MIDMACC
Mid-mountain adaptation to climate change

LIFE18 CCA/ES/001099

Climate change adaptation measures in the mediterranean mid-mountain area: a practical guide

Title:

"Climate change adaptation measures in the Mediterranean mid-mountain area: a practical guide"

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Introduction

The mountainous areas of Southern Europe are very sensitive spaces to the impacts of climate change, spaces that, in recent decades, have suffered progressive depopulation due to the abandonment of the traditional primary sector, which has caused revegetation and, consequently, a homogenisation of the landscape and the decrease in its environmental resilience.

In this context, the LIFE MIDMACC project has, as its main objective, the promotion of adaptation to climate change of the Mediterranean mid-mountain area through the recovery of a mosaic landscape that is more resilient to climate change through the recovery of pastures, forest management and cultivation of grapevines. The project is developed in three representative territories of the mid-mountain area to the south of the Pyrenees: Aragon, Catalonia and La Rioja.

This guide you are holding first of all summarises the risk analysis of the Mediterranean mid-mountain area in the face of the impacts of climate change. Next, it describes the methodology used, the results, the basin-scale approach and the recommendations based on the deployment of measures in the three territories. Finally, it proposes other adaptation measures for the Mediterranean mid-mountain area based on the work carried out with the actors in the territory.

The LIFE MIDMACC project has been developed over five years (2019-2024) and has been funded by the European Commission through the LIFE programme (Climate Change Adaptation) programme. The Centre for Ecological Research and Forest Applications (CREAF) has been the coordinating entity and has had the participation of the Pyrenean Institute of Ecology (IPE) of the Higher Council for Scientific Research (CSIC), the Institute of Agri-Food Research and Technology (IRTA), the Catalan Office for Climate Change (OCCC), the Pyrenees Work Community (CTP), the Autonomous University of Barcelona (UAB), the University of La Rioja (UR), and the University of Zaragoza (UZ).

Risk analysis

01

This chapter analyses the risks and vulnerabilities of the mid-mountain areas to face the impacts of climate change in Aragon, Catalonia and La Rioja, three territories with environmental characteristics typical of the mountainous regions of Southern Europe.

Based on bibliographic data and the contributions of the actors who participate in the regional committees (CR) of the three territories, the evolution over time of temperature and precipitation is studied, and the observed and potential risks produced are assessed by climate change in different sectors and systems (*for more information, see Deliverable no.12*).

ARAGON

CLIMATE PROJECTIONS

Temperatures:

Tendency to increase, both in maximums and minimums, in the three scenarios proposed by the IPCC.

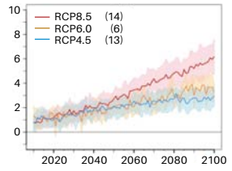
Precipitacion:

Tendency to decrease, which is not very representative, due to the irregularity and annual variability of rainfall.

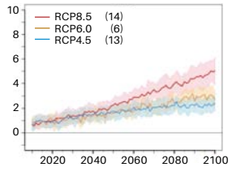
RCP Emissions scenarios

Source: AEMET, 2020

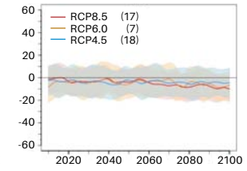
MAXIMUM *TEMPERATURE*



MINIMUM *TEMPERATURE*



ANNUAL *PRECIPITATION*

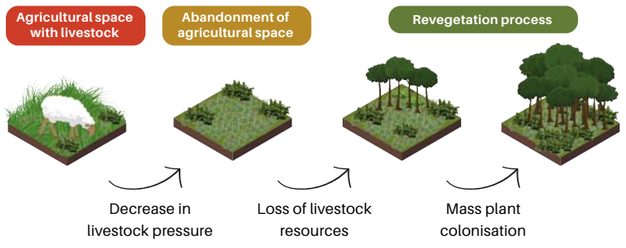


	RCP 4.5	RCP 6.0	RCP 8.5	RCP 4.5	RCP 6.0	RCP 8.5	RCP 4.5	RCP 6.0	RCP 8.5
2020-2040	+2ºC	+2ºC	+2ºC	+1,5ºC	+1,5ºC	+1,5ºC	-5%	-5%	-5%
2041-2100	+2,5ºC	+3ºC	+6ºC	+2ºC	+3ºC	+5ºC	-5%	-10%	-10%

RISK ANALYSIS

Abandonment of farmland and pastures

70% of the agricultural space in the Aragonese Pyrenees was depopulated between 1940 and 1975. The abandonment of these spaces has promoted their revegetation and, consequently, the increase in areas of bushes and forests has led to the loss of pastoral resources.



