external stakeholder, as local administrations (municipalities), farmers, citizens (local group targeted by specific risks).

In synergy with M2R project (which between its goals has also the support to implementation of climate adaptation plans for the Municipalities of the Covenant of Mayors) the CliMarcheX project has involved municipalities for the risk exploration.

2.1.4 Application of principles

The Regional Strategy of Sustainable development, that represents the framework for the RPACC and hence for the CRA, integrated the principles as enable conditions, to guide decision making and prioritization.

Social justice is integrated with the concept of just resilience, with the aim of "leaving no one behind". In both the risk addressed in the CRA (agricultural drought and river floods), the focus on prevention of economic loss, protects potential vulnerable groups which cannot be able to sustain costs of restoration or to afford insurance protection tools. Moreover, considering key groups that are disproportionately affected by climate change and/or adaptation options in the regional agriculture system, the main group to focus on is the one of farmers. In addition, the CRA also integrates procedural justice (fair, transparent and inclusive decision-making processes), since the output of the workflow on agricultural droughts will be used in a transparent a participatory process for a more efficient allocation of financial resources (see section 2.6).

Quality, rigor, and transparency are on the basis of the CRA. In all the risk analyzed, the workflows have been used with a rigorous, transparent, and high-quality approach. The risk related to river floods was validated with local data applied to different locations (see section 2.3.3). This kind of validation, within the combination of workflows on river discharge and on building damage, as allowed a standardization of the process in the regional context with the possibility of further application in addition to the pilot presented below. For agricultural droughts, quality results were ensured by comparing different climate models. Finally, to ensure transparence, in December 2025, Marche Region has made public a website on climate change, with a page dedicated to the work of marche in CLIMAAX and a page dedicated to climate data. The webpage will be implemented with the CRA results.

Finally, Precautionary approach is included considering the worst-case scenario emerging by the CRA. This has been done for both the key risks.

2.1.5 Stakeholder engagement

The involvement of internal stakeholders was continuous and followed the project implementation step by step, with constant discussion on the result obtained.

Inside the capacity building meeting of the 26 February 2025 project CliMarcheX was introduced to municipalities involved in M2R project, in order to discuss the potential of CRA for risk flooding. To the meeting attended 26 participants from municipalities plus 3 members of Climate Alliance (partner of M2R project).

In addition, the scoping on regional risks was presented inside dissemination events to the University (as the one held for the University of Camerino on 28/11/2025), for a discussion.

Finally, the risk analysis was discussed with municipalities inside the activity of Marche Region for M2R.

A first evaluation of the risk has been shared with the stakeholders, and in particular with municipalities. On the basis of the feedback obtained in different discussions, it was possible to refine risk exploration.

In particular, the output of discussion suggested to explore different rcp scenarios to compare results (the analysis performed in the RPACC only included rcp 8.5). This feedback has been applied in the CRA performed in this phase 2.

Project outcomes obtained in this phase will be further shared with stakeholders. In particular, outputs of the workflow on agricultural droughts will be share with:

- Internal stakeholders (Regional Agricultural Department) to refine the adaptation measures, within the EAFRD regional programme;
- Internal and External stakeholders (farmers, trade associations, experts, universities and research body, etc) to understand the uncertainty and the "acceptable risks".

2.2 Risk Exploration

The analysis performed in the RPACC shows increase in temperature and shift in the precipitation regime. In the deliverable of the first phase, a summary of the climate analysis performed in the RPACC to identify the main risks was presented.

Anomalies with the 1981-2010 period show that either the annual and seasonal average temperatures have increased with a statistically significant trend between 1961 and 2020, with an increase of the annual mean temperature anomalies of +0,4% per decade.

For the precipitation, the anomalies in respect to the 1981-2010 period show no statistically significant trend for the annual average. Nevertheless, data show change in the annual distribution of events and in the intensification of extreme events.

A more detailed framework on climate risk for the region was presented in Deliverable of phase 1.

Also based on the stakeholder involvement, a preliminary and qualitative risk assessment has been drafted, as shown in the following table.

Table 22 Preliminary risk exploration based on stakeholder consultation

Risk Workflow	Severity		Urgency	Capacity	Risk Priority
	C	F		Resilience/ CRM	
River flooding					Very hight
Coastal flooding					High
Heavy rainfall					High
Heatwaves					High
Drought					Very hight
Fire					Low
Snow					Low
Wind					High

Severity	Urgency	Resilience Capacity	Risk Ranking
Critical	Immediate action needed	High	Very high
Substantial	More action needed	Substantial	High
Moderate	Watching brief	Medium	Moderate
Limited	No action needed	Low	Low

The preliminary analysis confirms the prioritization shown by data.

The increase in temperature and the shift in precipitations shown for Marche by rcp 8.5 at 2050 implies higher risk of drought. Although the drought is caused by various ecological and geo-pedological factors, climate factors can be used to identify the areas subjected to potential hazard. In particular, the anomalies in the projections of the Consecutive dry days are critical in the northern coastal area and the southern inland areas. The Consecutive summer days distribution is related to the orography of the Region, with higher values along the coastal areas and lower in the inland areas. Therefore, an increased risk of drought is expected in the northern coast, the center hill areas, and a hotspot in the southern mountain.

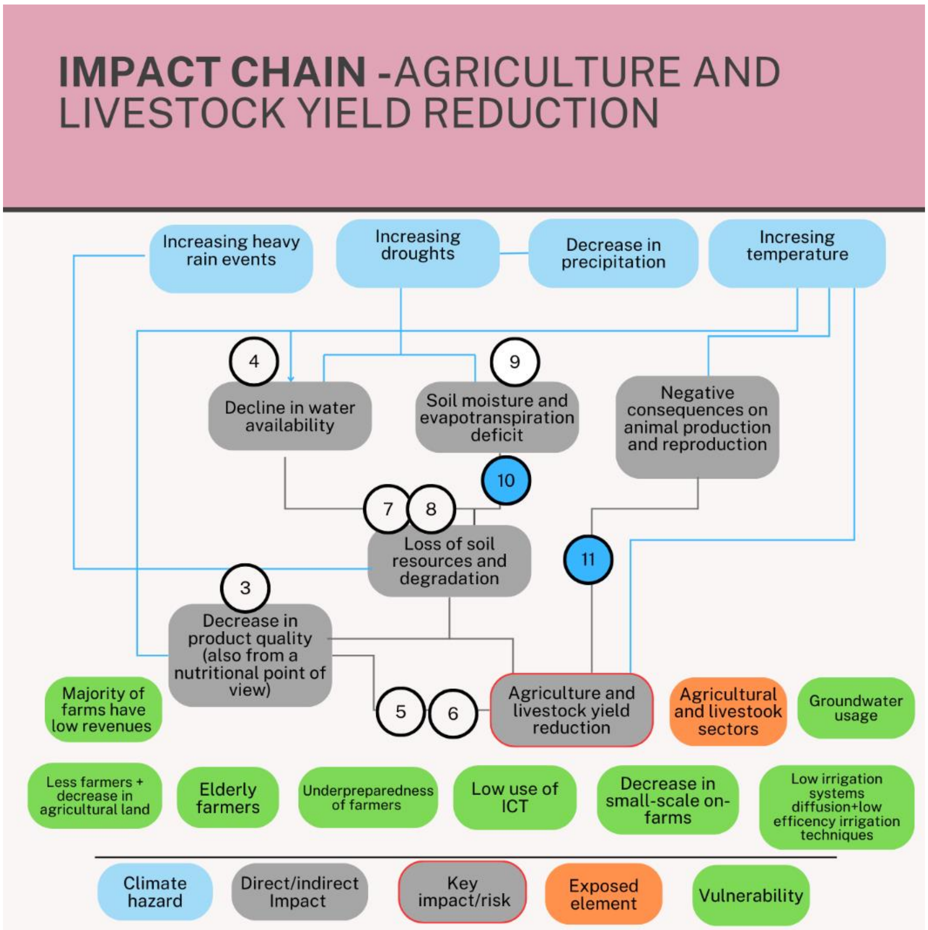
The shift in precipitation regime, and especially the intensification of extreme events, imply a risk in the frequency and intensity of river floods. To investigate the risk of floods, one important index is the *Mean precipitation amount on wet days,* which for Marche increases on average from 7,75 mm/per day during the 1991-2020 period, to 8,82 mm/per day in the projection, with higher anomalies in the South of the region. The *Highest one-day precipitation amount* index rises by 12,9% in the projections; the highest values are in the coastal southern area.

2.2.1 Screen risks (selection of main hazards)

From the risk analysis performed in the RPACC and revised in the first phase emerged two main risks on which a focus is needed, namely agricultural droughts and river flooding. This is confirmed also by the stakeholder involvement on a firs risk screening.

Within the project M2R, the impact chain analysis presented in the RPACC is revised for the main economic sector, to find key risks. In Figure 2-2 is shown the impact chain for the agricultural sector, from which it emerges agricultural yield reduction as a key risk.

The increase in temperature and the shift in precipitations implies a higher risk of drought. The agricultural sector, by its nature closely linked and dependent on variations in temperatures and precipitation, is strongly affected by the alterations caused by climate change, also in terms of economic yield. To properly assess the risk, it is essential to have information on the type of cultivation. These data are available at regional level from the regional Department of agriculture but are not complete and homogeneous.



