



FARCLIMATE

DELIVERABLE 3.9

Analysis of the agriculture,
forestry and fishery sector

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Table of contents

Table of contents.....	1
Project information	2
Deliverable details	3
Executive summary.....	4
1 Introduction.....	5
2 Integration with the Living Lab process	6
2.1 Mapping of T3.6 to the Case Study Journey of D2.3.....	7
3 Stakeholders' workflow	9
4 Assess climate change impact and vulnerabilities	10
4.1 General analysis.....	10
4.2 Specific analysis	11
5 Proposal of action strategies based on the climate change impacts	14
5.1 Selecting Adaptation Strategies.....	14
5.2 Identify and implement adaptation actions	15
5.3 Monitor and evaluate effectiveness	20
6 RAST (Regional Adaptation Support Tool)	20
7 Conclusion	21
ANNEX I: Example of applicability of the methodology in a real case of climate change adaptation in the forestry sector in Soria (Spain)	22
o Introduction	22
o Definition of the area of interest.....	24
o Climate change assessment.....	25
o Climate change impact assessment.....	30
o Identifying adaptation strategy.....	32
o Identifying actions and measures of adaptation	32
o Monitoring	33
o Conclusion.....	33
References.....	34

Project information

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5	INVIALE LIFE CYCLE THINKING S.L.	INV
6	MUNICIPIO DO FUNDAO	FUNDAO
7	GREEN GROWTH GENERATION	GCG
8	UNIVERSITE DE LIEGE	ULIEGE
9	FUNDACIÓN CENTRO DE SERVICIOS Y PROMOCIÓN FORESTAL Y DE SU INDUSTRIA DE CASTILLA Y LEÓN	CESEFOR
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Abstract:	This document outlines the roadmap for the proposed methodology developed to analyse the impact of climate change on three sectors: forestry, agriculture, and fisheries. It includes strategies for assessing climate change impacts and proposed action plans to enhance the resilience of value chains to evolving environmental conditions. However, this methodology serves as a recommendation and can be adapted, simplified, or even replaced by a complementary approach that achieves the same objective: identifying climate change adaptation actions.

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Executive summary

The FARCLIMATE project addresses climate change challenges in forestry, agriculture, and fisheries by developing stakeholder-driven adaptation strategies. Rising temperatures, extreme weather, and ecosystem degradation threaten food security and livelihoods. The project integrates a Living Lab approach, ensuring stakeholders actively shape climate solutions through structured engagement and evaluation tools. The recommended methodology presented, open to modifications or replacements, is focused on a climate change assessment and then on a seeking of solutions to the climate change impact, in the study area.

Climate impact assessments combine general analyses using large-scale datasets with local studies on sector-specific vulnerabilities. Forestry faces biodiversity loss and extreme events, agriculture struggles with soil degradation and water scarcity, and fisheries are affected by ocean warming. Identifying these risks enables tailored adaptation strategies.

Adaptation falls into three categories: resistance (defensive measures), resilience (enhancing recovery), and transition (facilitating ecosystem shifts). Proposed actions include sustainable forest management, efficient water use in farming, and climate-resilient aquaculture. Stakeholder collaboration ensures practical and widely supported solutions.

The Regional Adaptation Support Tool (RAST), from the European Environment Agency, offers a structured framework for risk assessment, adaptation planning, and monitoring. By integrating data, participatory innovation, and evaluation tools, FARCLIMATE advances climate resilience in Europe's forestry, agriculture, and fisheries sectors.

1 Introduction

In recent years, the climate has undergone significant variations, with global temperatures rising approximately 1.1°C above pre-industrial levels due to human-induced greenhouse gas emissions. Currently, the world is experiencing unprecedented climatic shifts, including rising sea levels, shrinking glaciers, and more frequent heatwaves. Extreme weather events, such as devastating hurricanes, prolonged droughts, intense wildfires, and severe floods, are becoming more common, affecting both ecosystems and human populations. Looking ahead, projections indicate that without immediate and substantial emission reductions, global warming is likely to surpass 1.5°C in the coming decades, increasing the risk of more severe climate impacts and making adaptation efforts even more urgent (IPCC, 2023).

On this way, climate change is severely affecting forests, agriculture, and fisheries, threatening ecosystems, food security, and livelihoods. Forests are increasingly impacted by extreme events like droughts, wildfires, storms, and pest outbreaks, which threaten their health, reduce biodiversity, and weaken their ability to act as carbon sinks. Rising temperatures and shifting precipitation patterns are further harming tree growth and forest-dependent communities. Similarly, agriculture faces reduced crop yields, soil degradation, and water scarcity due to climate change, while pests and diseases spread, threatening food production and livelihoods, especially for small-scale farmers. Livestock are also affected by heat stress and disrupted ecosystems. Fisheries are impacted by ocean warming and acidification, reducing fish stocks, shifting species, and threatening coastal communities that rely on fishing for income and sustenance. Extreme weather events, rising sea levels, and storm surges further endanger coastal fisheries and aquaculture (IPCC, 2023).

Under this context, several adaptation strategies are taken into consideration in these three sectors to better adapt to the impact of climate change. In forestry, sustainable forest management, afforestation, reforestation, and conservation efforts are essential to enhance resilience and mitigate climate effects. In agriculture, climate-smart practices, improved water management, sustainable farming, and crop diversification are critical for adapting to changing conditions. For fisheries, sustainable management, aquaculture diversification, marine conservation, and reducing overfishing are necessary for adaptation (IPCC, 2023).

However, not only the environment is being affected by climate change, but also people related to these three sectors. Given this, further efforts should be made to find solutions involving all the related stakeholders in order to collect as many perspectives as possible. In this way, the proposed solution could be pleasing to everyone, but also, the probability that all the stakeholders support the action strategies is higher since they were included in the action development process.

This deliverable is written within the FARCLIMATE project, which is supported by funding from the Climate Change Adaptation Mission of the European Union. In particular, the Deliverable is an output of the Task 3.6 System Climate Innovation under Work Package 3 Characterisation of the case studies. This Work Package seeks to analyse the economic sectors (forestry, agriculture and fishery) in each case study involving the stakeholder's interests, to identify the main problems related to climate change that affect the sustainable management of the sectors resources and to identify actions and solutions, not only technically but also socially feasible, to the identified problems.

In order to reach that multiple objectives, the following methodology presented in this deliverable was developed as a recommended pathway, but being open to be adapted, simplified, or even replaced by a complementary approach that achieves the same main objective: identifying climate change adaptation actions. However, to obtain results for this methodology, it is necessary to create a community of stakeholders that can participate in the solution process. Building the community is the objective of the Living Lab methodology (presented in Deliverable D2.1), which will not be reached until further steps of the FARCLIMATE project. In this way, the results of Task 3.6 are pending for the Living Lab methodology, being both methodologies aligned.

This deliverable describes a recommended methodology for seeking innovative solutions within FARCLIMATE's three core sectors: agriculture, forestry and fishery. This methodology serves as a crucial bridge, connecting the creation of solutions within the Living Labs (WP2) with the specialised sectoral and environmental technical assistance provided by FARCLIMATE, especially with WP5. A bridge that should also be understood in the context of the overall characterisation of the case study's value chains that other tasks in WP3 are carrying out as well as with the potential synergies with other FARCLIMATE activities such as training (WP4), policy recommendations (WP6) or the sharing of climate adaptation knowledge and success stories (WP7). In a more general sense, T3.6 aims to streamline the discovery of innovative, environmentally sustainable, and practically applicable solutions tailored to each sector and the particularities of each case study.

Therefore, in this deliverable, a methodology of seeking solutions for climate change adaptation with applicability to the three sectors of interest is presented. To show its successful applicability, in ANNEX 1, one example case is presented for the forestry sector in the province of Soria (Spain).

2 Integration with the Living Lab process

D2.1 outlined the Living Lab methodological approach for the FARCLIMATE project case studies. There, it was established that the developments of Living Labs in the case studies will be structured with the help of the Living Lab Mapping Canvas. This tool was developed by ENoLL to examine key structural and operational aspects of Living Labs and has been adapted to multitude of co-creation project across Europe. The canvas covers the following topics:

- Purpose of the Living Lab.
- Vision and scope.
- Host organisation.
- Stakeholders.
- Living Lab context.
- People and Internal Roles.
- Strategy.
- SWOT.
- Governance.
- Value for the stakeholders.
- Resources and sustainability.
- Living Lab Communication Channels.

- Monitoring and Evaluation.

In addition, D2.1 introduces the Living Lab Evaluation Framework. This framework is developed to evaluate the maturity levels of both existing Living Labs and those striving to achieve Living Lab status. The Evaluation framework is divided into 5 different sections: Strategy, operations, openness, users & reality, impact & value and stability & harmonization. Moreover, D2.1 also provides Technology Readiness Levels (TRL) applied to Living Labs. The goal is to emphasize the types of exploratory and confirmatory research objectives conducted at each stage and to outline the level of solution maturity. This TRL framework will be used for tracking the evolution of the developed solutions of the FARCLIMATE Living Labs. Key Performance Indicators essential for evaluating Living Labs are also provided.