Increase in bush and forest lines and loss of habitats

Due to the decrease in livestock activity and warmer conditions as a result of climate change, it is expected that there will be an upward movement of the tree lines towards higher elevations and that, consequently, some species such as the northern stonechat (*Saxicola rubetra*) or the Alpine accentor (*Prunella collaris*) could lose their habitat.

Growth of forested area and reduction of river flow

The proliferation of forests will be faster and more abundant than that of bushes, thus leading to a predominance of unmanaged forest areas, which may lead to a reduction in river flows.

	Initial	10 years	20 years	30 years
Pastures	12,4%	12,4%	10%	8%
Scrub	21,2%	8,4%	2,6%	4,4%
Forests	50,8%	63,6%	71,8%	72%

Estimation of the conversion of pastures into scrub, and scrub into forest in the Estarrún basin

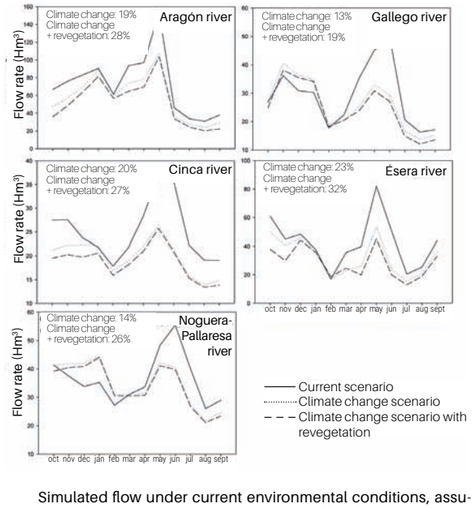
Source: Khorchani et al. (2021).

Reduction of water availability and modification of water quality

The impacts of climate change and the abandonment of agricultural lands have an impact on water resources, **drastically reducing flow rates** in the rivers of Aragón.

The process of **revegetation** combined with the increase in **temperatures** and the decrease in **precipitation** entails a lower availability of water in the basins with a significant decrease in spring and summer.

The decrease in flows or the use of aquifers leads to changes in water quality.

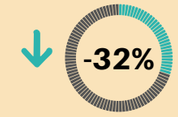


Simulated flow under current environmental conditions, assuming climate change and the combined effect between climate change and land use in five Aragonese basins.

Source: López-Moreno et al. (2014).

FLOW RATES

Minimum expected annual decrease



Maximum expected annual decrease

Estimation of the decrease in flow in basins of Upper Aragón between 2021-2050. Source: Lopez-Moreno et al. (2014).

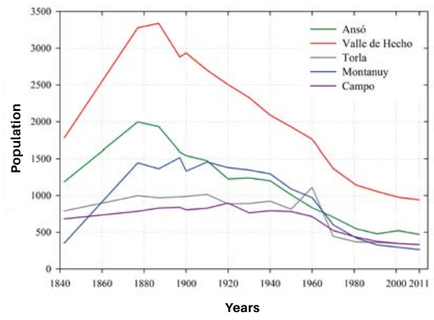
Floods and torrentiality

The abandonment of the land and the absence of dry stone walls or terraces increase the **risk of flooding and torrential rain**.

Changes in economic sectors

Tourism

The decrease in water resources will affect winter sports and snow-related activities due to less snowfall.



Regressive demographic evolution in a selection of municipalities in Aragon (Pyrenees).
Source: García-Ruiz et al. (2015).

Natural systems

- Increase in pest attacks – such as the pine processionary – due to water stress.
- Expansion of invasive species such as the Asian predatory wasp or the signal crayfish.
- Increase in the fire risk due to the increase in biomass given the abandonment of lands and the impacts of climate change.
- Greater impact on ecosystem-related services.
- Increased movement of alpine species – such as spruce, capercaillie or wood pecker – to higher altitudes and possible appearance of larger fauna.
- Biodiversity loss.

Social and demographic impacts

Risk of loss of infrastructure, knowledge and services due to the depopulation suffered in the Pyrenean municipalities in the last century.