No.	RPACC adaptation measures (options)	No.	RPACC adaptation measures (options)
1	A.03 Reduction of pesticides and fertilizers in agriculture	7	I.04 Promote systems to prevent erosion
2	A.04 Disincentives for fertilizer use in nitrate vulnerable areas	8	I.05 Incentives for agricultural management that improve hydrological capacity
3	B.10* Strengthening of knowledge-gathering activities on water resources in agriculture	9	C.01*** Soil monitoring network
4	B.12 Efficiency of irrigation techniques	10	C.02 Soil degradation risk maps *(enabling condition)*
5	I.01** Support for crop choices based on climate trends	11	C.04 Training activities for farmers (*enabling condition*)
6	I.02 Incentives for resilient crops		

*B.10 option is a decision support tool to help in the use of water in agriculture. The tool works as an early warning about drought or precipitation (see art. 7 technical law)
**I.01 option is a decision support tool to help in the choice in resilient crop. The tool works as a warning based on climate trends (see art. 7 technical law)
***C.01 option is an application of new technologies such as advance sensor in climate smart agriculture

Figure 2-2 - Impact chain for agricultural sector Figure source: Progect Marche2Resilience (in P2R)

For the risk of flood, it is important to consider vulnerability and exposure, related to the characteristic of the territory. The Floods Directive (2007/60/EC) identifies the areas at hydraulic risk based on three scenarios. ISPRA presents data regarding the areas at hydraulic risk produced by the District Basin Authorities on the three scenarios defined by the Floods Directive. In the Region, 0.1% of the territory is associated with high-risk flood events areas, 2.7% with medium-risk areas and 4% with low-risk areas. The values are lower than the national averages, which are respectively 5.4%, 10% and 14%. Nevertheless, direct experiences show in recent years an increase of flooding with economic damages and in some case with loss of lives, both in terms of frequency and intensity. An example is the event occurred in September 2022 and associated with extreme precipitation (with peak of 419 mm recorded by rain gauges) and causing catastrophic damage to infrastructure and property, as well as tragic loss of life. Maps of flooding with different return period are essential to properly assess the risk. These maps are not available for the whole region but have been produced for some river basins. In this work, the risk analysis is applied to a pilot, the Foglia river, for which maps of floods with different return period are available.

2.2.2 Choose Scenario

The choice of the scenario combines the need of accounting for the timeframe of public policies with the effect and consequence of climate change on social and economic dynamics. Public policies are usually focused on short-term impact; nevertheless, climate dynamics impose to act now to prevent future impacts. For this reason, both the near future and the medium term are assumed as relevant scenarios, with a near-future term fixed in 2030 and a medium term in 2050. This latter coincides with the scenario chosen for the RPACC and it is available in the workflows.

For agricultural drought, the near future is important for adjust the immediate actions, whereas the medium term allow to give insights to the agricultural policies and strategies that usually have a horizon of 10 or more years (from the start of the strategi definition to the end of implementation).

For river flooding, scenarios are set in terms of return period. This, as known, represents a probability, and not properly a time. Different return periods have been considered, from 10 years (near future) to 500 years (far future, but able to represent worst the case scenario).

The simulations are performed using two rcp scenarios namely rcp 8.5 and rcp 4.5. The first is the same used in the RPACC, the second has been added to introduce a comparison and to explore potential changes in the consequences associated to different shifts in temperature and precipitation regimes.

2.3 Regionalized Risk Analysis

2.3.1 Hazard #1 – River flooding - fine-tuning to local context

For the application of the framework, a pilot area was chosen, corresponding to the last part of the River Foglia Basin. The hazard expresses the probability that a damaging flood of a given severity occurs in a given timeframe (return period - RP). The following RPs have been considered in the analysis: 10yr, 50yr, 100yr and 500yr.

In the first phase according to the standard methodology, river flood extent and depth from the European Commission's Joint Research Centr at 3 arc-seconds resolution, were used.

In addition, in this second phase, maps of flooding developed locally available for the River Foglia Basin (Gabellani et al. 2021) have been used for a comparison.

In the workflow methodology, the estimation of the change in river flood potential due to climate change uses as baseline scenario (1980) the Aqueduct dataset. This has a coarse resolution for the pilot area (and for Marche region in general) which doesn't allow for a proper risk assessment. For this reason, in this phase, a further refinement has been applied using the workflow on river discharge (see Section 2.3.3). Even this doesn't supply directly maps of floodings for future scenarios, it can help to understand the increase in frequency of the extreme events.

Exposure is accounted with the land use map, available from the Copernicus Land Monitoring Service and with the Flood-damage curves for infrastructure expressed as relative damage percentage, available from JRC. The economic value for different types of land use account for vulnerability. In addition, in the second phase, the "Flood building damage and population exposed" workflow was applied to the pilot. This has allowed to consider population exposed (from population maps) and building data, including infrastructures (derived from openstreet maps and from the regional data)

Table 2-3 Data overview workflow #1

Hazard data	***Vulnerability data***	***Exposure data***	*Impact metrics/Risk output*
River flood maps	Economic value for land use	Land use	River flood damage
	Flood damage curve	Buildings and infrastructures	Population exposed
			Building damage

2.3.1.1 Hazard assessment

The hazard assessment has analyzed the flood potential with different return period. In the first phase, present day scenario was considered.

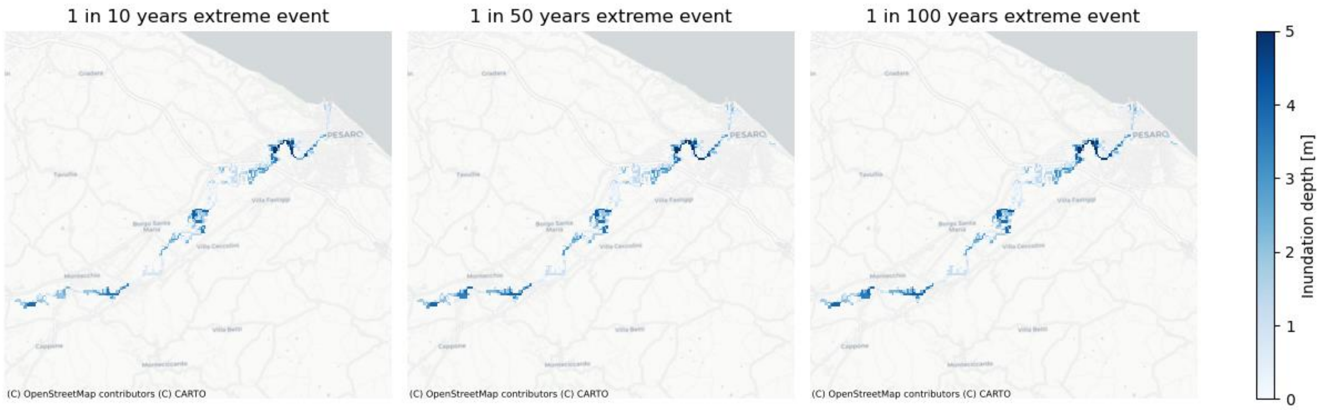


Figure 2-3 - River flood potential for different return period for the river Foglia pilot, present day-scenario with JRC floods map.

In the second phase, in addition to data from European Commission's Joint Research Centre, local maps for river flooding have been used. These have been produced within the Interreg Italy-Croatia project "Stream" for Marche Region, in collaboration with Cima foundation. A bidimensional hydraulic model, TELEMAC-2D, was applied on the Foglia river, for the computation of a set of hazard maps for different return periods. Buildings, bridge, embankments and perimeter walls have been checked to test permeability and their influence on the dynamic of simulations. The use of these maps overcomes some of the limitation identified for the methodology of the workflow. As shown in Figure 2-4 local maps presents a better resolution and a more accurate distribution of flooded areas. This is of peculiar importance for the risk analysis, especialli in terms of bulding damage and population exposed.

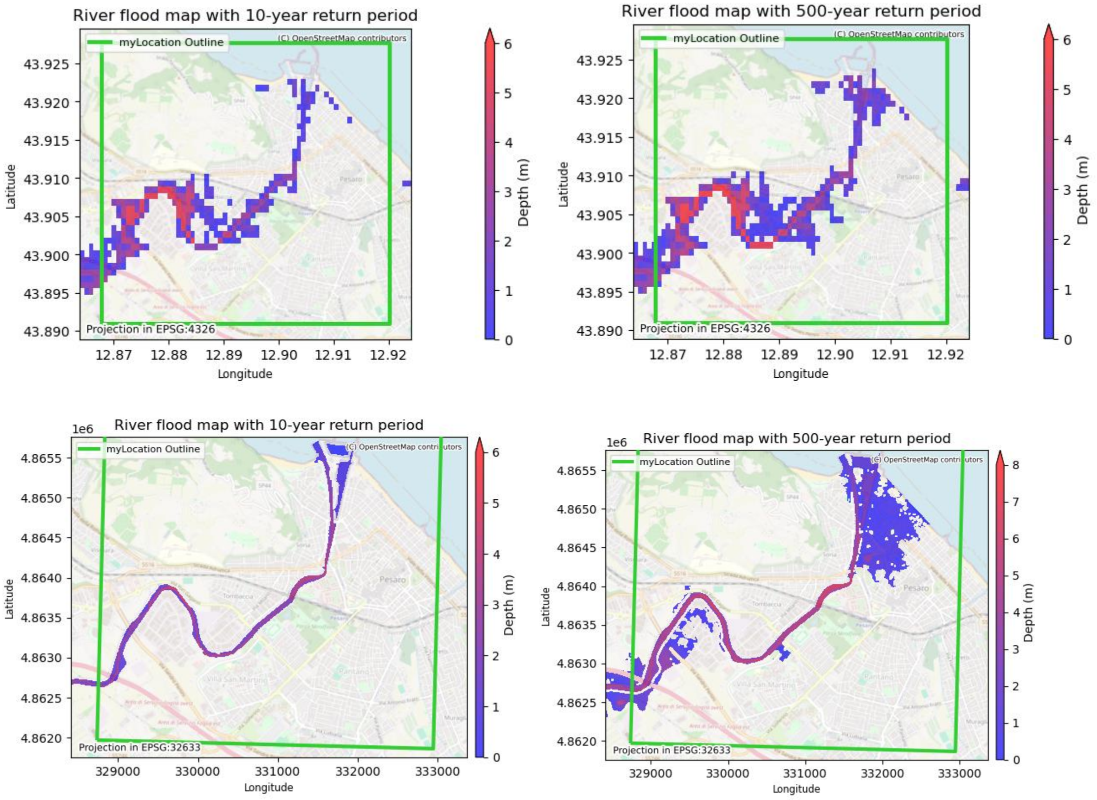


Figure 2-4 - River flood maps for different return periods for the river Foglia mouth pilot, for 10 yr (left) and 500 yr (right) return period. Top: JRC floods map. Bottom: Cima foundation local map.

To read information in terms of future scenarios, the relative increases in flood recurrence for different return periods have been analysed with the workflow of river discharge (see section 2.3.3).