D2.3 further expanded D2.1. The deliverable documented a strategy to help and guide the setup and deployment of the first group of Living Labs, in the context of the general stakeholder engagement and management strategy of FARCLIMATE (also outlined in D2.1). Regarding the approach to Living Labs, D2.3 provided a blueprint for the Living Lab setup, deployment, and operation specifically adapted to FARCLIMATE case studies. This blue print consists specifically of:

- An adaptation of the Living Lab Mapping Canvas as a template for Living Labs setup and development.
- Integration of the Living Lab processes and phases in a detailed Case Study Journey.
- Design a general Case Study Journey for the setup of Living Labs.

The Case Study Journey of D2.3, in simple terms, outlines the timing and sequence of actions, the connections and dependencies among them, and the main types of stakeholders involved. Actions define touchpoints where different stakeholders interact with a definite goal and produce some result (whether a piece of knowledge or a decision). In this way, the blueprint provides a detailed plan for setting up, deploying, and operating a Living Lab.

Specifically, the Case Study Journey proposes a series of activities needed to develop each case study in a Living Lab format, with each activity representing a touchpoint with stakeholders characterised by a clearly defined objective, a suggested main tool, the participants (using the categories of stakeholders and general roles in Living Labs) and other tools. Additionally, the blueprint suggests durations and timing for each activity.

In summary, D2.1 provides the core elements of Living Labs and the framework to evaluate Living Labs. D2.3 further expands D2.1, by providing a roadmap of the Living Lab methodology adapted to FARCLIMATE case studies.

2.1 Mapping of T3.6 to the Case Study Journey of D2.3

The Case Study Journey comprises a sequence of activities that guide the development of the Living Lab, incorporating elements related to complementary processes (e.g., training, evaluation). The journey consists of a series of touchpoints – actions that involve interaction among stakeholders (partners, core team, local stakeholders, FARCLIMATE partners) to achieve specific objectives, generating knowledge (e.g., maps, documents, artefacts) and/or decisions.

These touchpoints are critical as they establish the key activities through which T3.6 primarily interacts with the Living Lab. In Table 1, we map the D2.3 Case Study Journey touchpoints to the T3.6 methodology outlined in this deliverable. Several categories of interaction were identified, ranging from those contextual to T3.6 to core Living Lab activities where T3.6 close interaction occurs.

Five types of connections between the Case Study Journey and T3.6 were identified:

Three contextual/indirect touchpoints for establishing the Living Lab's community and strategy:

- Stakeholder engagement touchpoints: Important for T3.6 as they involve stakeholders who will participate in its activities.
- Living Lab strategy touchpoints (e.g., Living Lab Mapping Canvas): Define the Lab's overarching strategy, including principles and aims for solutions, which provide the strategic context for T3.6 activities.
- Living Lab evaluation touchpoints: Relevant as later evaluations will assess how solutions are developed within the Living Labs.

Two direct touchpoints. They represent Living Lab activities focused, like T3.6, on climate adaptation solutions. Furthermore, this coordination is crucial as T3.6 bridges the Living Lab with other FARCLIMATE activities, notably WP5. Moreover, it is important to take into account that, in the Case Study Journey, these activities are described from the Living Lab perspective and planned around the methodology's development.

- Preliminary problem/solution identification: Initial discussions by Living Lab participants to identify climate adaptation challenges and solutions. These act as precursors to T3.6's focused activities (highlighted in light blue in Table 1).
- Solution co-creation activities: Core processes where T3.6 collaborates closely. While the Living Lab manages community-driven co-creation, T3.6 ensures alignment with FARCLIMATE partners' sectoral and environmental inputs. These are the activities of the LL that are closely coordinated with T3.6 (highlighted in dark blue in Table 1).

#	Touchpoint	Connection with T3.6
1	Introductory Sessions about Living Labs for partners	Stakeholder engagement
2	Mapping relevant problems and territories, communities, economic activities	Preliminary activity by the LL
3	Negotiation with potential host organisations and core teams	Stakeholder engagement
4	Definition of Canvas (Desirability): 3, 4	Provides strategic context
5	Challenge mapping and preliminary prioritisation	Preliminary activity by the LL
6	Stakeholder mapping	Preliminary activity by the LL
7	Stakeholder classification and strategy for engagement	Provides strategic context
8	Definition of Canvas (Desirability): 1, 2	Provides strategic context
9	Introductory sessions on Living Labs and FARCLIMATE to stakeholders	Stakeholder engagement
10	Stakeholder integration in the Living Lab project for a specific case study	Stakeholder engagement
11	Definition of Canvas (Feasibility): 5-9	Provides strategic context
12	Challenge prioritisation and selection	Preliminary activity by the LL
13	Definition of Canvas (Feasibility): 10 Strategy, 11 SWOT	Provides strategic context
14	Evaluation of cycle 1	Evaluation of the LL

#	Touchpoint	Connection with T3.6
15	Living Lab Crash Course	Stakeholder engagement
16	Co-creation of prototypes and experiments	Coordinated activity
17	Definition of Canvas (Viability): 12, 13, 14	Provides strategic context
18	Design of prototypes	Coordinated activity
19	Pilot interventions	Coordinated activity
20	Evaluate the performance of prototypes	Coordinated activity
21	Evaluation of cycle 2	Evaluation of the LL
Iterate activities 16 to 20 in successive cycles		
	Evaluation of successive cycles of interaction	Evaluation of the LL
	IMPLEMENT: Demonstrate the system	Coordinated activity
	SCALE UP: Exploit the solution	Coordinated activity

Table 1. Mapping of D2.3 Case Study Journey touchpoints to the T3.6 methodology outlined in this deliverable D3.9.

3 Stakeholders' workflow

Once the community is established using the Living Lab Methodology (Deliverable D2.1), a series of in-person meetings should be conducted to assess climate change impacts and vulnerabilities while identifying potential solutions.

Pre-Meeting Preparation

Before each session, the coordination team will prepare relevant data (as detailed in Sections 2 and 3).

Meeting Structure and Topics

Each session, led by the coordination team, will cover the following key topics:

1. Introduction to Climate Change – Overview of climate change effects in the study area.
2. Sector-Specific Impacts – Identification of climate change effects on the economic sector of interest.
3. Adaptation Frameworks – Exploring resistance, resilience, and transformation in the local context.
4. Solution Development – Co-creating strategies and actions to adapt to climate change impacts on the sector.

Session Format

The meetings will follow a structured format to ensure effective engagement:

1. Welcome Coffee.
2. Stakeholder Introductions.
3. Presentation of Meeting Goals.
4. Step-by-Step Topic Presentation.
5. Interactive Questionnaires & Data Collection (e.g., Mentimeter, Google Forms, Manually, etc).
6. Q&A Session.
7. Conclusion and Next Steps.

Post-Meeting Analysis

Following each session, the coordination team will analyse collected feedback and questionnaire data to refine insights and develop actionable recommendations.

4 Assess climate change impact and vulnerabilities

To identify effective climate change adaptation solutions, the first crucial step is to analyse the impact that climate is having on the study area. This impact assessment is approached from two perspectives. First, a general analysis, focused on a broader geographical perspective, provides a general understanding of climate trends and patterns at a larger scale. Then, a specific analysis, focused on the study area itself, allowing for a detailed examination of local vulnerabilities and challenges. This two-step approach ensures a comprehensive evaluation, forming the foundation for well-informed and targeted adaptation strategies.

4.1 General analysis

The general analysis should address past climate variability and possible future scenarios. To achieve this, various databases provide relevant information, such as the Copernicus Climate Data Store (CDS) (<https://cds.climate.copernicus.eu/>), which offers free access to historical climate data, projections, and climate analyses at the European level. Another example is the European Environment Agency (EEA) Climate Data (<https://www.eea.europa.eu/themes/climate/data-and-maps>), which provides access to various climate indicators and data on climate change impacts in Europe.

Additionally, it is essential to conduct an analysis focused specifically on climate change risks within the sector of interest. In this regard, the FARCLIMATE project has carried out a risk assessment for these sectors at the NUTS 3 level (Deliverable D2.2). See Figures 1, 2 and 3. This risk analysis was developed by combining hazard, exposure, vulnerability, and response factors for each sector.