CATALONIA

CLIMATE PROJECTIONS

Temperatures:

Increase in average (AAT), maximum (Tmax) and minimum (Tmin) temperatures in all scenarios. It is expected that the increase will be higher in the area of the Pyrenees compared to the coast and the pre-coast.

Precipitacion:

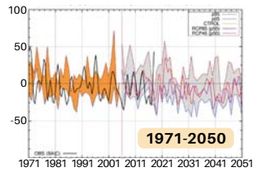
Trend towards a moderate decrease in the three scenarios. Reductions between 5 and 20%, with the coastal area becoming the most affected.

INCREASE IN TEMPERATURES

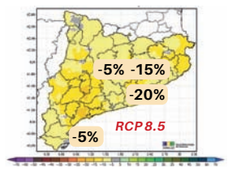
	AAT	Tmax.	Tmin.
RCP 4.5	+0,13ºC	+0,15ºC	+0,11ºC
RCP 8.5	+0,41ºC	+0,48ºC	+0,35ºC

**Higher increase per decade*

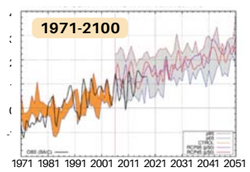
*Evolution in **AAT***



AAP



*Evolution in **AAP***



Fuente: METEOCAT, 2021

AAT Average annual temperature

RCP Emissions scenarios

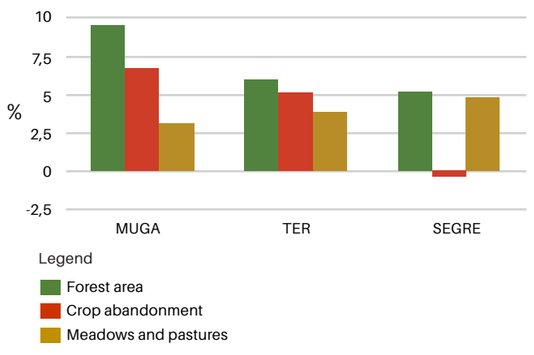
AAP Average annual precipitation

RISK ANALYSIS

Changes in land use

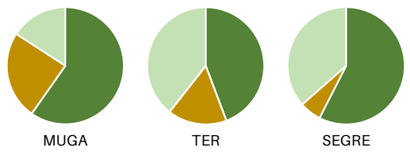
Between the years 1970 and 2005, land uses in the Muga, Ter and Segre river basins have changed towards an increase in forest area produced by the expansion of forests and the loss of meadows, pastures and crop fields, due to the abandonment of agricultural territory.

Changes in land use



Source: Cantos et al. (2022).

Changes in distribution in space (km²) of scrub between 1970 and 2005



Source: Vicente-Serrano et al. (2016).

Legend: Scrub to forest; Meadows and pastures to scrub; Crops to scrub

The landscape has been modified, mainly, by the fact that large areas of scrub have evolved into forest stands, while scrub has occupied areas of crops and meadows.

Increase in forest stands and changes in species distribution

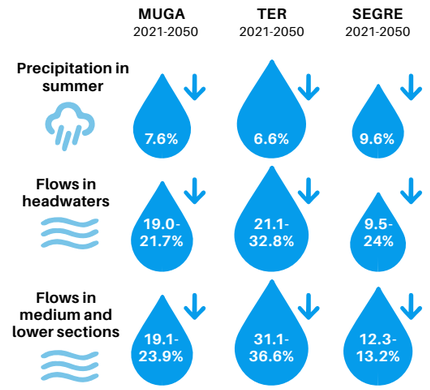
Plant communities and some species of wild fauna such as wild boars and roe deer have altered their population dynamics due to a combination of factors, including changes in land use and climate change, producing, as a consequence, significant impacts on agriculture and livestock.

Reduction in water availability and impact on groundwater

According to the evaluation of the impacts of climate change on the water cycle and changes in land use, a generalised reduction in the flow of Muga, Ter and Segre basins is expected during the first half of the 21st century. These descents vary depending on the section of the river:

- **Headwater:** severe reductions in flow due to climate change and changes in land use such as the increase in forest surface.
- **Lower river section:** flows strongly conditioned by the reservoir management regime.

These changes in the water balance will affect hydroelectric energy production and groundwater, especially aquifer recharge, with a decrease of up to 20%.



Source: Pla et al. (2018).

High water levels and floods

The change in the snowmelt calendar and the change in the regime of extreme periods of precipitation can increase the frequency of natural disasters due to high water levels and floods.