2.3.1.2 Risk assessment

According to the standard methodology, in phase 1 an estimation of damage from risk of river flooding to building infrastructure was computed for different return periods.

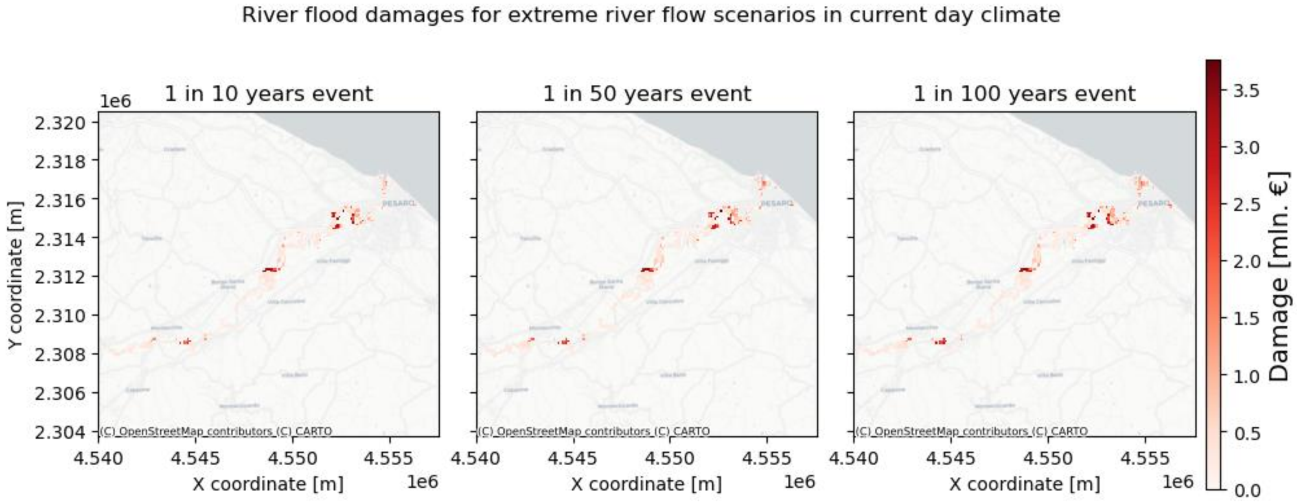


Figure 2-5 - River flood potential for different return period for the river Foglia pilot, present day-scenario with JRC floods map.

In the second phase the workflow "flood building damage and population exposed" is applied to the same pilot, with a focus on the city center of Pesaro at the mouth of Foglia river. Two options have been selected for the river flood maps: the ones obtained with the hazard derived by JRC data, and the ones developed within the Interreg Italy-Croatia project "Stream" for Marche Region, in collaboration with CIMA Foundation. In the following, only results obtained with the regional floods maps are presented, since they are more accurate (see Figure 2-4 on the comparison between the hazards).

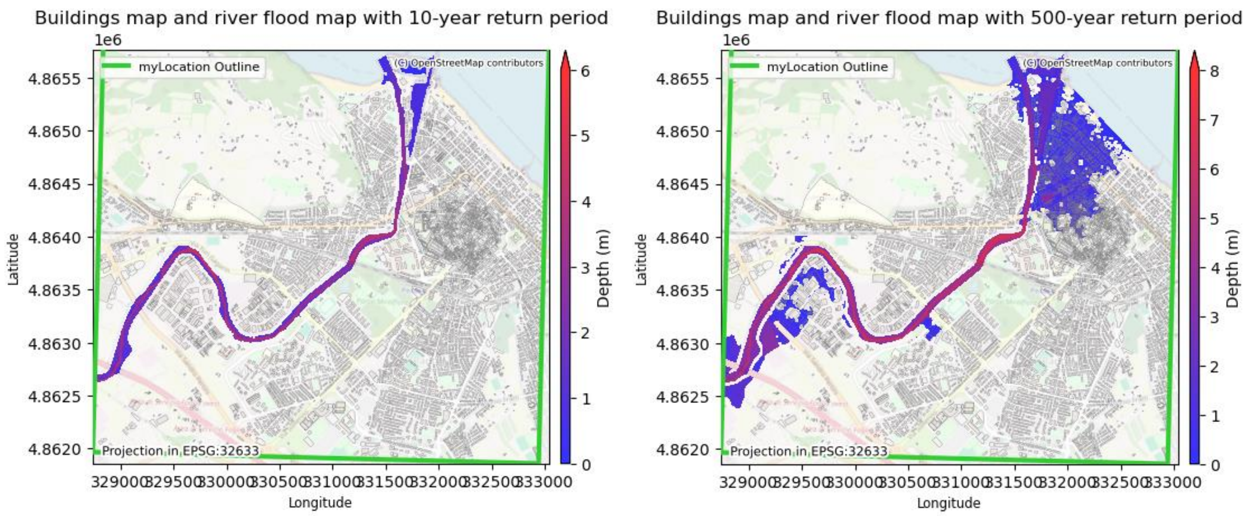


Figure 2-6 - River flood map for 10 yr (left) and 500 yr (right) return period for the river Foglia pilot, with the general view of buildings exposed.

Buildings have been classified on the basis of OSM. Data have been checked with the regional technical map, showing consistency for the examined area. The combination of the flood maps with different return period with building data allows to examine potential risks. The analysis on critical infrastructures confirms that the urban planning has placed all the critical infrastructure outside the potentially flooded areas.

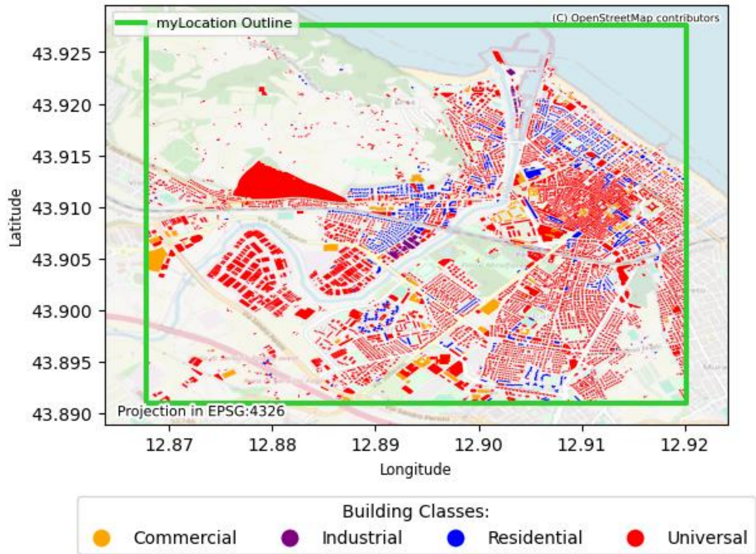


Figure 2-7 – Building classification for the pilot area.

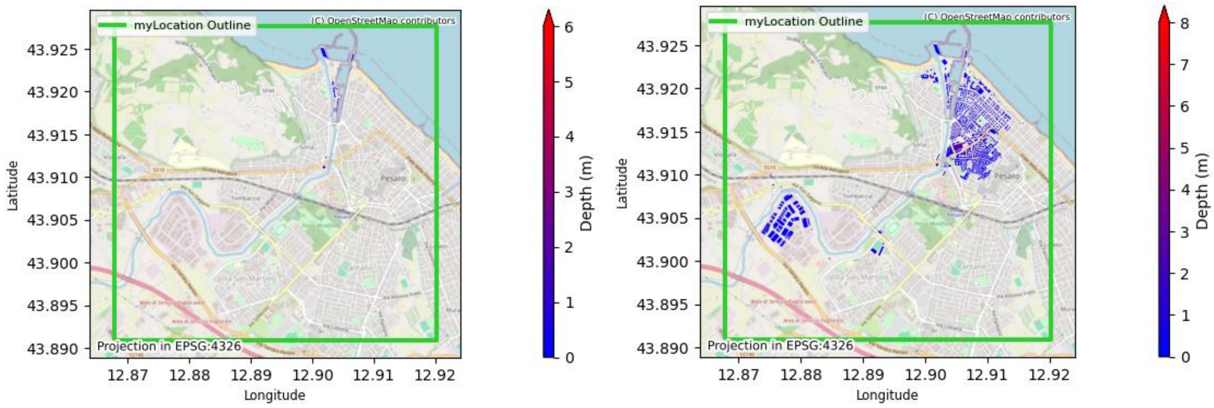


Figure 2-8 – Mean flood depth at building locations derived from flood map with 10 yr (left) and 500 yr (right) return period at the pilot location.

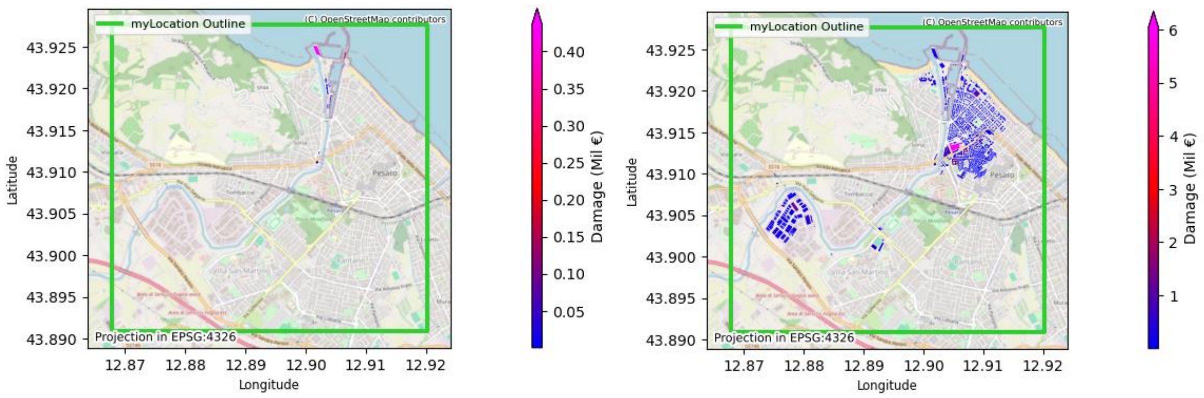


Figure 2-9 – Damage to buildings by mean flood depth based on flood map with 10 yr (left) and 500 yr (right) return period.