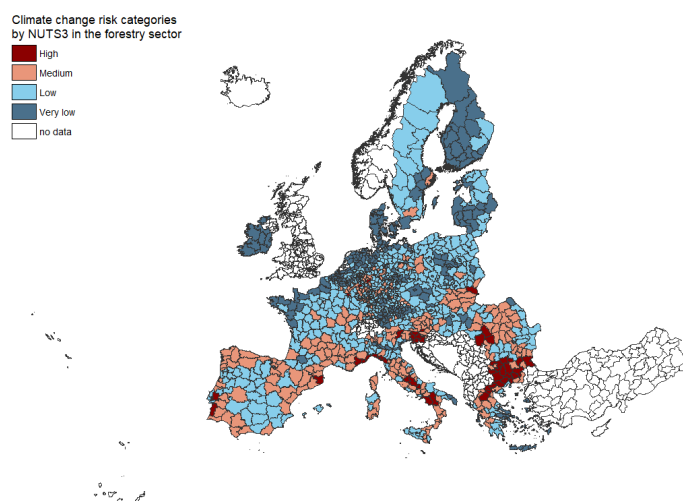


Figure 1. Climate change risk categories by NUT3 in the forestry sector (Source: FARCLIMATE project, Deliverable D2.2)

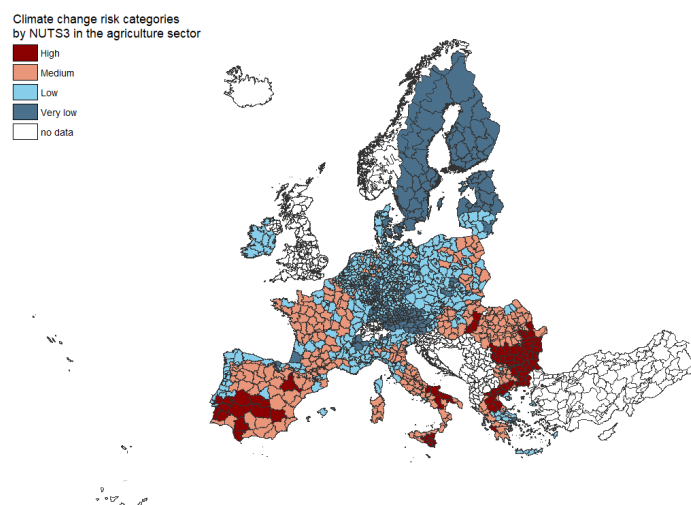


Figure 2. Climate change risk categories by NUT3 in the agriculture sector (Source: FARCLIMATE project, Deliverable D2.2)

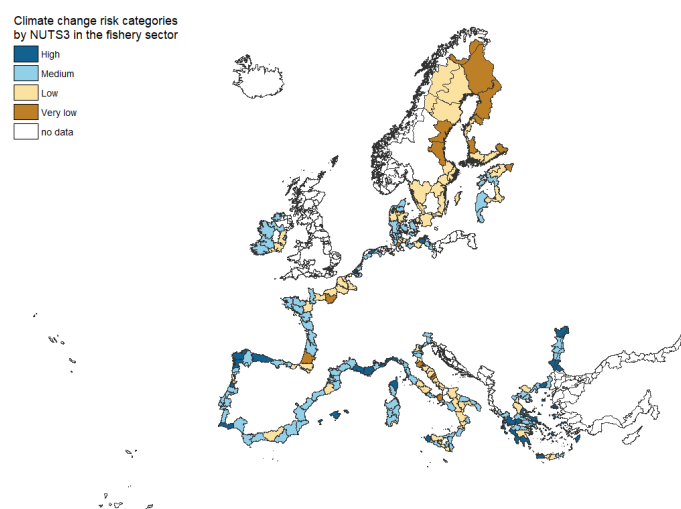


Figure 3. Climate change risk categories by NUT3 in the fishery sector (Source: FARCLIMATE project, Deliverable D2.2)

4.2 Specific analysis

Once the general analysis has been conducted, the next step is to perform a specific analysis of the study area. This involves examining different databases, depending on their open availability.

First, local meteorological station records should be analysed to reliably assess climate variability in the study area. Depending on the sector of interest, key climate variables to consider are:

- **Atmospheric Variables:**
 - Air temperature (maximum, minimum, and average).
 - Precipitation (annual total, seasonal variability, extreme events. Being important for the vegetation, it also impacts on the salinity of the local marine ecosystems)
 - Relative humidity of the air.
 - Wind speed and direction (impact on erosion and pest dispersion, but also to the marine currents).
- **Water and Soil Interaction Variables:**
 - Evapotranspiration (water loss through soil evaporation and plant transpiration).
 - Soil moisture (variations due to droughts or heavy rains).
 - Water temperature.
- **Radiation and Energy Balance Variables:**
 - Solar radiation (affecting photosynthesis and crop growth).
- **Extreme Climate Events:**
 - Drought frequency and intensity.
 - Hurricanes.
 - Floods.
 - Heatwaves.
 - Heavy snowfall.
 - Frost events.
 - Wildfires.

Additionally, future climate projections should be addressed, including the indicators of the last IPCC report, for the climatic variables of interest. On this way, climate change impact on the study area would be successfully assessed including future perspectives. Also, future species distribution models of the main species of the study area should be produced for a better understanding.

Second, sector-specific variables should be examined to assess how climate change is directly affecting the study case.

In the forestry sector, relevant variables include:

- **Forest and Vegetation Variables:** Tree growth (diameter and height increase), tree mortality and regeneration, species composition (biodiversity and dominant species changes), phenology (flowering, fruiting, and leaf fall in response to climate), canopy cover (density and structural changes), and vegetation health (chlorophyll levels, water stress, pests, and diseases).
- **Soil Variables:** Soil moisture (variations due to droughts or heavy rains), soil temperature, organic matter content, soil erosion and loss, and nutrient availability.
- **Socioeconomic Variables:** production and profitability (wood extraction, income from forest products), employment and livelihoods (job availability, rural migration), governance and policies (land tenure, conservation programs) and market dynamics (demand, prices, and certification of sustainable products).

In the agricultural sector, key variables include:

Agriculture is shaped by three interconnected dimensions: ecological, economic, and social.

1. Ecological variables: These factors influence environmental sustainability and agricultural production:

- Soil health: Soil moisture (water availability for crops), soil temperature (affecting germination and root growth), organic matter content (fertility and water retention capacity), and nutrient availability (nitrogen, phosphorus, potassium) determine soil productivity.
- Soil degradation: Soil erosion (loss of topsoil due to heavy rains or winds) and soil salinity (caused by improper irrigation or saline water intrusion) reduce long-term agricultural sustainability.
- Water resources and biodiversity: The availability of clean water and diverse plant species contributes to ecosystem resilience and climate adaptation. Farmers with access to natural resources and sustainable practices can better withstand environmental stress.

2. Economic variables: These factors impact the financial sustainability of farming and food production:

- Water availability for irrigation: Access to reliable water sources affects crop productivity and economic stability. Farmers with adequate irrigation infrastructure are less vulnerable to droughts and erratic rainfall.
- Agricultural inputs and costs: The availability and affordability of fertilizers, pesticides, and improved seeds influence production efficiency. Rising costs can reduce farmers' profitability, especially for smallholders with limited financial resources.
- Economic losses and market access: Climate-related disasters such as droughts, floods, and frost lead to financial losses. Farmers with diverse income sources, insurance, or cooperative membership have greater economic resilience.
- Food security and employment: Agricultural production directly impacts food availability, rural employment, and migration patterns. Financial challenges often push farmers to seek off-farm work or migrate to urban areas in search of stable income.

3. Social variables: These factors influence farmers' well-being, community resilience, and adaptive capacity:

- Knowledge and skills (human capital): Farmers' education, training, and experience determine their ability to adopt improved agricultural techniques and respond to climate risks. Limited access to extension services weakens adaptation capacity.
- Community support and networks (social capital): Farmer cooperatives, local organizations, and knowledge-sharing networks provide crucial support during crises. Strong social connections improve access to resources, labor, and market opportunities.
- Migration and labor availability: Climate change and economic instability influence labor patterns in rural areas. The movement of people from farming to other sectors affects food production and rural development.

By strengthening these three key dimensions (i.e., ecological, economic, and social) and improving access to livelihood assets, farmers can enhance their resilience, sustain production, and adapt to environmental and market challenges.

In the fishery sector, relevant variables include:

- Environmental variables of the aquatic ecosystem: Surface and bottom sea temperature, water salinity (highlighting changes due to increased rainfall or droughts), water pH (ocean acidification caused by higher atmospheric CO₂), eutrophication, dissolved oxygen levels (affecting fish and marine organisms' survival), harmful algal blooms), nutrient availability (impacting phytoplankton productivity, hence the overall food chain), wind speed and average direction at the sea surface (affecting episodes of ocean recirculation) and ocean currents and tides (potentially altering species migration routes).
- Biological Variables (Species and Fisheries Production): Abundance of commercial species (population reductions or shifts), fish size and weight (indicator of environmental stress and overfishing), reproductive phenology (changes in spawning seasons), presence of invasive species (potential displacement of native species), appearance of new pathologies (new bacteria or viruses affecting the resource) and species redistribution (shifts toward colder or deeper waters).
- Socioeconomic Variables: Catch per unit effort (CPUE) (indicator of fish stock availability), fishers' and communities' income (impacted by variations in catches), fuel and operational costs (if longer distances are required for fishing), demand and prices of fishery products (fluctuations due to supply and market changes), low generational change of workers (due to uncertainty on the profitability of the practice) and local food security (dependence on fisheries for sustenance).