Changes in economic sectors

High variability in the quality and quantity of harvests and crops due to the impacts of climate change:

Vineyards

- Reductions in production.
- Increase in sugars, reduction in acidity and affectation of colour and aromas.
- Impact on the size of the grape.
- Need for new varieties with less water dependence.

Tourism

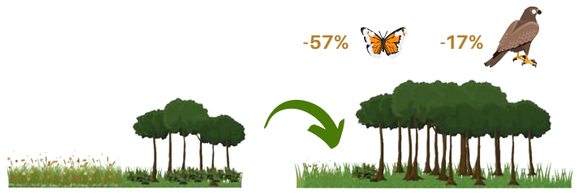
- Affected by decreased visual appeal due to irreversible changes in the landscape.

Social and demographic impacts

- Lack of management and maintenance of the territory.
- Changes in the landscape that lead to a progressive loss of cultural heritage, such as, for example, the deterioration of dry stone walls.

Natural systems

- Weakness of riparian forests due to drought, which can increase erosion in the basin.
- Increase in pathologies such as pine processionary (*Thaumetopoea pityocampa*) in dense pine forests.
- Increased risk of fires due to an increase in temperatures combined with the expansion of the forest stands due to the abandonment of crops and logging residues.
- Greater difficulty in forest maturation due to continued rejuvenation.
- Increased changes in flowering periods and fauna phenology.
- The loss of open forest spaces due to the increase in forest biomass has led to the decrease in lepidopteran and bird species typical of these spaces.



LA RIOJA

CLIMATE PROJECTIONS

Temperatures:

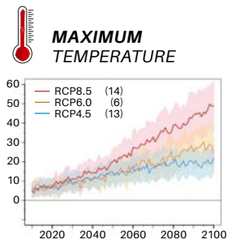
Trend towards a pronounced increase in maximum temperatures and a moderate increase in minimum temperatures.

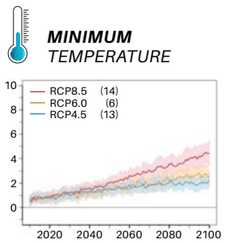
Precipitacion:

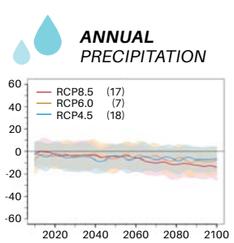
Trend towards a moderate decrease in the three scenarios.

RCP Emissions scenarios

Source: AEMET, 2020







	RCP 4.5	RCP 6.0	RCP 8.5	RCP 4.5	RCP 6.0	RCP 8.5	RCP 4.5	RCP 6.0	RCP 8.5
2020-2040	+2ºC	+2ºC	+2ºC	+1,5ºC	+1,5ºC	+1,5ºC	-10%	-5%	-5%
2041-2100	+3ºC	+4ºC	+6ºC	+2ºC	+3ºC	+4,5ºC	-5%	-10%	-15%

RISK ANALYSIS

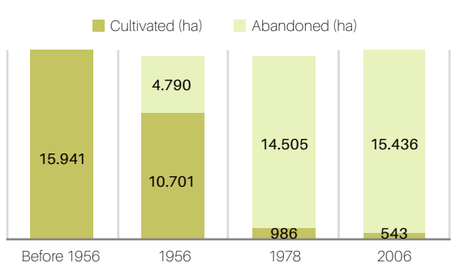
Abandonment of croplands and pastures

Since the middle of the 20th century, the decrease in agricultural pressure in the territory has been accompanied by a decrease in population. As the territory has become depopulated, there has been a contraction of the agricultural area, to the point that only 0.13% of the total area of the territory is used for crops.

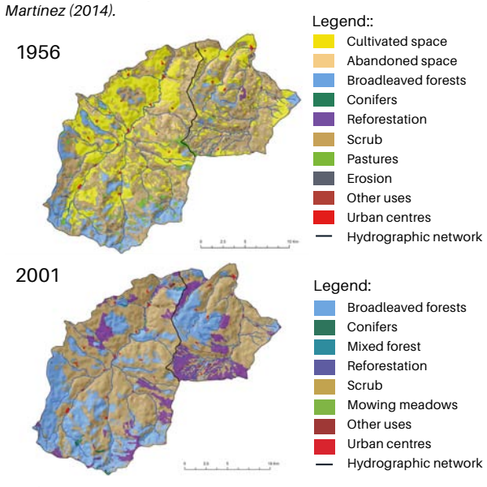
Increase in forests and loss of pastures

The decrease in livestock pressure on the territory has led to a significant expansion of the vegetation cover. In the Camero Viejo area "where the space reserved for agricultural activity has practically disappeared", we can see how the lands are currently forest and scrub areas.