The quantification of total damage to buildings is shown in the following table. For comparison the result obtained with the JRC's flood maps are also reported. The coarse resolution of the JRC flood maps and the not consideration of barriers and structures for floods protection tend to overestimates the flooded area (see Figure 2-4), resulting in larger damage costs (see Table 2-4). This confirms the importance to use accurate data for the estimation of the risks.

Risk was assessed in terms of building damage and population exposed. Results shows that risk of flood is concentrated in some areas (within meander and in the river mouth), implying relevant cost in terms bot of damage and population exposed even for low return period.

Damage costs increase with RP, passing for the area considered from ~1M€ for events with RP of 10 yr to ~74M€ for events with RP of 500 yr. It is also important to note that the computation of costs refers to buildings and not, for example, to damage to infrastructures (roads, water supply or sewage systems, electric infrastructure, etc.) or costs related restoration works.

Table 2-4 Economic damage to buildings for different return period

Return period	*Local floods maps*	*JRC floods maps*
RP=10	*1.130.206 €*	*72.127.617 €*
RP=50	*13.538.419 €*	*94.066.685 €*
RP=100	*36.452.708 €*	*100.100.947 €*
RP=500	*74.027.491 €*	*117.137.149 €*

Based on the flood depth maps, the exposed population is determined in respect to different return periods. It is also considered the displaced population, as a subset of the exposed population that experience flood depths above a given threshold. It is interesting to note that even if with low return period (10 yr) there is a consistent number of people exposed (>3000). The population displaced increases with RP (from 150 with RP 10 yr to over 1300 with RP 500 yr).

Figure 2-10 – Exposed population for the river flood event with 10 yr (left) and 500 yr (right) return period (population statistics based on estimate for year 2025).

Figure 2-11 –Displaced population for the flood event with 10 yr (left) and 500 yr (right) return period (population statistics based on estimate for year 2025).

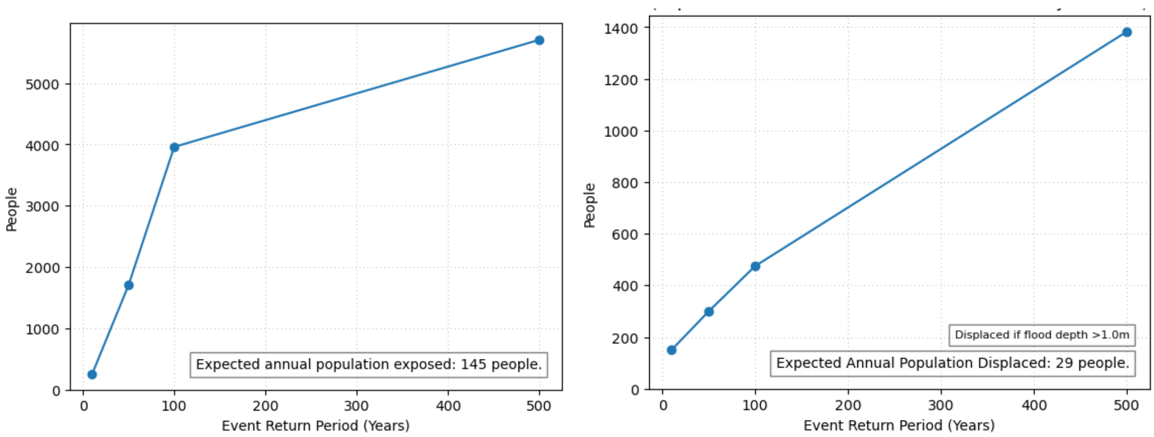


Figure 2-12 – Estimated exposed population (left) and displaced population (right) per flood event return period (population statistics based on estimate for year 2025).

Table 2-5 Population exposed and population displaced with different return period

Return period	*Population exposed*	*Population displaced*
RP=10	*3365*	*150*
RP=50	*3858*	*299*
RP=100	*3863*	*475*
RP=500	*4196*	*1383*

2.3.2 Hazard #2 – Agricultural droughts - finetuning to local context

In the first phase of the project, the workflow was applied with the standard methodology for a first screening of potential risks. The whole Marche region was selected as study area. This choice is motivated by the fact that both agricultural and adaptation policies are managed at the level of Regional Administration.

In this second phase the following refinements have been applied to the analysis:

- two timeframes are selected: a "near future" 2026-2030 and a mid-century scenario 2046-2050.
- all the simulations have been checked with two emission scenarios, the RCP4.5 and the RCP8.5.
- three different combinations of General Circulation Model and Regional Climate model were selected (since more adequate to Mediterranean area) in order to compare the result obtained, namely:
    - GCM= mpi_m_mpi_esm_lr, RCM= smhi_rca4 [short name in the following: mpi-smhi or SMHI]
    - GCM= cnrm cerfacs cm5, RCM= cnrm aladin63 [short name in the following: cnrm-aladin or ALADIN]
    - GCM= cnrm cerfacs cm5, RCM= knmi_racmo22e [short name in the following: cnrm-racmo or RACMO]
- The crops were selected in function of their relevance for the regional context (or in terms of production or for the characterization of the local market): from the list available in the standard methodology two cereals (maize and wheat) and two legumes (beans and lentil); two additional cultures: olive and grapes. The information for these two latter crops derives from literature (in particular *Raes et al. 2012* and *Fereres, E. 2012*) and are adapted to the regional context based on evidences from local agricultural sector.

Table 2-6 Data overview workflow #2

Hazard data	*Vulnerability data*	*Exposure data*	*Impact metrics/Risk output*
Wind speed *Relative humidity* *Maximum temperature* *Mean precipitation flux* *Minimum temperature*	Crop specific information (lentil, beans, *maize and* weath) …	Cropland production	Yield loss
		Crop aggregated value	Revenue loss

2.3.2.1 Hazard assessment

Yield loss is expressed as the percentage reduction in yield if crops are grown under rainfed only conditions rather than fully irrigated. The percentage is computed to catch the variation in the 5-year period of reference (in our simulation corresponding to the 2026-2030 for the near future and to 2046-2050 for the mid future).

The overall result for the three simulations (as the average on the regional territory) is listed in the following table. Internal model variability was characterized using the standard deviation of each model.

Table 2-7 Average value of yield loss for the selected crops according to the different simulations

	RCP 4.5		
	ALADIN	**RACMO**	**SMHI**

	2030	σ	2050	σ	2030	σ	2050	σ	2030	σ	2050	σ
olive	3,46	2,86	2,35	2,49	2,04	2,09	2,25	2,19	5,51	2,38	5,66	2,38
grapes	20,84	14,54	14,00	13,92	13,30	11,56	14,58	12,22	31,09	11,31	31,74	11,58
maize	29,52	15,24	21,76	15,37	17,22	8,52	21,05	9,08	45,91	9,27	47,02	9,02
wheat	4,81	7,11	3,11	5,08	8,75	6,09	6,77	7,48	8,04	8,54	8,85	9,31
lentil	23,45	10,41	16,52	10,59	13,66	4,83	15,01	5,39	35,23	6,93	36,07	5,81
beans	29,96	13,26	23,47	14,23	19,31	6,10	22,57	7,46	47,38	8,48	49,40	7,26
	RCP 8.5											
	ALADIN				**RACMO**				**SMHI**			
	2030	**σ**	**2050**	**σ**	**2030**	**σ**	**2050**	**σ**	**2030**	**σ**	**2050**	**σ**
olive	2,43	2,36	2,28	2,26	1,64	1,80	2,01	2,00	4,14	2,47	5,61	2,44
grapes	15,15	12,88	13,44	12,77	10,65	10,39	11,68	11,25	24,33	12,52	30,67	12,42
maize	29,52	15,24	15,49	12,62	12,27	6,03	8,08	6,92	37,70	12,12	42,80	11,94
wheat	4,81	7,11	7,53	7,56	7,81	9,81	6,53	7,20	12,13	10,73	11,02	9,89
lentil	19,67	9,23	12,59	8,81	11,20	3,87	5,15	4,22	28,51	8,12	32,73	7,85
beans	27,35	13,67	17,56	10,83	17,60	5,33	4,93	3,31	39,77	10,88	41,25	10,11

The uncertainty between models was estimated as the standard deviation of the average of the three models, normalized to the multi-average model. A detailed analysis is included in ANNEX A. The analysis on uncertainty together with considerations on each pair of GCM-RCM based on available literature, suggest to privilege results obtained with the cnrm-aladin simulation. Results of the other two simulations are detailed in ANNEX A. Main figures (as the comparison between scenarios and rcps) are consistent in the three models.

The analysis performed show in general important percentage of yield loss for all the crops considered. Olive and wheat are those less affected, whereas beans and maize will be affected strongly by climate change effects, with loss in production of over 20%.

All the corps considered, with the exception of grapes, show greater share of loss in the near future compared with the mid future. This evidence is confirmed also by the cnrm-racmo simulation, but not by mpi-smhi.

The comparison between rcp 4.5 and rcp 8.5 shows larger yield loss according to rcp 4.5. This is confirmed in the output of the other two models for all the crops. Even if this could appear not logic, it is important to consider that yield is sensitive to the intrinsic characteristics of climatic variables, as the rainfall timing more than the annual average. In this sense, RCP 4.5 may produce more seasonally "unfavourable" scenario as less rainfall during critical phases or more consecutive dry days. RCP 8.5 may have heavier but concentrated rainfall or a slight increase in precipitation in some seasons/regions. Selected crops suffer more the "moderate but persistent" drought (a prolonged moderate stress) shown by rcp 4.5 than the extreme but shorter events (severe but brief stress) shown in rcp 8.5.