By conducting this sector-specific analysis, a comprehensive understanding of climate change impacts can be achieved, allowing for the development of effective adaptation strategies tailored to the needs of each sector.

5 Proposal of action strategies based on the climate change impacts

Having assessed how climate change is impacting the economic sector in the study area, different adaptation strategies should be selected depending on the expected changes. Once done that, the next step is going further to identify and implement the more appropriate adaptation actions.

5.1 Selecting Adaptation Strategies

Adaptation strategies form a continuum from broad conceptual approaches to practical implementation, helping ecosystems respond to climate change. This framework is based on three key options: resistance, resilience, and transition (Swanston et al, 2020; Nagel et al, 2017). See Figure 4 for a better understanding.

Resistance or mitigation actions focus on strengthening ecosystem defences against anticipated changes or disturbances to maintain existing conditions. While effective in the short term, they require increasing effort and resources over time, particularly as climate shifts further from historical norms. Resistance is most suitable for ecosystems with low vulnerability but carries the risk of irreversible change if climate conditions become unsuitable.

Resilience actions enhance an ecosystem's ability to recover from disturbances and tolerate changing conditions while maintaining overall function. It allows some changes, but eventually it returns to the reference situation. These actions are most effective in systems that already withstand environmental variability. However, resilience has limitations, as excessive environmental change can push ecosystems beyond their capacity to recover, leading to transformation.

Transition actions proactively accommodate and facilitate ecosystem changes, helping them adapt to new climate conditions. Unlike resistance and resilience, which aim to preserve existing ecosystems, transition strategies guide the transformation toward a different ecosystem with new characteristics. This approach is best suited for highly vulnerable ecosystems where maintaining current conditions is impractical or unsustainable. Transition strategies are typically long-term and phased into broader management plans.

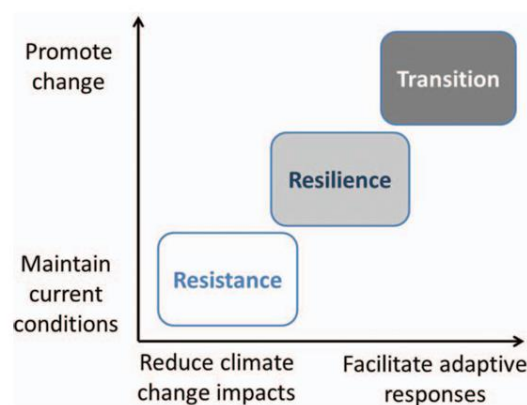


Figure 4. Adaptation options used in the ASCC study, representing a continuum of management goals related to levels of desired (or tolerated) change in ecosystem attributes (represented here on the vertical gradient) and mechanisms for coping with climate change (here, the horizontal gradient). Source: Nagel et al, 2017.

These three adaptation options—resistance, resilience, and transition—represent different points along the adaptation continuum, with increasing specificity in their application. Adaptation strategies generally follow a progression from resistance-focused approaches to transition-oriented solutions, though no single approach is prioritized over another. Effective adaptation requires flexible, site-specific strategies tailored to varying climate vulnerabilities and management goals (Swanston et al, 2020).

5.2 Identify and implement adaptation actions

To address the challenges posed by a changing climate and environmental conditions, management practices may need to be adjusted. Identifying potential challenges and opportunities will facilitate the development of actions that can adapt strategies to achieve property goals (Janowiak et al, 2022).

The evaluation of specific actions or tactics should begin with the following considerations:

Time Frames: When will the action be implemented? Some actions may be short-term, while others may occur long-term or after specific events.

Benefits: What advantages does the action provide? Does it address a major challenge, multiple challenges, or offer co-benefits such as carbon mitigation and improved visitor experiences?

Drawbacks and Barriers: What challenges might arise from this action, including legal, financial, infrastructural, or social barriers?

Effectiveness: Will the action achieve its intended goal?

Feasibility: Is the action implementable?

By evaluating these factors, a better understanding will emerge of which actions best address the challenges, offer significant benefits, and are feasible given available resources.

Below is a list of example adaptive actions proposed for each studied economic sector along with other potential actions not included here.

In the forestry sector (Swanston et al, 2020):

Strategy 1: Sustain fundamental ecological functions.

- 1.1. Reduce impacts to soils and nutrient cycling.
- 1.2. Maintain or restore hydrology.
- 1.3. Maintain or restore riparian areas.
- 1.4. Reduce competition for moisture, nutrients, and light.
- 1.5. Restore or maintain fire in fire-adapted ecosystems.

Strategy 2: Reduce the impact of biological stressors.

- 2.1. Maintain or improve the ability of forests to resist pests and pathogens.
- 2.2. Prevent invasive species establishment and remove existing invasive species
- 2.3. Manage herbivory to promote regeneration of desired species.

Strategy 3: Reduce the risk and long-term impacts of severe disturbances.

- 3.1. Alter forest structure or composition to reduce risk or severity of wildfire.
- 3.2. Establish fuelbreaks to slow the spread of catastrophic fire.
- 3.3. Alter forest structure to reduce severity or extent of wind and ice damage.
- 3.4. Promptly revegetate sites after disturbance.

Strategy 4: Maintain or create refugia.

- 4.1. Prioritize and maintain unique sites.

4.2. Prioritize and maintain sensitive or at-risk species or communities.

4.3. Establish artificial reserves for at-risk and displaced species.

Strategy 5: Maintain and enhance species and structural diversity.

5.1. Promote diverse age classes.

5.2. Maintain and restore diversity of native species.

5.3. Retain biological legacies.

5.4. Establish reserves to maintain ecosystem diversity.

Strategy 6: Increase ecosystem redundancy across the landscape.

6.1. Manage habitats over a range of sites and conditions.

6.2. Expand the boundaries of reserves to increase diversity.

Strategy 7: Promote landscape connectivity.

7.1. Reduce landscape fragmentation.

7.2. Maintain and create habitat corridors through reforestation or restoration.

Strategy 8: Maintain and enhance genetic diversity.

8.1. Use seeds, germplasm, and other genetic material from across a greater geographic range.

8.2. Favour existing genotypes that are better adapted to future conditions.

Strategy 9: Facilitate community adjustments through species transitions.

9.1. Favour or restore native species that are expected to be adapted to future conditions.

9.2. Establish or encourage new mixes of native species.

9.3. Guide changes in species composition at early stages of stand development.

9.4. Protect future-adapted seedlings and saplings.

9.5. Disfavour species that are distinctly maladapted.

9.6. Manage for species and genotypes with wide moisture and temperature tolerances.

9.7. Introduce species that are expected to be adapted to future conditions.

9.8. Move at-risk species to locations that are expected to provide habitat.

Strategy 10: Realign ecosystems after disturbance.

10.1 Promptly revegetate sites after disturbance.

10.2. Allow for areas of natural regeneration to test for future-adapted species.

10.3. Realign significantly disrupted ecosystems to meet expected future conditions.

In the agriculture sector (FAO, 2017):

Strategy 1. Use of Climate-Resilient Seeds and Crop Varieties

- 1.1 Selecting and planting high-quality seeds and well-adapted crop varieties that enhance productivity and reduce crop failure risks.
- 1.2 Choosing drought and temperature-resistant crop species that can ensure agricultural sustainability under extreme climatic conditions.
- 1.3 Promoting intra- and inter-specific crop diversity (e.g., intercropping, crop rotations) that improve ecosystem resilience and economic stability by reducing dependency on a single crop.

Strategy 2. Sustainable Soil and Land Management

- 2.1 Implementing conservation agriculture to improve soil health and enhances productivity.
- 2.2 Enhancing soil organic matter to increase water retention and reduces erosion, benefiting long-term sustainability.
- 2.3 Using minimum tillage and direct seeding techniques.
- 2.4 Applying integrated soil fertility management (organic and inorganic inputs) to balanced nutrient supply and sustainable farming.

Strategy 3. Water Management for Resilience

- 3.1 Using precision irrigation techniques (drip irrigation, deficit irrigation).
- 3.2 Implementing rainwater harvesting and water conservation practices.
- 3.3 Establishing efficient drainage systems in flood-prone areas.

Strategy 4. Agroforestry and Biodiversity Conservation

- 4.1 Integrating trees and shrubs into farming systems to improve microclimates.
- 4.2 Protecting and restoring ecosystems such as mangroves and grasslands.
- 4.3 Enhancing pollination and pest control through diversified landscapes.

Strategy 5. Integrated Pest and Disease Management (IPM)

- 5.1 Using biological control agents and habitat manipulation.
- 5.2 Employing resistant crop varieties to reduce pesticide dependence.
- 5.3 Applying timely pest monitoring and forecasting techniques.