Camero Viejo	1956	2001
Reforestation	76 ha	4.278 ha
Broadleaved forests	4.434 ha	11.384 ha
Pastures	+	−
Scrub	−	+



Evolution of agricultural space (cultivated and abandoned) in Camero Viejo (La Rioja) from before 1956 to 2006. Source: Lasanta Martínez (2014).



Land uses in Camero Viejo (1956-2001). Source: Lasanta Martínez (2014).

Reduction in water availability and impact on its management

The demand for water in the section of the Ebro River that passes through La Rioja is very high. Many population centres consume water resources from its basin.

Villages and towns near the Ebro basin at La Rioja. Source: La Rioja Government (2008).

Floods and torrentiality

The dismantling of agricultural terraces in various parts of La Rioja has accelerated erosion processes, such as in the Cidacos Valley and Leza-Jubera Valley. The loss of these elements entails a greater risk of torrential rain and flooding.

Changes in economic sectors

Pastures and livestock

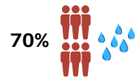
- Decrease in the productivity of pastures and livestock activity.
- Shorter livestock stabilisation time due to high temperatures.

Vineyards

- Expansion of the vines to higher levels.
- Changes in the grape variety.

Tourism

- Reduction of tourist attraction due to modification of the landscape and less snowfall.



220.000 inhabitants plus industrial centres

15.672 hectares of irrigated area

Irrigation dams and electricity production

The abandonment of agricultural lands and climate change, added to the high demand for water, will lead to:

- Alterations in the flow regime.
- Modifications of seasonal distribution.
- Changes in the magnitude and frequency of floods.
- Impact on runoff.

Natural systems

- Densification of meadows due to the abandonment of crops (homogenisation of the landscape).
- Increased fire risk due to lack of management in areas with difficult access and steep slopes.
- Changes in the distribution of species (rise in the tree line).
- Biodiversity loss.
- Increase in pathologies.

Social and demographic impacts

- Lower population growth due to decades of rural exodus, social changes and ageing of the population.
- Changes in the landscape that lead to a progressive loss of cultural heritage.

Adaptation measures implemented in the project

02

Measures implemented in the project

High vulnerability to the impacts of climate change together with rural abandonment and the decline in socioeconomic activity are putting the mountains of Southern Europe at risk.

To improve their environmental and socioeconomic resilience, the ecological and socioeconomic effectiveness of various adaptive measures has been evaluated in three representative pilot test areas of the mid-mountain areas of **Aragon**, **Catalonia** and **La Rioja**.

The adaptation measures implemented by area are as follows:

- **Recovery of pastures** (Aragon and La Rioja)
- **Forest management** (Aragon and Catalonia)
- **Optimisation or introduction of vineyards** (Catalonia and La Rioja)

RECOVERY OF PASTURES

The recovery of pastures as a landscape management measure is based on an initial action of clearing scrubland followed by the introduction of extensive livestock farming.

In this way, the aim is to recover a mosaic landscape and, consequently, reduce the risk of fire, as well as other vulnerabilities typical of the Mediterranean mid-mountain areas.

I. METHODOLOGY

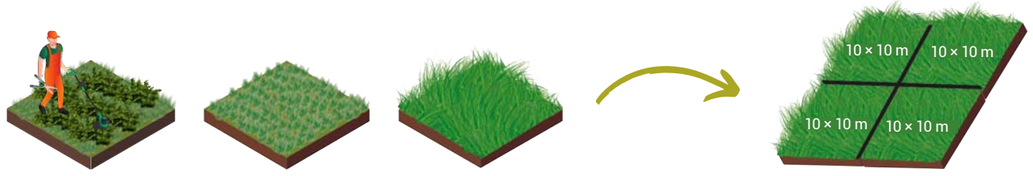
Pilot tests have been implemented in two representative areas of the Mediterranean mid-mountain: the localities of San Román de Cameros and Ajamil de Cameros in **La Rioja**, and La Garcipollera in **Aragon**.