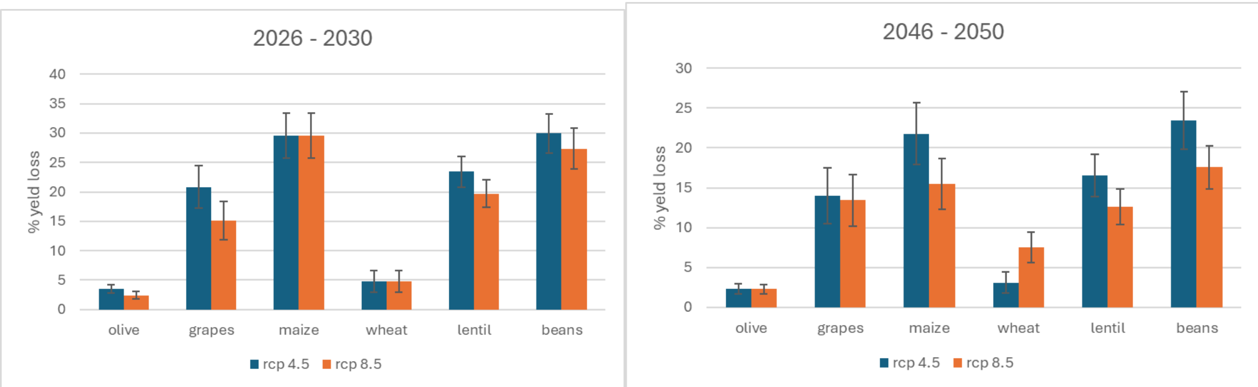


Figure 2-13 – Percentage of yeld loss for the selected crops: comparison between rcp 4.5 and rcp 8.5 in the near future (left) and in the mid future (right). The confidence interval was computed using a 95% confidence level. Model: cnrm-aladin

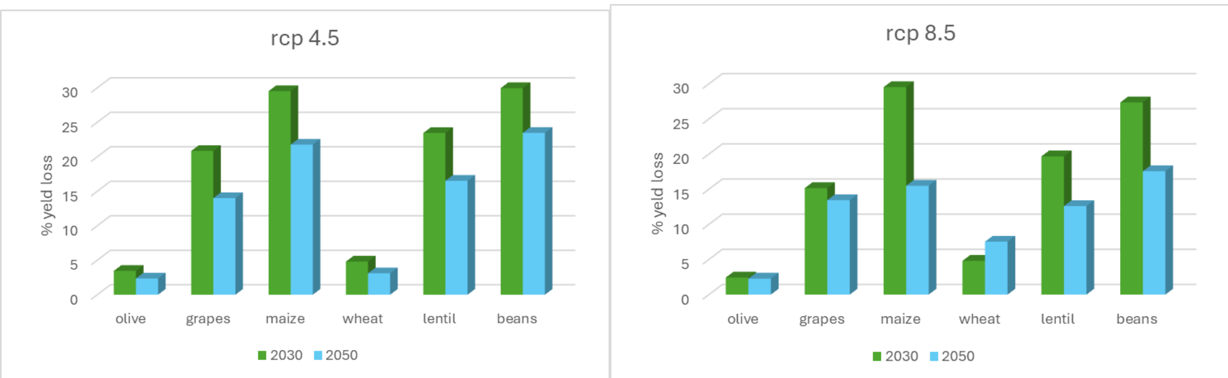


Figure 2-14 – Percentage of yeld loss for the selected crops: comparison between the near future and in the mid future for rcp 4.5 (left) and rcp 8.5 (right). Model: cnrm-aladin

2.3.2.2 Risk assessment

The methodology proposed in the workflow for the risk assessment, combines the information on yield loss, with data on production and the distribution of fully-irrigated cropland to account for vulnerability. This latter comes from GAEZ 2015 and presents different limitation when applied to Marche regional context. First, the crop considered in this study, with a partial exception of maize, are not traditionally irrigated, so that the indicator chosen does not well represents the vulnerability. Secondly, data on production and associated value date back to 2020. It is also necessary to consider that several factors influence prices of an agricultural product in addition to climatic conditions affecting yield. These include production costs (such as labor and energy), as well as market dynamics (local and global availability of the product); government policies, subsidies, and trade regulations also impact pricing, along with transportation and storage costs. The choice of vulnerability and exposure indicators is critical since vulnerability is influenced by many processes and over-simplifications might lead to unrealistic estimates (Villani et al., 2022).

For these reasons here, besides the risk analysis performed with the standard methodology, further considerations have been obtained combining data on yield loss with data on production and revenue at regional level.

Concerning the magnitude and distribution of yield loss, complete data are listed in ANNEX A. In general, coastal area is expected to host larger yield loss, with peaks on the northern or southern part depending from the crops. The distribution in yield loss for grapes and olives is crucial since this kind of crops are localized in particularly suitable areas, usually hills, and they are permanent crops (not subject to rotation). Results of the analysis shows potential loss larger than 15% for both the crops in the hill-area in the near future according with rcp 4.5.

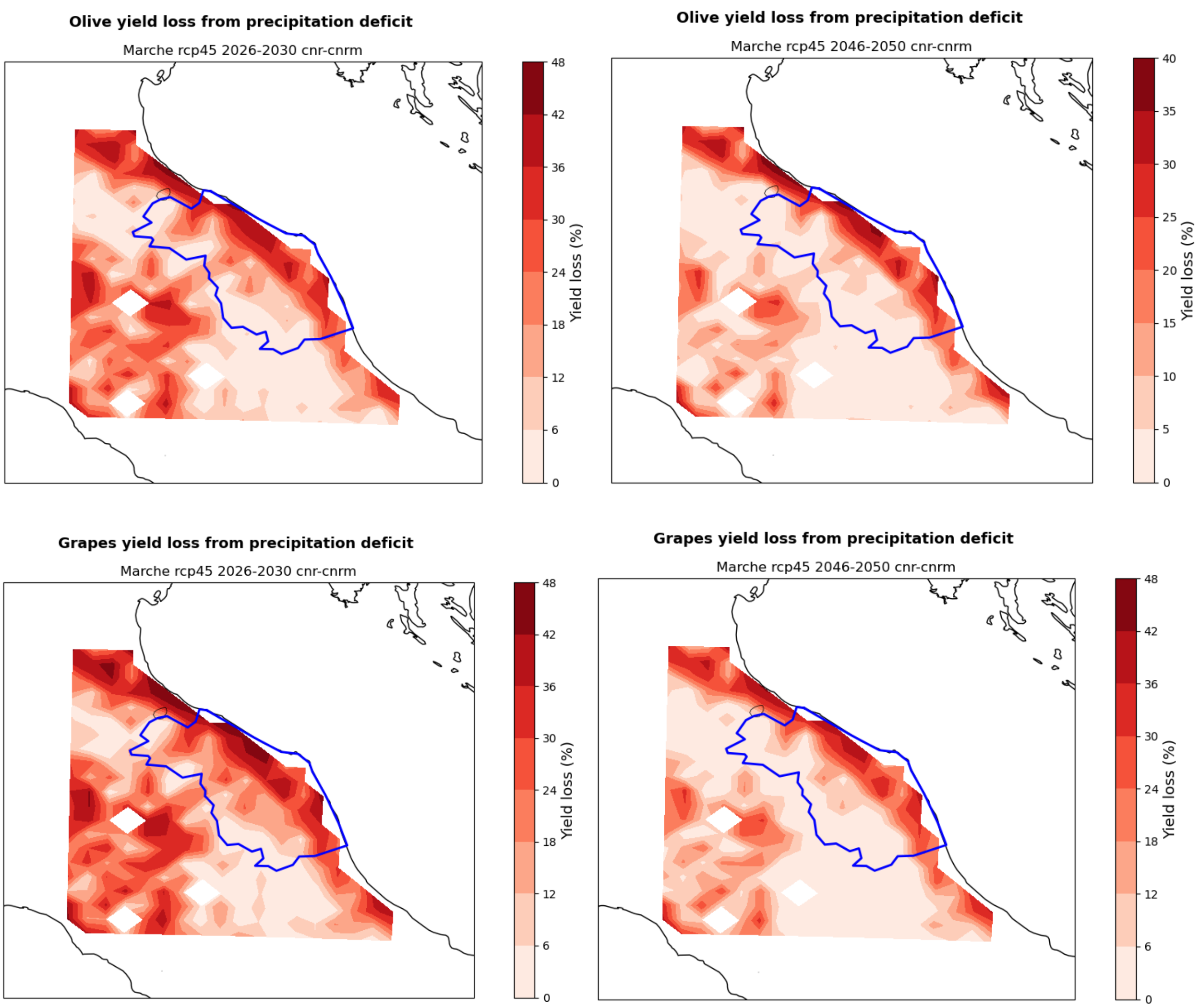


Figure 2-15 – Percentage of yield loss for olive (top) and grapes (bottom) with rcp 4.5. Left: near future (2026-2030); right:: mid future (2046-2050). Model: cnrm-aladin

The comparison between the standard methodology and the analysis based on data on production, poses a focus on maize and wheat.

Workflow common methodology shows a regional distribution of revenue loss that is congruent with that analyzed in terms of yield loss. Concerning the absolute value, for wheat the peak is near to 3 million of euros in coastal area. For maize, the magnitude of revenue loss appears lower, with peak of around 60.000 € in coastal spots.

Combining current data on production and prices trend, it is possible to estimate the actual expected loss.

For wheat, the price varies in years and for the different varieties (durum wheat and common wheat), with an average value for the period 2018-2025 of around 300 €/ton. For maize, the average price is around 240 €/ton for the same period.