Strategy 6. Climate-Smart Livestock and Agro-Pastoral Systems

- 6.1 Diversifying livestock breeds to withstand climate variability.
- 6.2 Implementing rotational grazing to maintain pasture health.

6.3 Integrating livestock with crop farming for nutrient cycling.

Strategy 7. Risk Management and Early Warning Systems

7.1 Using weather forecasting to optimize planting and irrigation.

7.2 Establishing community-based climate risk management plans.

7.3 Developing early warning systems for pests, diseases, and extreme weather.

Strategy 8. Diversified Farming Systems

8.1 Promoting crop-livestock integration for resilience.

8.2 Encouraging urban and peri-urban agriculture to enhance food security.

8.3 Supporting agro-tourism and alternative income sources for farmers.

In the fishery sector (FAO, 2017):

Strategy 1. Ecosystem-Based Fisheries Management

1.1 Implement marine protected areas (MPAs) or a similar protection figure to preserve biodiversity and replenish fish stocks.

1.2 Apply sustainable fishing quotas and gear restrictions to prevent overfishing.

1.3 Promote co-management approaches where local communities, from fishers to consumers and local administration, participate in decision-making.

Strategy 2. Biodiversity Conservation

2.1 Protect and restore mangroves, seagrass meadows, and coral reefs as natural shelters against climate change.

2.2 Implement habitat rehabilitation programs to support fish populations.

2.3 Reduce the reliability in mono-specific cultures and catches.

Strategy 3. Climate-Smart Aquaculture

3.1 Develop integrated multi-trophic aquaculture (IMTA) to optimize resource use and reduce waste.

3.2 Promote low-impact aquaculture systems such as recirculating aquaculture systems (RAS).

Strategy 4. Climate-Resilient Infrastructure and Technology

4.1 Improve fishing vessel designs for energy efficiency and safety.

4.2 Establish resilient coastal infrastructure for fish landing sites and storage.

4.3 Use smart aquaculture systems with automated water quality monitoring.

4.4 Increase the different gear on board to target different species

Strategy 5. Sustainable Feeds and Resource Use

- 5.1 Reduce reliance on wild fish stocks for feed in aquaculture practices by using alternative protein sources.
- 5.2 Optimize feeding strategies to improve feed conversion ratios.
- 5.3 Promote sustainable fishmeal and fish oil alternatives, such as insect-based proteins.

Strategy 6. Post-Harvest Loss Reduction

- 6.1 Improve cold chain logistics to prevent spoilage.
- 6.2 Develop solar-powered fish drying and smoking facilities.
- 6.3 Encourage community-based fish processing to add value and reduce waste.
- 6.4 Improve the management and energetic sustainability of canneries.

Strategy 7. Monitoring and Early Warning Systems

- 7.1 Utilize satellite and remote sensing technology for oceanic and climate monitoring.
- 7.2 Implement community-based fish stock and climate observation programs.
- 7.3 Develop digital platforms for real-time climate data sharing.

Strategy 8. Community-Based Adaptation Strategies

- 8.1 Provide capacity-building programs for fishers and aquaculture farmers on climate risks.
- 8.2 Establish alternative livelihood programs to reduce dependence on vulnerable fish stocks.
- 8.3 Support fisher cooperatives for shared resource management and adaptation planning.

5.3 Monitor and evaluate effectiveness

Monitoring helps ensure desired outcomes over time by assessing whether project goals are being met and how effective actions are. While scientific methods can be costly and complex, the focus here is on evaluating goal achievement and action effectiveness. Monitoring supports adaptive management by allowing flexible adjustments in response to new information, especially in the face of uncertainty due to climate change (Janowiak et al, 2022).

6 RAST (Regional Adaptation Support Tool)

Complementary to the presented methodology here, also it is recommended the use of the RAST Tool. The Regional Adaptation Support Tool (RAST) is a resource developed by the European Environment Agency (EEA) to assist local and regional authorities in planning, implementing, and evaluating climate change adaptation strategies (European Environmental Agency, 2025). It provides practical guidance through six key steps aligned with the climate adaptation policy process:

1. Preparing the Ground for Adaptation.
2. Assessing Climate Change Risks and Vulnerabilities.
3. Identifying Adaptation Options.
4. Assessing and Selecting Adaptation Options.
5. Implementing Adaptation Policies and Actions.
6. Monitoring, Evaluation, and Learning.

Each step includes an overview and detailed support, supplemented by resources such as data providers, examples, and tools from the EU Mission on Adaptation, Climate-ADAPT, and other partners.

RAST is designed to be flexible and iterative, adapting to the unique context and progress of each local or regional authority. Whether starting from scratch or further along in the policy process, users can find guidance on the steps relevant to their situation.

By utilizing RAST, stakeholders and authorities can develop comprehensive adaptation strategies, implement effective actions, and establish robust monitoring and evaluation frameworks to enhance resilience to climate change.

7 Conclusion

The FARCLIMATE project highlights the pressing need for climate adaptation strategies in forestry, agriculture, and fisheries, emphasizing stakeholder involvement as a key component. By integrating both general and specific climate impact analyses, the project ensures a comprehensive understanding of vulnerabilities and risks, allowing for tailored adaptation solutions. The proposed methodologies categorize adaptation into resistance, resilience, and transition strategies, ensuring flexible responses to varying climate challenges.

To maximize the effectiveness of these strategies, their implementation should be integrated into the Living Lab process. On one hand, these methodologies facilitate stakeholder engagement by setting a common goal and identifying shared climate risks, fostering a sense of commitment. On the other, they establish collaborative solution-seeking dynamics, ensuring that adaptation actions are co-developed and widely supported. This participatory approach strengthens adaptation efforts, making them more socially and technically feasible while increasing the likelihood of successful implementation.

ANNEX I: Example of applicability of the methodology in a real case of climate change adaptation in the forestry sector in Soria (Spain)

This annex presents a real study case conducted as part of the *Life Soria Forest Adapt* project (<https://www.soriaforestadapt.es/>). The study was carried out in the province of Soria, Spain, through a collaboration between Cesefor and the Territorial Service of Soria (Regional Government of Castilla y León), acting the later as key stakeholder responsible for managing the pilot forest under study.

The methodology applied in this study case follows, in broad terms, the same approach outlined in this report. Specifically, it is based on the methodology proposed by *Swanston et al. (2016)* in *Forest Adaptation Resources: Climate Change Tools and Approaches for Land Managers (2nd edition)*, available at: https://www.fs.usda.gov/nrs/pubs/gtr/gtr_nrs87-2.pdf

Introduction

This study is part of the Life Soria Forest Adapt project (<https://www.soriaforestadapt.es/>), conducted between 2021 and 2025. The project's main objective was to enhance the adaptive capacity of forest formations in the province of Soria, Spain, and, by extension, the forests of Southern Europe, in response to climate change. This was achieved by incorporating adaptive measures into the management plans of 15 public and private forests, covering a total area of 36,000 hectares.

The project focused on eight key forest species that are most representative of the province:

- *Pinus sylvestris*.
- *Pinus pinaster*.
- *Pinus nigra*.
- *Juniperus thurifera*.
- *Fagus sylvatica*.
- *Quercus pirenaica*.
- *Quercus faginea*.
- *Quercus ilex*.

The general study area is the province of Soria, Spain (See Figure 5). However, this particular case study focuses on the Public Forest 195 – Hayedo (MUP 195 from now in advance) (See Figure 6).



Figure 5. Location of the province of Soria (red) in Spain.

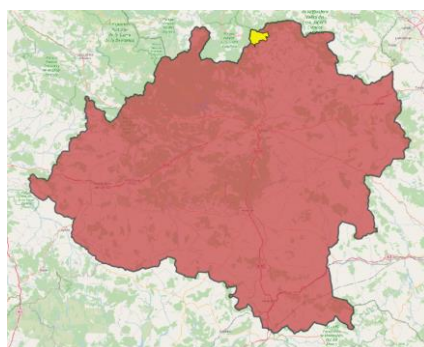


Figure 6. Location of the MUP 195 (yellow) in the province of Soria (red).

This forest is publicly managed through a forest management plan with a validity period of approximately 10 to 15 years. The primary objective of the study was to identify the impacts of climate change on MUP 195 and propose adaptation measures to the current management plan. To reach that objective the methodology presented in Swanston et al (2016) (Figure 7) was followed with adaptations, that are presented in the following sections.