With the aim of evaluating the recovery of pastures as an adaptation measure against climate change, the following steps have been carried out:

1 *Scrub clearing:*

Clearing consists of the elimination of bush cover in a large space with similar conditions of altitude, orientation and lithology. The intensity of clearing – whether manual or mechanical – will depend on the initial conditions of the study area.

Clearing actions should take into account that they cannot be carried out in places where the slope is greater than 30%, or in areas with more than 20% trees, while clearing trees and bushes that have a height of over 1.5-2 m must be avoided.

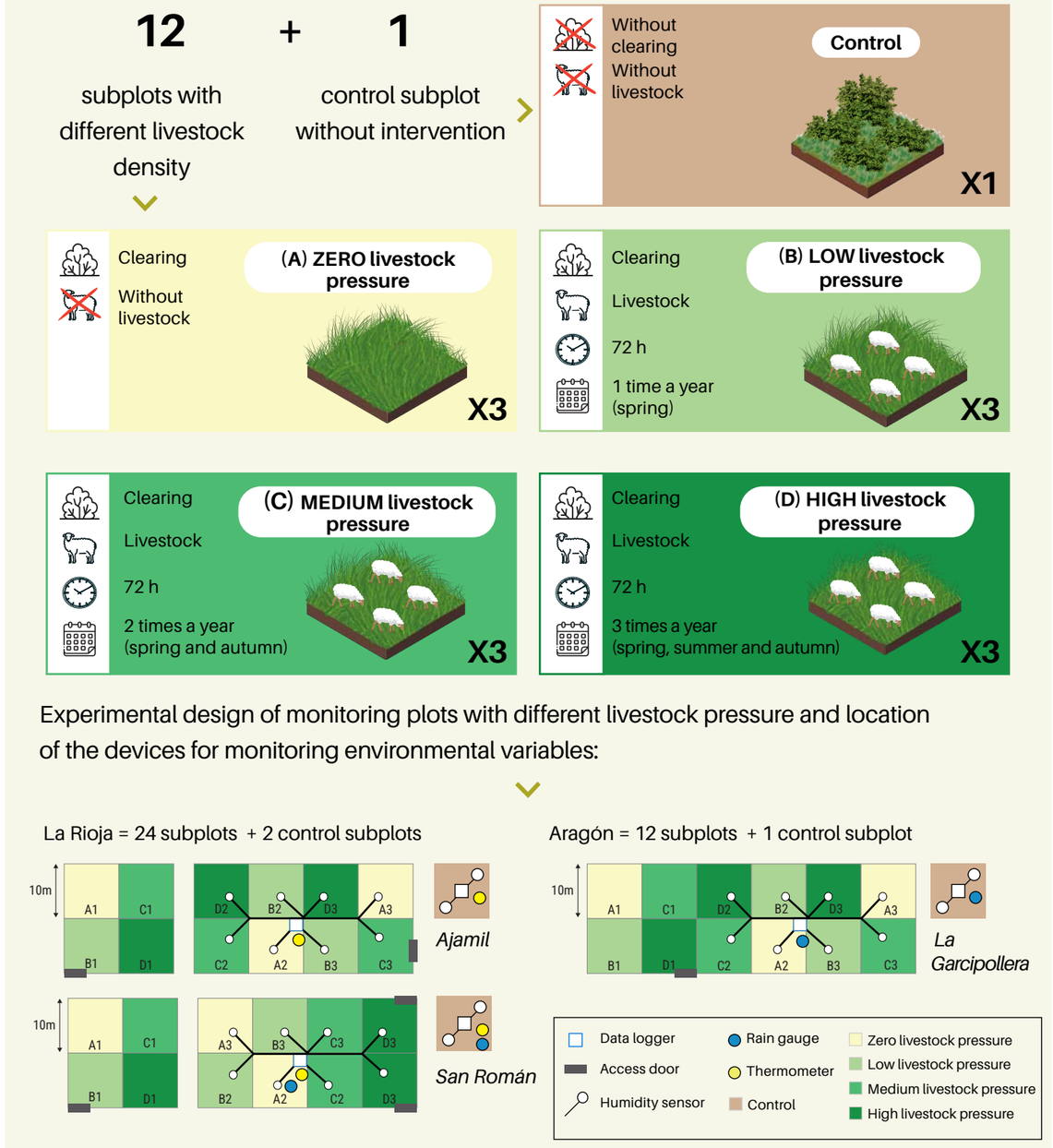


Scrub clearing *Herbaceous revegetation* *Monitoring subplots*

2 *Installation of monitoring plots*

After clearing, the monitoring plots are delimited. In each one, four scenarios with different livestock pressure are recreated (A, B, C and D): four sheep that will be introduced into the subplots different times a year during a period of 72 hours.