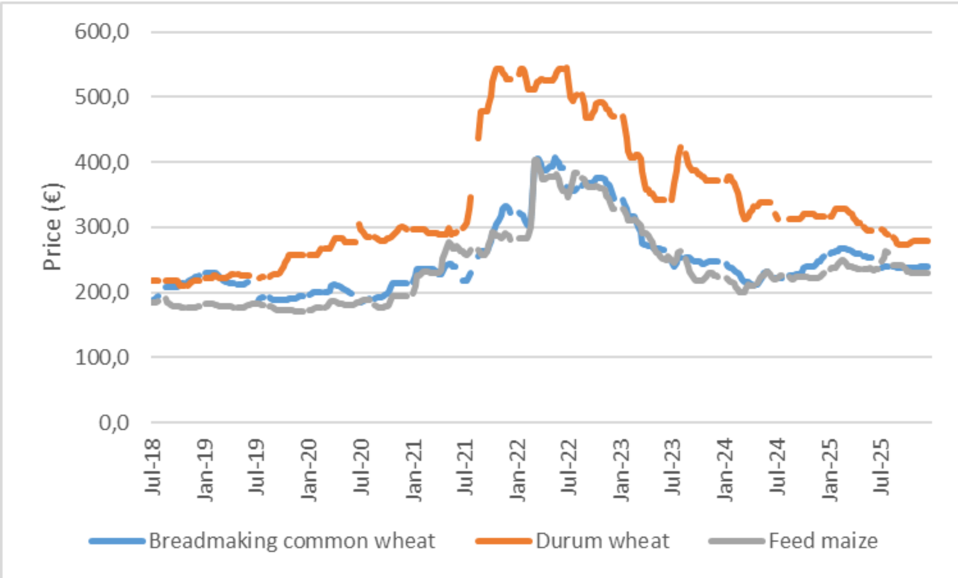


Figure 2-16 – Wheat and Maize price delivered to first customer of breadmaking common wheat, durum wheat and feed maize in €/ton in Central Italy, source EU DG Agri dashboard

Data on production are extracted from ISTAT (the Italian national institute of statistics) and are included in ANNEX A. The total production in Marche region of wheat for 2025 is 442.705,3 tons, with a negative rate of 11.470,8t/yr for the period 2006-2025 (and a negative variation of 29,4%). The total production in Marche region of maize for 2025 is 14.653 tons with a negative trend for the period 2006-2025 of -2.858,8 t/yr. Considering the total surface dedicate to each crop, the production per hectare has remained stable both for maize and wheat. Complete information of productions is listed in ANNEX A.

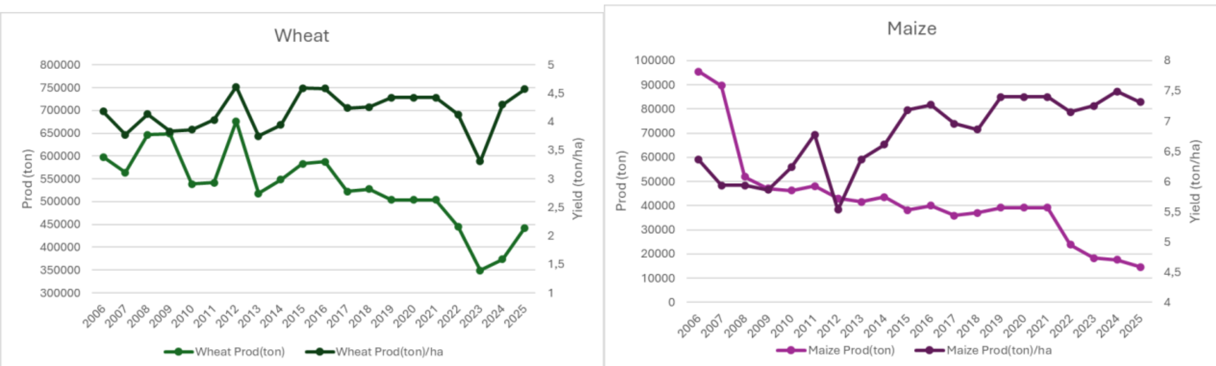


Figure 2-17 Wheat and Maize yearly total production and yield in Marche Region. Source ISTAT.

Considering current prices and current production and the yield loss percentage obtained with the simulation, emerged at 2030 a risk of economic loss for yield reduction of ~ 6.100.000 € for wheat and ~1.600.000 for maize according to rcp 4.5. The figures will slightly decrease in 2050 (3.900.000 for wheat and 1.200.000 for maize). Even if potential yield loss for wheat is smaller than the yield loss estimated for maize, the larger amount of total production in the region makes the risk associated to wheat more relevant.

2.3.3 Additional assessments based on local models and data

In order to deepen the hazard analysis for river floods on Foglia basin and test the robustness of the results on Marche region territories, *the river floods-discharge work flow* has been tested on 4 different regional *basins*, where longer flow data series were available for validation and on Foglia basin. Investigation of climate change scenarios, in terms of monthly discharge and extreme events on the whole basin, seems relevant both to improve Early Warning System and drought long term strategies.

We downloaded the historical daily time series (1991-2005) and monthly means of river discharges for 1971-2000 from the E-HYPEcatch models which are useful for checking longer-term statistics of river discharges in the historical climate and download monthly means of discharges for future periods of 2011-2040, 2041-2070 and 2071-2100 and analyzed 2, 5, 10 and 50 years return period.

We associated Foglia basin and regional water level (WL) station outlets (from north to south) to the following E-HYPE ID subbasins:

- Code ID 9001103 - Foglia basin outlet
- Code ID 9000605 - Acqualagna WL station n. 1185
- Code ID 9000602 - Camponocecchio WL station n. 1016
- Code ID 9000601- San Severino WL station n. 1032
- Code ID 9744229- Brecciarolo WL station n. 1108

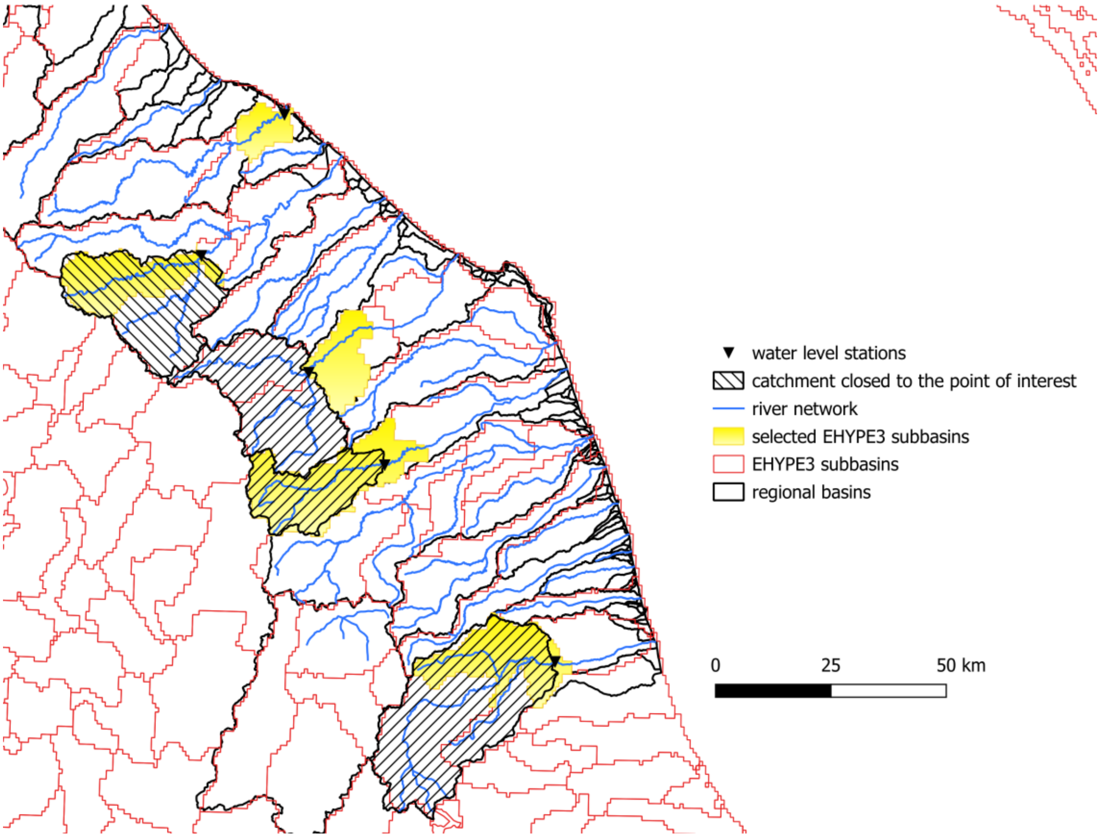


Figure 2-18 – Water level stations localization and related selected E-HYPE subbasins

A complete description of the workflow is contained in ANNEX B.

Since a long discharge data set is not available for Foglia river, the robustness of E-HYPE methodology was investigated on the other four regional basins in order to adopt it also for Foglia basin. Result applied to Foglia watershed are presented in Figure 2-19. Relative changes in river extreme discharge larger than 20% are expected according to rcp 8.5 (median of model) for the mid-term future (2041-2070) and for the far future (2070-2100) for RP ≥ 5yr. It is interesting to note that for far future rcp 4.5 shows larger changes for all the RP considered. For RP of 10 yr and 50 yr expected change around 25% are expected according with rcp 8.5 both for the mid-future and for the near future.