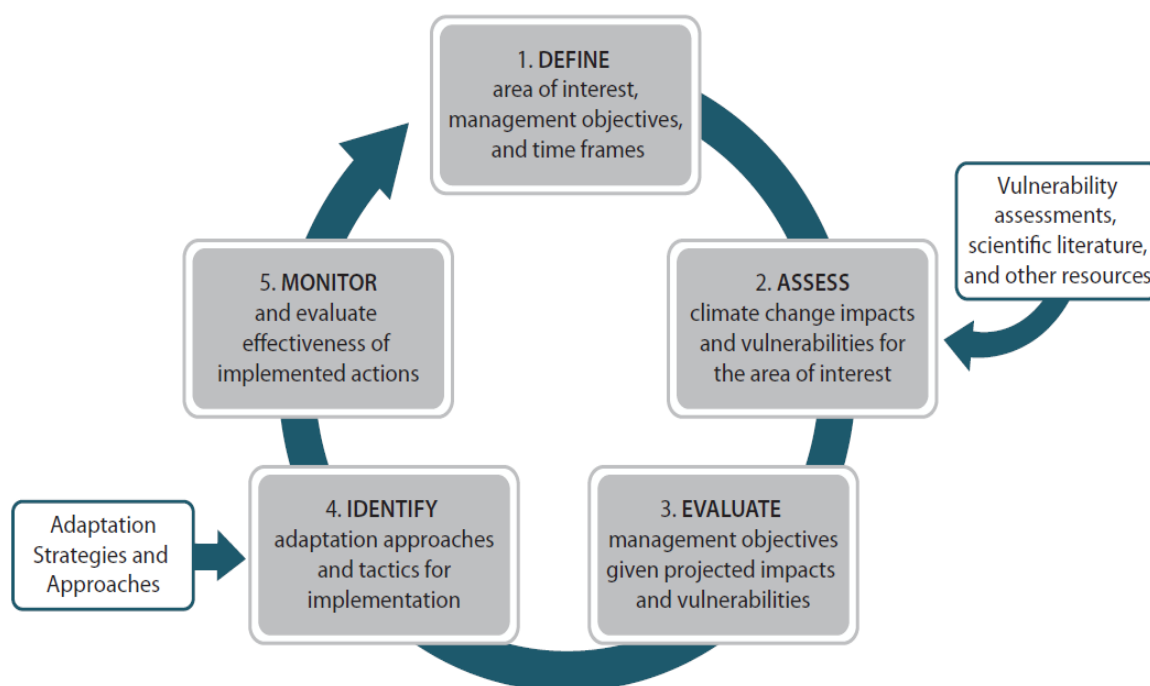


Figure 7. Adaptation process used to incorporate climate change as a management consideration and help ecosystems adapt to the anticipated effects of climate change. Source: Swanston et al (2016).

This methodology was implemented by the Cesefor team, acting as a meeting coordinator, while public technicians responsible for forest management participated as stakeholders. A total of three joint in-person sessions were held to address the different key aspects of the study (Figure 8).



Figure 8. One of the three in-person sessions carried out during the application of the methodology.

Definition of the area of interest

General Information

- Total Area: 2,678 ha.
- Location: Santa Cruz de Yanguas / Villar del Río.
- Ownership: Excomunidad de Yanguas y su Tierra.
- Administrative Division: Territorial Section III, Tierras Altas Forest District.
- Province: Soria.
- Forest Management History:
 - First management plan: 1963.
 - First revision: 2008.
 - Latest revision: 2024.

Forest Types

- Dense natural Scots pine forest (*Pinus sylvestris*).
- Open regenerating Scots pine forest (affected by natural disturbances).
- Beech forest (*Fagus sylvatica*).
- Planted Scots pine forests.

Topography and Soils

- Altitude: Ranges between 1,240 m and 1,790 m.
- Average Slope: 28.9%; terrain is undulating with variable slopes allowing accessibility.
- Aspect Distribution:
 - North: 26.0%.
 - South: 18.3%.
 - East: 31.4%.

- West: 22.6%.
- Hydrology:
 - Baos River (tributary of the Cidacos River, Ebro Basin).
 - Ostaza River.
 - Three streams and three ravines.
- Soil Characteristics:
 - Generally low rockiness, but includes scree and rocky outcrops.
 - Sandy-clay soil with acidic pH.

Change Factors

- Storms (wind and snow).
- Pest outbreaks (notably bark beetles).
- Herbivore pressure.
- Potential risk of wildfires.

Forest Management Background

The dense natural Scots pine forest is managed through selective silviculture, with a focus on identifying and promoting future dominant trees. The rotation period is approximately ten years, and thinning is carried out using a Successive Uniform Thinning approach. Within this forest type, two reserve areas covering a total of 47 hectares have been established. Additionally, five stands, covering 214 hectares, function as ecological corridors and are managed under ProSilva principles, three of which consist of beech forests. These corridors also include the designated reserve zones.

In areas where Scots pine forests are regenerating following natural disturbances, a stand-by-stand assessment is conducted to determine whether natural regeneration is progressing effectively or if additional interventions are required. The beech forest within the study area is currently left unmanaged, with no harvesting activities taking place. In the planted Scots pine forests, initial thinning has been carried out across most of the area following a selective silvicultural approach.

Climate change assessment

Observed climate data

This data was obtained from ALLUÉ CAMACHO, C. & GARCÍA LÓPEZ, J.M., 2024. FITOCLIM. Diagnóstico fitoclimático de cubiertas forestales en un contexto de cambio climático (<https://soriaforestadapt.es/fitoclim/>).

The following variables were studied:

FACTOR	MEANING	UNIT
K	Aridity intensity. Calculated by the ratio A_s/A_h , where A_h is the humid area of the climodiagram (P_i curve above T_i , meaning $2T_i < P_i$) and A_s is the dry area of the climodiagram (P_i curve below T_i , meaning $2T_i > P_i$).	-
A	Duration of aridity, in the sense of GAUSSEN, meaning the number of months in which the T_i curve is above the P_i curve, i.e., when $2T_i > P_i$.	months
P	Total annual precipitation.	mm
PE	Minimum summer precipitation (June, July, August, or September).	mm
TMF	Lowest mean monthly temperature.	°C
T	Annual mean temperature.	°C
TMC	Highest mean monthly temperature.	°C
TMMF	Mean of the minimum temperatures of the month with the lowest mean temperature.	°C
TMMC	Mean of the maximum temperatures of the month with the highest mean temperature.	°C
HS	Guaranteed frost. Calculated as the number of months where $T_i \leq 4^\circ\text{C}$.	months
PV	Free plant activity period, calculated as the number of months where $T_i \geq 7.5^\circ\text{C}$, excluding periods where $A > 0$.	months
OSC	Thermal oscillation. Calculated as $TMC - TMF$.	°C

Table 2. Explanation of the climatic variables analysed during the methodology application.

Firstly, in general at the Soria province level:

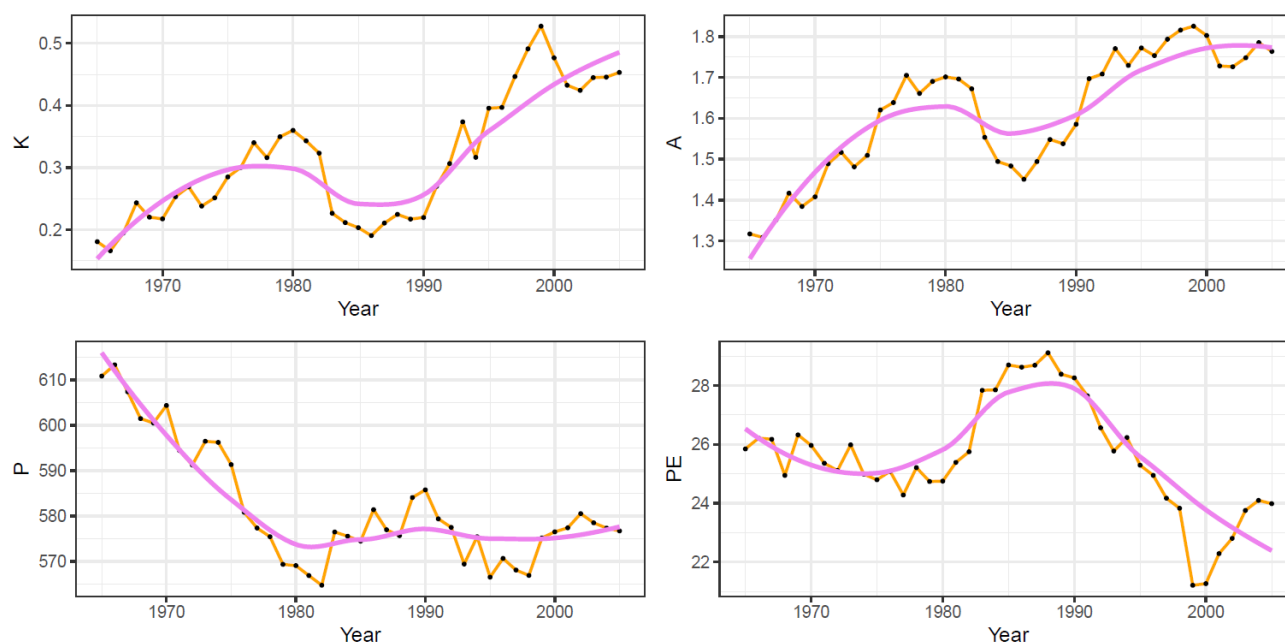




Figure 9. Observed variation in the province of Soria for the studied climatic variables. Own elaboration from data obtained in <https://soriaforestadapt.es/fitoclim/>