A control subplot is also created, without intervention. Each scenario has three replicas (x 3) achieving a total of **12 subplots** with different livestock pressure and **1 control subplot** (x 1).



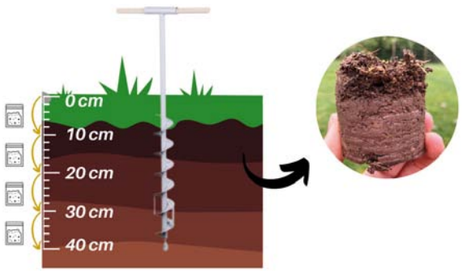
Experimental design of monitoring plots with different livestock pressure and location of the devices for monitoring environmental variables:

3 *Protocol and monitoring variables*

In order to evaluate the effects of clearing and livestock management on pasture recovery, after the installation of the monitoring plots, the following environmental variables are monitored (*for more information, see the Deliverable no. 8*):

Soil properties

Changes in land use modify the composition of the vegetation cover, affecting the content and quality of soil properties, especially organic matter and organic carbon, which constitutes an element of great interest for the mitigation of climate change. For this reason, continuous monitoring of soil moisture is carried out, with specific monitoring at the beginning and at the end of the experiments on soil properties (C/N, organic matter, among others), except for variables related to carbon storage, in which the monitoring is annual.



Local weather conditions

In order to interpret the evolution of the monitored environmental variables, a continuous record of meteorological conditions is made throughout the project.

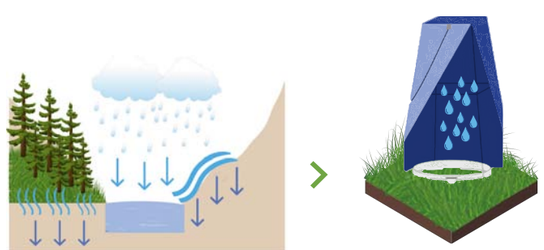
- *Air temperature sensor*
- *Soil moisture sensor*
- *Rain gauge*

Pastures

The effect of different livestock intensities on the production and quality of pastures is evaluated through the analysis of the abundance and composition of plant species, and also of nutritional quality, biomass productivity and pastoral value. All sampling is carried out at the end of spring, before the start of livestock activity, and coincides with the peak of flowering to ensure identification.

Hydrological response and erosion

Land uses and cover determine the relationship between precipitation, runoff and soil erosion. In this context, and through rainfall simulations, it is evaluated how clearing and different livestock intensities affect the hydrological response (runoff coefficient and infiltration depth) and, also, the soil erosion.



II. RESULTS

MONITORING RESULTS AT LANDSCAPE SCALE

Below are the effects – at landscape scale – of the application of clearing as an adaptive measure against climate change in the studies carried out in La Rioja and Aragón to recover pastures and control forest fires in the mid-mountain areas:

a Mosaic landscape

- Increase in the diversity of land uses and types of cover
- Promotion of diversity and aesthetics in the landscape

b Livestock development

- Increase in livestock census
- Promotion of extensive livestock farming
- Increase in population retention (young livestock farmers)

c Reduction of fire risk and burned surface

- Removal of combustible material
- Reduction of vertical and horizontal continuity of combustible material
- Mosaic landscape, which prevents the continuity of combustible material, thus facilitating fire extinguishing
- Elimination of pastoral fires to create new pastures, the main cause of ignition

d Increase in the provision of water resources

- Increase in surface runoff and, therefore, water resources
- Slight increase in erosion rates due to scrub clearing
- Increase in the provision of water resources in the basins with practically no loss of soil

e Improvement of the state of the pastures

- More fertile and higher quality soils on land with clearing in the past (>25 years)
- Greater stocks of organic carbon and nitrogen associated with pasture cover
- Basic food source for livestock; above all, those that are found under tree cover in Mediterranean environments during the summer are key*

** Pastures under tree cover are at risk because they are not susceptible to receive subsidies from the Common Agricultural Policy (CAP)*

RESULTS OF MONITORING AT PLOT SCALE

Below, it is shown on a more detailed scale (100 m² plot), the role of livestock intensity on the efficiency of clearing and the different environmental variables studied during monitoring in La Rioja and Aragon (*for more information, see Deliverable no.30*):

Interpretation of the results

The results obtained from monitoring the different clearing and livestock management scenarios are shown through qualitative interpretation tables.