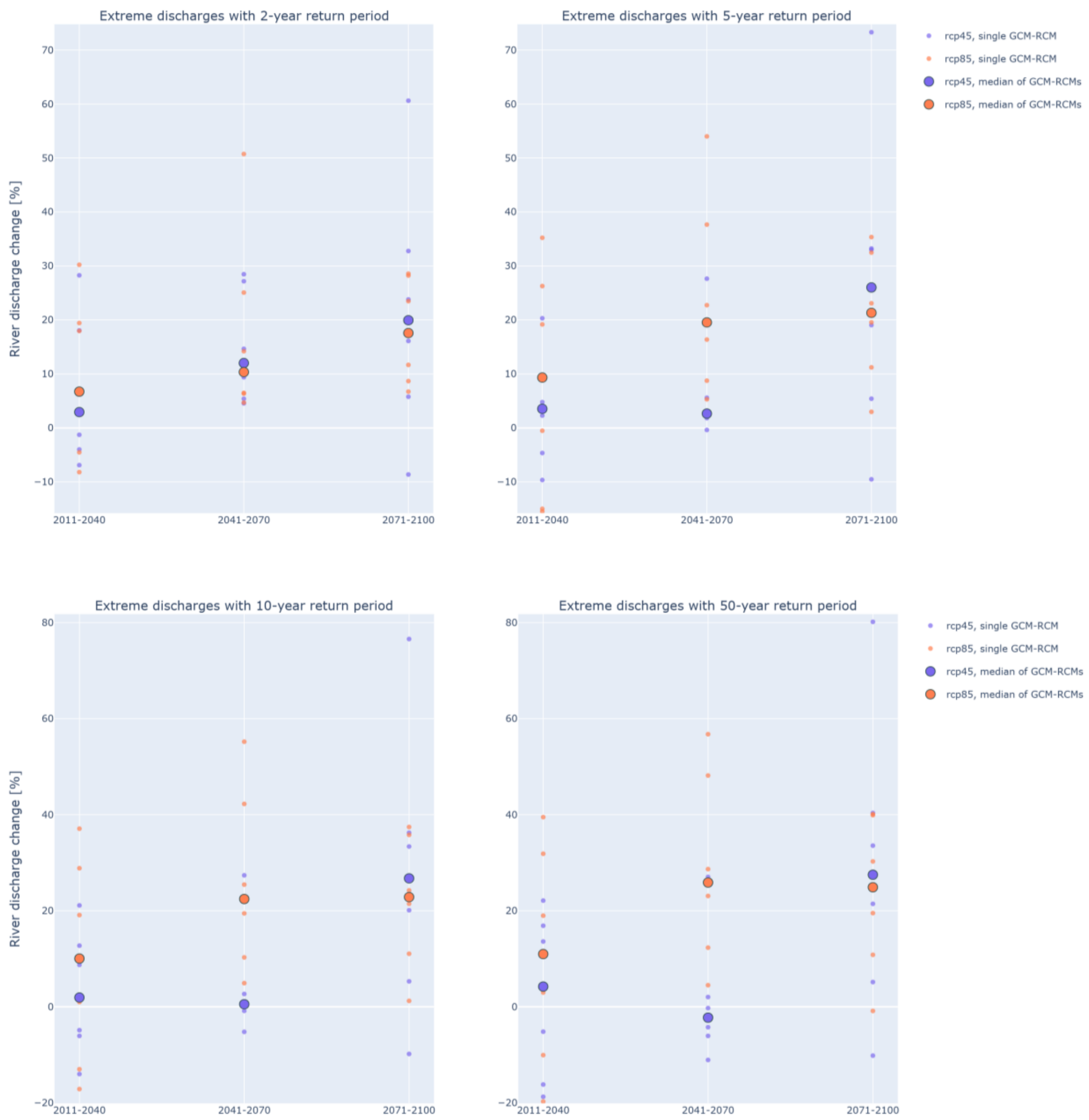


Figure 2-19 – Relative change in extreme river discharge in Foglia basin for different GCM-RCM combinations and averaged across the hydrological multi-model ensamble. Top: 2 yr return period (left) and 5 year return period (right); Bottom: 10 yr return period (left) and 50 yr return period (right)

Looking over at the monthly results, winter months (December, January, February) show a general wetter trend, spring months (March, April May) a drier one, probably due to a lower contribution of snowmelting (see Annex B for further details and results).

The discharge work flow confirms a future increase in extreme events and so a potential increase of flooded areas on Foglia territories, but at the same time a different distribution of the monthly discharge during the year, that must be thinking to a different organization in terms of water resource exploitation.

2.4 Key Risk Assessment Findings

2.4.1 Mode of engagement for participation

Climate policies in Marche Region are subject to a continuous participatory process, which is implicit in the governance model of the RPACC. Within the CLIMAAX's activity, participation as followed two paths: (i) an internal participation with the experts and officers responsible for the implementation of adaptation measures; (ii) an external participation with the involvement of relevant stakeholders such as local administrations.

As exposed in section 2.1.5, the involvement of internal stakeholder was continuous and followed the project implementation step by step, with constant discussion on the result obtained.

External stakeholders have been involved mainly in the first phases of the project (scoping phase, screening of risks, risk selections) and will be further involved in the third phase for discussion on output and on adaptation options. Nevertheless, a first evaluation of the risks has been shared with the stakeholder, and in particular with municipalities.

2.4.2 Gather output from Risk Analysis step

The quantitative risk information obtained by the Risk Analysis for the selected hazards have been used for the risk evaluation. In particular, for the risk of flooding, maps of buildings and population exposed for different return period obtained with local flood maps have been used for the evaluation. Consideration about the increasing frequency of the vents obtained with the workflow on river discharge have been used to consider the urgency.

Concerning Agricultural droughts, maps of potential yield loss for both rcp 4.5 and 8.5 and for mid and near future have been considered. Estimation of economic loss have been based on the actual data on crops production and prices.

Historical data (especially on catastrophic events) and information on adaptation capacity gathered in the scoping and risk exploration phases have contributed to the risk assessment.

2.4.3 Assess Severity

For the flood river, the risk analysis in the pilot area shows high level of damage in localized spot even for low return period (10 yr). More intense events (i.e. with return period of 100 or 500 yrs), extend the areas damaged and, consequently, increase the risk both in terms of building damages and population. Results obtained with the discharge workflow indicates and increase in intensity and frequency of extreme events, indicating an increasing probability in the occurrence of events currently classified with high result period. Recent experiences have confirmed the occurrence of this risks risk for all the major rivers in the Region. Hence, severity is assessed as critical.

Concerning agricultural drought, data show an increase in in yield loss from precipitation deficit for all the crops considered, especially with rcp 4.5. The expected percentage of yield loss is high also for the near future (2026-2030), with average of ~30% for beans and maize and larger than 20% for lentil and grapes. The comparison with historical data on production show that consequences of climate change would strongly impact on the agricultural sector. Hence, severity is assessed as critical.

2.4.4 Assess Urgency

For the flood river risk, the pilot analysis shows potential consistent damage even with low return period (10 and 50 yr). This implies an urgency in the application of adaptation measures. Furthermore, the concept of "return period" is associated to the probability of the occurrence of the event; a return period of 100 yr represents a high intensity with low (but not null) probability. According to the analysis performed on the workflow of discharge, it emerged an increasing probability in extreme events. This is confirmed by the several catastrophic events with high return period occurred in the las few years in the regional territory. For example, the flash flood that hit the Misa basin in central on September 15, 2022 was an event with a return period of over 500 years, causing 13 victims, 50 wounded, and damage for 2 billion euros. The risk is hence assessed as urgent, and immediate actions are needed.

Agricultural droughts analysis has shown that major losses will happen in the near future. This implies the urgency of intervention. Furthermore, in recent years droughts caused in Marche region loss of income to agricultural sector to the point that in 2017, 2022, 2024 was officially recognized from national and regional governments the state of natural calamity for agricultural drought for the territory of Marche. The analysis performed has allowed to gather information to address adaptation measure on more urgent territory or more critical crops.

2.4.5 Understand Resilience Capacity

To afford the risk of flooding, civil protection has developed systems for alert and response to the events. Furthermore, the municipalities, are developing and improving their climate adaptation plans, also with the coordination and support of Marche region, with the project Marche2Resilience (in P2R project); in their adaptation plans, municipalities consider river flood as a priority.

Nevertheless, the application of adaptation measure such as displacement or revision of urban planning, needs of accurate risk analysis, as those obtained with the application of CLIMAAX workflow using local foods data. Unfortunately, these kind of data (floods map obtained with locally tested models) are not available for all the basins of the region. In this sense the adaptation capacity could be assessed between medium and low.

For agricultural drought, the regional Agricultural Department (managing the European funds for agriculture), for past events has restored farmers for loss of income derived by drought episode recognized has natural calamity. This can be considered a mitigation measure, since it acts to mitigate a damage after this is happened. Both the RPACC and the Regional Program for the Agricultural Fund has adaptation measures, finalized to make the agricultural system more resilient acting directly on agricultural assets (in terms of choice of culture, modality of cultivation, use of water resources, etc.) and/or on knowledge and awareness (with climate service addressing farmers' choices, but also with information and formation of farmers). It is important to note that in the regional context the resilience in terms of implementation of irrigation is limited by the scarce availability of water resources. Measures in this sense are focused on high efficient system of irrigation.

Results emerging from the CRA are crucial in helping public policies to address they effort to the most affected and vulnerable areas or more critical crops in order to implement the adaptation strategies. At the same time, the information, outputs on areas and products less affected by water stress, can be used to guide cropland expansion.

2.4.6 Decide on Risk Priority

Based on the consideration in the paragraphs above, it is possible to assess risk priority integrating the three components: Severity, Urgency and Resilience Capacity.

The river flooding is assessed with a priority "very hight". The severity is Substantial for the current situation and critical in the future, since it is associated with the potential increase in frequency of extreme events. Urgency requires immediate actions, since an increment of potential damage is expected for the near future. Concerning the adaptation capacity, even if some actions are already in place (as the emergency system of civil protection), a homogeneous application of adaptation measures for the increase of resilience (as delocalization, deurbanization, etc) is still lacking. This is also due to the lack of precise information to motivate the decisions (as local floods maps, not available for all the basins).

For agricultural drought, the analysis has demonstrated the severity of risks in terms of potential loss for all the crop considered. This risk is expected to interest the near future and it is hence urgent. Adaptation measure are currently put in place, but the characteristics of the regional context (as the general scarcity of water resources that make not possible to compensate with irrigation the increment in evapotranspiration) reduce the resilience of the agricultural system.

The summary of the key risk assessment is listed in the following table.

Table 2-8 Key risk assessment according to the Risk Evaluation Protocol

Risk Workflow	Severity		Urgency	Capacity	Risk Priority
	C	F		Resilience/ CRM	
River flooding					Very hight
Drought					Very hight

Severity
- Critical
- Substantial
- Moderate
- Limited

Urgency
- Immediate action needed
- More action needed
- Watching brief
- No action needed

Resilience Capacity
- High
- Substantial
- Medium
- Low

Risk Ranking
- Very high
- High
- Moderate
- Low

2.5 Monitoring and Evaluation

The second phase of the climate risk assessment has allowed to gather knowledge on the key risks useful to finalize adaptation measure. As already mentioned in phase 1, a broad risk analysis in Marche Region was performed within the RPACC; in the CRA's phase 1 the analysis has allowed to identify the potentiality for improvement. The specific work done in this phase, with the use of local data, has allowed to better understand how to implement adaptation measure identified.

For the river flood, the use of floods maps developed locally (hence considering local peculiarity as building permeability and defense work) has allowed to have precise information on potential damage with different return period. Results are useful to precisely addressed urban planning or intervention in urban development. Nevertheless, local floods maps are not available for all the river basins in the region. The CRA applied to the Foglia River pilot has allow to refine the methodological approach which can be transfer on other basins where/when local data are available.