Then, more specifically, at the MUP 95 level:

Variable	Period 1950-1979	Period 1990-2019	Variation	Variation (%)
T	7,4	8,4	1,0	13,5%
TMF	0	1,5	1,5	-
TMC	16,7	17,3	0,6	3,6%
TMMC	24,1	24,5	0,4	1,7%
TMMF	-3,2	-2,8	0,4	12,5%
HS	4,8	3,7	-1,1	-22,9%
P	925	869	-56,0	-6,1%
PE	40	37	-3,0	-7,5%
K	0	0	0,0	-
A	0	0	0,0	-
PV	5,4	5,9	0,5	9,3%
OSC	16,7	15,8	-0,9	-5,4%

Table 3. Observed variation in the MUP 195 for the studied climatic variables. Own elaboration from data obtained in <https://soriaforestadapt.es/fitoclim/>

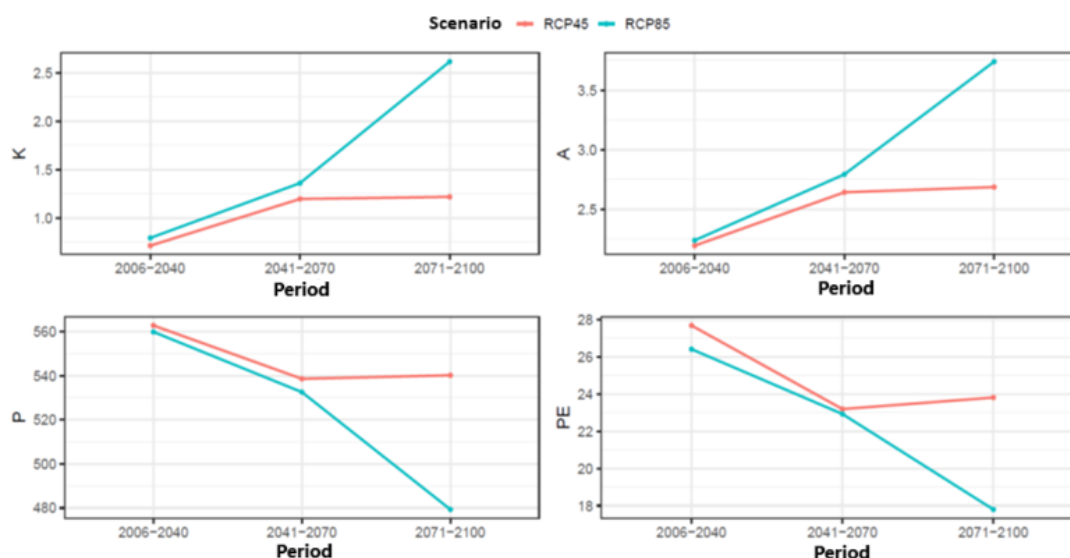
In summary, the more important observed trends were:

- Increase in the mean temperature.
- Increase in the minimum temperatures.
- Increase in the maximum temperatures.
- Decrease in the precipitation.
- Stability in terms of no aridity.
- Decrease in the period of the guaranteed frost.
- Increase in the free plant activity period.

Predicted climate data

This data was obtained from ALLUÉ CAMACHO, C. & GARCÍA LÓPEZ, J.M., 2024. FITOCLIM. Diagnóstico fitoclimática de cubiertas forestales en un contexto de cambio climático (<https://soriaforestadapt.es/fitoclim/>).

Firstly, in general at the Soria province level:



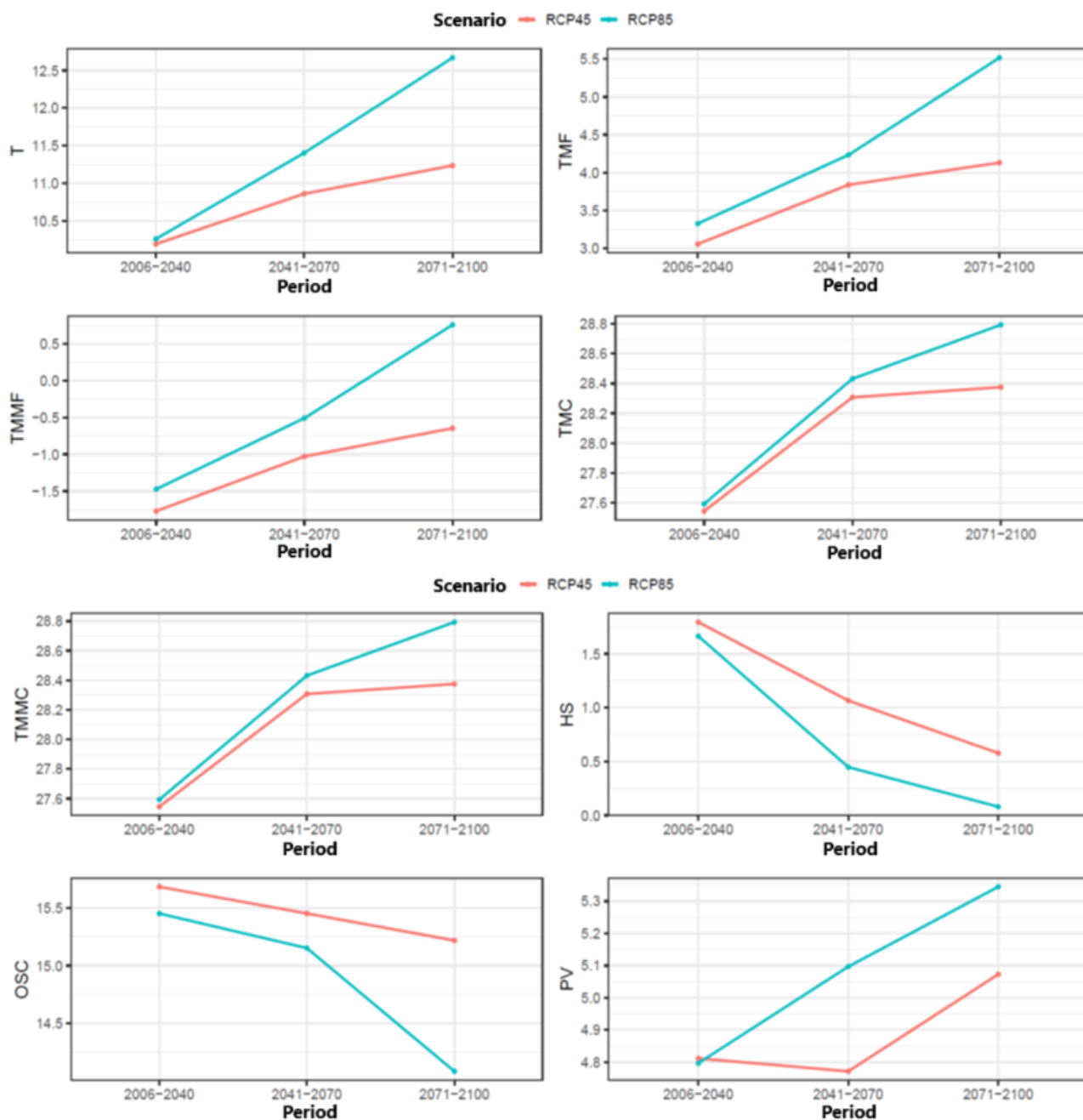


Figure 10. Predicted variation in the province of Soria for the studied climatic variables. Own elaboration from data obtained in <https://soriaforestadapt.es/fitoclim/>

Then, more specifically, at the MUP 95 level:

Factor	Reference period 1990-2019	RCP 4.5 (2070- 2100)	Variation	Variation(%)	RCP 8.5 (2070- 2100)	Variation	Variation(%)
T	8,4	9	0,6	7,1%	10,5	2,1	25,0%
TMF	1,5	2,5	1,0	66,7%	4	2,5	166,7%
TMC	17,3	16,9	-0,4	-2,3%	17,2	-0,1	-0,6%
TMMC	24,5	24,5	0,0	0,0%	25,2	0,7	2,9%
TMMF	-2,8	-1,3	1,5	53,6%	0,3	3,1	-110,7%
HS	3,7	3,2	-0,5	-13,5%	0	-3,7	-100,0%
P	869	797	-72,0	-8,3%	702	-167,0	-19,2%
PE	37	40	3,0	8,1%	32	-5,0	-13,5%
K	0	0	0,0	-	0,044	0,0	-
A	0	0	0,0	-	1,22	1,2	-
PV	5,9	6,3	0,4	6,8%	6,3	0,4	6,8%
OSC	15,8	14,9	-0,9	-5,7%	14,7	-1,1	-7,0%

Table 4. Predicted variation in the MUP 195 for the studied climatic variables. Own elaboration from data obtained in <https://soriaforestadapt.es/fitoclim/>

In summary, the more important predicted trends are:

- Increase of the mean temperature.
- Increase of the minimum temperatures.
- Stability of the maximum temperatures.
- Decrease of the precipitation.
- Stability in terms of no aridity.
- Decrease in the period of guaranteed frost, especially in the scenario RCP 8.5.
- Increase in the free plant activity period.