The stakeholder involvement on this topic has confirmed the need to implement adaptation measure inside urban planning. An involvement of stakeholder on the Foglia River Basin is planned in phase three for the use of CRA's results at urban level.

For agricultural drought the second phase has shown clearly potential risks in terms of yield loss for the crops considered. The useful output are data and maps on potential loss for the different scenarios (near and mid-term future) more then the straight indication of loss of income. For this latter, the methodology has some limitations when applied at the regional context of Marche region. Since adaptation measure for agricultural drought has a regional scale, the choice for phase two was not to focus on pilot but instead to have the broad vision of the regional situation. Further consideration on economic costs have been added using local data on production and prices.

Magnitude and distribution of potential yield loss will be shared with stakeholder to refine adaptation measure already identified. In particular, the regional strategy for the EAFRD fund and regional agricultural policies, already include measures to contrast climate change effects on crops (regarding for example cultivar selection, tillage practice, irrigation systems, and so on): outputs of the CRA would be used to understand

2.6 Work plan Phase 3

The phase two was focused on the refinement of the workflows in the local context. This has allowed to obtain important results on risks assessment. The third phase will be dedicated to use the results obtained to refine the adaptation measure previously identified.

For river flooding, two main adaptation measures were identified, namely the displacement of structures and infrastructures at risks and the inclusion of assessed risks in urban planning. Based on results obtained for the pilot of Foglia river, in phase three will be activate an involvement of stakeholders, including local community and local authorities, and will be started a dialogue with policy makers to understand how the knowledge of risks could be included in urban planning.

Concerning agricultural droughts, the two adaptations measure previously identified refer to support for crops choice based on climate trend and incentives to more resilient corps. Data obtained with the phase two will be shared with stakeholders and policy makers and in particular with the Regional Agricultural Department responsible for the EAFRD fund and for the rural development strategy. The CRA would be used to address the next programming period of the EAFRD in the Marche. In addition, in phase 3 will be verified further need in terms of risk analysis, especially in term of crop selections or changes in growing period.

3 Conclusions Phase 2- Climate risk assessment

The second phase of the application has allowed reaching different kind of conclusions for the two workflows.

For both the workflow considered, the work done inside Climaax project has allowed to set the methodological approach that could be replicated in other regional context or, in the case of agricultural drought, with other crops.

The Flood River workflow at the pilot level has allowed understanding the importance of the accuracy of the evaluation. Since from this workflow it is expected to understand the opportunity of displacement (or, more in general, where and how by urban planning we would increment the resilience in respect to the specific risk), it is important to evaluate the potential damages in terms of "real" exposure. The use of local data has allowed to refine the analysis and to have precise information about the potential risks. Nevertheless, local data are not available for all the river basins of the Marche Region, and this hinder the application of the workflow in other context.

In addition, the use of the river discharge workflow, has allowed to partially overcome the lacking of an accurate knowledge of the hazard in terms future scenarios. The analysis has shown a relative increase in flood recurrence (larger than 20%) for return period of 5, 10 and 50 years. This has corroborated the assessment of the urgency and enforced the assessment of severity on the risk with different return periods.

The output on the pilot gives accurate information in terms of potential economic loss and identifies location of potential risks. This could help in the refinement of the more general adaptation measures identified in the RPACC, at least in the area analyzed in the Pilot. Nevertheless, the aim of the regional administration is to find adequate adaptation measure for the whole Marche territory. For this reason, in phase three, beside a focus on the Foglia river pilot, the outputs will be used to identify common approach to include in urban planning the knowledge of risks in climate scenarios.

For agricultural drought, in the phase 2 the analysis has refined the risk assessment for 6 selected crops. In Marche in the near future (2026-2030) are expected relevant yield loss for all the crops considered, in particular for maize and beans. The assessment of economic loss with the different scenarios, based on yield loss and data on current production, show critical figures for wheat and maize.

A relevant outcome of the analysis is the evidence that main losses are expected for the near future: this makes urgent the action on adaptation. To contrast the potential loss expected in productivity, different measure can be put in place, ranging from changes in water and soil management, to the adoption of drought-resistant varieties to cope with increased evapotranspiration and precipitation variability. According with literature (*Zhao et al 2022)*, especially for Mediterranean region, changes in cropping systems and revisions to environmental regulations and subsidies, along with efficient and precision irrigation systems are the measures expected to contrast yield loss.

The analysis performed allows for the understanding of future dynamics in crops production and is essential to implement the climate adaptation measures inside strategies and policies of agricultural sector.

4 Progress evaluation

According to the project presented, in the following are listed the key performance indicator and the state of the progress.

Table 4-1 Overview key performance indicators

Key performance indicators	***Progress***
[n. 1] M-R-A formally completed in Marche Region using CLIMAAX methodology	With the conclusion of the second phase, the climate risk analysis in Marche Region according to CLIMAAX methodology is completed.
[n. 2] annual meeting report on stakeholder engagement	1 report produced. The stakeholder engagement will be completed in phase 3.
[n. 2] of notes for policy makers	1 note produced (the second in phase three)
[n. 4] of adaptation measures identified/refined	2 adaptation measures identified for the river floods (displacement and urban planning): further refinement in phase 3. 2 adaptation measures identified for agricultural drought (support for crops choice based on climate trend, incentives to more resilient corps): further refinement in phase 3
[n. 10] articles in regional media mentioning the project	3 articles mentioning the project. To be completed in phase 3
[n. 1] scientific article published regarding Marche Region CLIMArcheX project and its pilot action	To be done before the end of the project and based on the project final results

With the conclusion of phase 2, the MRA is formally completed. Nevertheless, for the workflow on river flooding, it was applied to a pilot area: further implementation in other river basin will be performed after the project closure. Furthermore, in the phase 3, the results of the MRA will be used to refine selected adaptation measures and to improve the adaptation plan.

The stakeholder involvement is described in paragraph 2.1.5; a report on stakeholder engagement for 2025 has been produced. The second report will be produced for the engagement in phase 3.

A first note for policy makers has been presented during the "European Weeks for Regions and Cities 2025", inside the meeting Regional partnership *Climate governance in Mediterranean regions for sustainable growth, held the* 15th October 2025 in Brussels. The communication mentions the work done with CLIMAAX both for agricultural drought and river flooding.

The work done in phase 1 and 2 has allowed to identify adaptation measures: 2 for the river floods displacement and urban planning) and 2 for agricultural drought (support for crops choice based on climate trend, incentives to more resilient corps). In phase three is planned the refinement of these measures. In addition, for agricultural drought, within the stakeholder involvement, will be explore further possible adaptation measures.

Communication to the broad public has been organized by media. A dedicated page to the participation of Marche Region to the project has been activated (CLIMArcheX). Inside the regional web site on climate change adaptation, a section on the contribution of CLIMAAX project to the regional adaptation policy is inserted (CLLIMARCHEX contribution).

A specific note on the participation of Marche region to the CLIMAAX meeting held in Barcellona in June 2025 has been published on LinkedIn.

For the milestones, according to the project, for the second semester the following two were expected:

- M2: 1 Study visit and exchange of experience
- M5 Attend the Climaax workshop held in Barcellona

To optimize the efficiency, the study visit, originally placed between phase 2 and 3, is planned in February/March 2026. In fact, the visit would beneficiate of the output result of the workflow, which have been available only at the end of this second semester.

Concerning M5, two members of the regional team participated to the meeting in Barcellona

Table 4-2 Overview milestones

Milestones	***Progress***
M2: Study visit 1 organized	The study visit was originally planned between phases 2 and 3. To optimize the efficacy, the study visit is planned in 2.1.5 2026
M5: Attend the CLIMAAX workshop held in Barcelona.	Two members of the regional team participated to the meeting in Barcellona

5 Supporting documentation

- *Annex A: Report on agricultural workflow ANNEX_A_Agricoltural_drought.pdf*
- *Annex B –Report on River discharge workflow ANNEX_B_Discharge.pdf*

- ***River floods workflow with local maps***
  - *Hazard – Local flood map for Foglia River: WD_Q10_FFOGLIA.tif*
  - *Hazard – Local flood map for Foglia River: WD_Q50_FFOGLIA.tif*
  - *Hazard – Local flood map for Foglia River: WD_Q100_FFOGLIA.tif*
  - *Hazard – Local flood map for Foglia River: WD_Q500_FFOGLIA.tif*
  - *Risk Building and Polpulation - Foglia_Italy_OSMbuilding_preclassification.png*
  - *Risk Building and Polpulation - Foglia_Italy_criticalinfrastructure_10RP.png*
  - *Risk Building and Polpulation - Foglia_Italy_criticalinfrastructure_500RP.png*

- ***River floods workflow with JRC maps***
  - *Risk Building and Polpulation - myLocation_building_damage_meandepth_10RP.png*
  - *Risk Building and Polpulation - myLocation_building_damage_meandepth_500RP.png*
  - *Risk Building and Polpulation - myLocation_building_flooddepth_10RP.png*
  - *Risk Building and Polpulation - myLocation_building_flooddepth_500RP.png*
  - *Risk Building and Polpulation - myLocation_buildingoutline_floodmap_10RP.png*
  - *Risk Building and Polpulation - myLocation_buildingoutline_floodmap_500RP.png*
  - *Risk Building and Polpulation - myLocation_damage_graph.png*
  - *Risk Building and Polpulation - myLocation_floodmap_10RP.png*
  - *Risk Building and Polpulation - myLocation_floodmap_500RP.png*
  - *Risk Building and Polpulation - myLocation_OSMbuilding_classified_simple.png*
  - *Risk Building and Polpulation - myLocation_popdisplaced_graph.png*
  - *Risk Building and Polpulation - myLocation_popexposed_graph.png*
  - *Risk Building and Polpulation - myLocation_popdisplaced_map_10RP.png*
  - *Risk Building and Polpulation - myLocation_popdisplaced_map_500RP.png*
  - *Risk Building and Polpulation - myLocation_popexposed_map_10RP.png*
  - *Risk Building and Polpulation - myLocation_popexposed_map_500RP.png*

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