Synergies between climate change and other drivers of change

In the MUP 195 the following disturbances were occur often during recent years:

- Wind and snow gales.
- Pests (scolytids).
- Herbivore pressure.

Climate change impact assessment

Observed impacts in the forest

Dense Scots pine forest:

- No functional variations. In good condition.
- Expansion of holly under pine canopy.
- Expanding beech under pine canopy.

Open regenerating Scots pine forest:

- Pending detection of possible regeneration problems. In any case, the effect of herbivores would also have an impact.

Beech forest:

- In good condition. Normally the beech trees turn yellow at the end of the summer period, when they do not last the whole summer, with the consequent impact on growth. They then recover.

Planted Scots pine forests:

- Good conditions.

Predicted impacts on the main forest species

Obtained from ALLUÉ CAMACHO, C. & GARCÍA LÓPEZ, J.M., 2024. FITOCLIM. Diagnosis fito-climática de cubiertas forestales en un contexto de cambio climático (<https://soriaforestadapt.es/fitoclim/>).

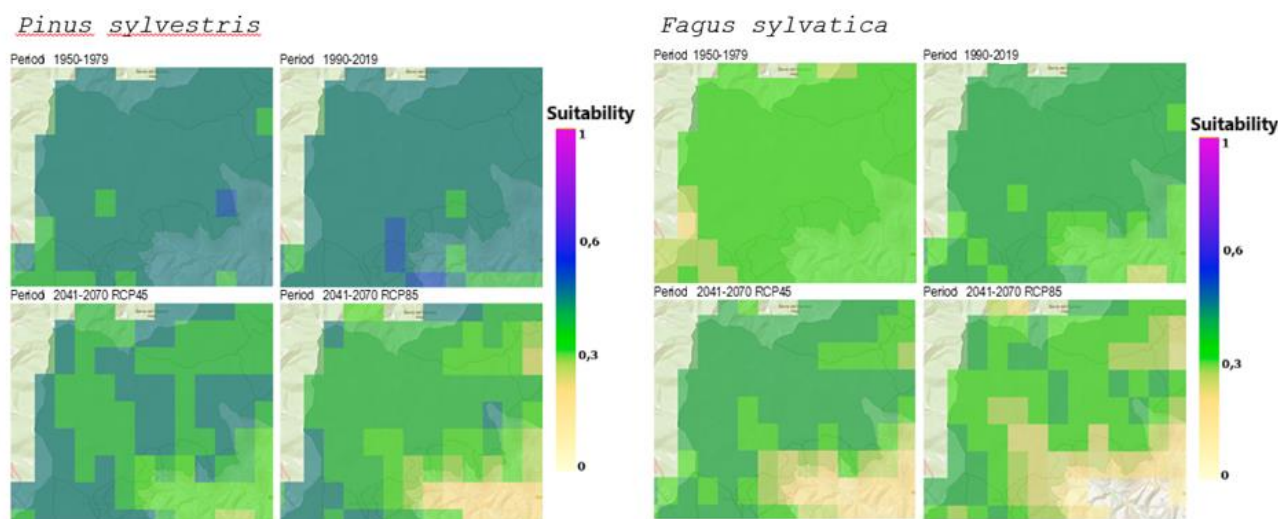


Figure 11. Predicted variation in the suitability of the forest species *Pinus sylvestris* and *Fagus sylvatica* in the MUP 195. Obtained from <https://soriaforestadapt.es/fitoclim/>

It can be observed in the models how in both species the suitability is slowly decreasing.

Future potential suitable species

Obtained from ALLUÉ CAMACHO, C. & GARCÍA LÓPEZ, J.M., 2024. FITOCLIM. Diagnosis fito-climática de cubiertas forestales en un contexto de cambio climático (<https://soriaforestadapt.es/fitoclim/>).

Scenario RCP-45

Período	Csa	Api	Fsy	Jth	Pha	Pni	Ppr	Ppi	Psy	Pun	Oeu	Qfa	Qhu	Qil	Qpe	Qpy	Qro	Qsu
2041-2070	0.57	FR	0.52	0.61	FR	0.65	0.54	FR	0.6	FR	FR	0.7	0.59	0.48	0.56	0.69	0.4	FR

Scenario RCP-85

Período	Csa	Api	Fsy	Jth	Pha	Pni	Ppr	Ppi	Psy	Pun	Oeu	Qfa	Qhu	Qil	Qpe	Qpy	Qro	Qsu
2041-2070	0.6	FR	0.45	0.69	0.11	0.71	0.58	0.11	0.59	FR	FR	0.73	0.58	0.53	0.5	0.7	0.35	0.27

Table 5. Predicted suitability for different forest species in the MUP 195. Where Csa is *Castanea sativa*, Api is *Abies pinsapo*, Fsy is *Fagus sylvatica*, Jth is *Juniperus thurifera*, Pha is *Pinus halepensis*, Pni is *Pinus nigra*, Ppr is *Pinus pinaster*, Ppi is *Pinus pinea*, Psy is *Pinus sylvestris*, Pun is *Pinus uncinata*, Oeu is *Olea europaea*, Qfa is *Quercus faginea*, Qhu is *Quercus humilis*, Qil is *Quercus ilex*, Qpe is *Quercus petraea*, Qpy is *Quercus pyrenaica*, Qro is *Quercus robur* and Qsu is *Quercus suber*. Obtained from <https://soriaforestadapt.es/fitoclim/>

In future scenarios, the following forest species are predicted to be suitable and convenient for this location:

- *Quercus faginea*.
- *Quercus pyrenaica*.
- *Pinus nigra*.
- *Pinus pinaster*.
- *Pinus pinea*.
- *Pinus halepensis*.

Then, they can be considered to be introduced in the forest as more adapted species in the future.

Identifying adaptation strategy

According with the previous analysis, where it was seen that the impact nowadays is smooth, but with expected changes in the forest species distribution due to the increasing changes in the climatic conditions, the more convenient adaptation strategy was Resilience / Incremental adaptation. This strategy is based on introducing some changes in the management, in order to maintain the structure of the reference situation, but with new natural strategies (new species, mixed structure, soil protection ...) that improve the variability of responses to better adapt to climate change.

Identifying actions and measures of adaptation

Following the strategies and actions presented in Swanson et al (2016), that are presented in this document in the Section 3.2, after discussing with the stakeholders during the in-person session, the more convenient measures to include in the management plan were following ones.

Following selective silviculture for future dominant trees, ensuring proper thinning rotations. This approach includes:

- Reducing stress caused by competition, particularly for water resources.
- Selecting the best trees based on vitality and quality.
- Applying a general selection process across all species, without intervening in those that do not interfere with forest dynamics.

Additionally, the forest should include an ecological corridor consisting of stands managed under ProSilva principles and reserved stands.

Special attention is given to regeneration viability in open areas caused by tree falls. If necessary, additional support measures such as soil preparation, seeding, or species replacement may be implemented.

Species introduction of *Pinus pinaster* and *Pinus pinea* in the contiguous forests is also recommended.

Monitoring

The primary goal of monitoring is to assess the effectiveness of adaptation measures and support improved decision-making for future forest management. This involves designing a realistic and feasible monitoring plan, identifying key parameters to track progress toward management objectives, and evaluating whether the implemented adaptation measures have been successful.

Additionally, the monitoring process aims to reduce knowledge gaps and uncertainties by drawing insights from on-site experience. However, this section remains pending for further development.

Conclusion

This study has provided a comprehensive framework for integrating climate change adaptation measures into forest management in the province of Soria, with a focus on MUP 195. The study confirms that while the current impacts of climate change on forest dynamics are moderate, long-term projections indicate significant shifts in species distribution and suitability.

By employing a Resilience/Incremental Adaptation strategy, the proposed management plan prioritizes selective silviculture, species diversification, and ecological corridor establishment to enhance forest resilience. Specific actions include thinning rotations, stress reduction, and the introduction of more climate-adapted species such as *Pinus pinaster* and *Pinus pinea*.

Continuous monitoring and stakeholder collaboration remain essential to refining adaptation strategies and reducing uncertainties. Although monitoring plans are still under development, their implementation will be crucial in assessing the effectiveness of adaptation measures and guiding future management decisions.

This study underscores the importance of proactive and science-based forest management in mitigating climate change impacts while ensuring the long-term sustainability and ecological integrity of Soria's forests.

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