The values are represented qualitatively, thus measuring the magnitude and direction of the change. In this way, it can be seen whether the variable is unchanged, increases or decreases, as well as with what intensity it does so. Those cases in which data are not available are also indicated.

It should be remembered that the results shown indicate a trend, but are not conclusive given the short study period (3-4 years) as well as the effects of climate variability and differences between the study areas.

Livestock pressure scenarios

Qualitative variation

EVOLUTION OF SOIL QUALITY

The quality of the soil improves with the presence of flocks that graze on it, since they favour an increase in the sequestration of organic carbon and nitrogen in the soil. However, given the little information available, it cannot be determined what level of livestock intensity is appropriate. On the other hand, the results for soil moisture are very diverse depending on the structure of the cover, the livestock and its pressure.

	Humidity	Carbon/nitrogen ratio	Organic carbon
Aragon - La Garcipollera			
Control	▲▲▲▲	▲▲▲▲	▲▲▲▲
Without livestock	▲▲▲▲	▲	▲
Low livestock intensity	▲	▲	▲
Medium livestock intensity	▲▲	▲▲	▲▲
High livestock intensity	▲▲▲	▲▲▲	▲▲▲
La Rioja - San Román			
Control	▲▲▲▲	▲▲▲	▽▽
Without livestock	▲	▲	▽▽
Low livestock intensity	▲▲▲▲	▲	▽▽▽
Medium livestock intensity	▲▲▲	▲▲	▽▽
High livestock intensity	▲▲	▲▲▲▲	▽
La Rioja - Ajamil			
Control	▲	▲▲	▲▲▲
Without livestock	▲▲	▲▲▲	▲▲
Low livestock intensity	▲▲	▲▲▲	▲
Medium livestock intensity	▲▲	▲▲▲	▲▲
High livestock intensity	▲▲▲▲	▲▲▲▲	▲▲▲▲

EFFECTS ON RUNOFF AND EROSION

The implementation of landscape management measures affects, among other issues, soil properties with important consequences for runoff and soil erosion.

In the evaluation of the effect of clearing and different livestock intensity on the hydrological response and soil erosion, high runoff rates are observed in the presence of high livestock intensity without detecting an increase in erosion rates. It is a result that is relevant for the production of "blue water" (water from rivers, lakes and aquifers) in the basins.

	Runoff	Erosion
Aragon - La Garcipollera		
Control	▲	▲▲
Without livestock	▲▲	▲▲▲▲
Low livestock intensity	▲	▲
Medium livestock intensity	▲▲▲	▲▲▲
High livestock intensity	▲▲▲▲	▲▲▲
La Rioja - San Román		
Control	=	=
Without livestock	=	=
Low livestock intensity	=	=
Medium livestock intensity	=	=
High livestock intensity	▲▲	▲
La Rioja - Ajamil		
Control	=	=
Without livestock	▲▲	▲
Low livestock intensity	▲▲	▲
Medium livestock intensity	▲▲	▲
High livestock intensity	▲▲▲	▲

	Bare soil	Herbaceous coverage	Production	Abundance of herbaceous plants	Quality
Aragon - La Garcipollera					
Control	▲	▲	▲▲	▲	▲▲
Without livestock	▲▲	▲▲	▽	▲	▲
Low livestock intensity	▲▲▲	▲▲	×	▲▲	×
Medium livestock intensity	▲▲	▲▲	×	▲▲	×
High livestock intensity	▲▲▲	▲▲	×	▲	×
La Rioja - San Román					
Control	▲	▲	▲	▲	▲
Without livestock	▲▲	▲▲	▲▲	▲	▲
Low livestock intensity	▽	▲▲▲	×	▲▲	×
Medium livestock intensity	▽	▲▲▲	×	▲▲	×
High livestock intensity	▽	▲▲▲	×	▲▲	×
La Rioja - Ajamil					
Control	▽	▲	▲	▲▲	▲
Without livestock	▲	▲▲	▲▲	▲	▲
Low livestock intensity	▲	▲▲▲	×	▲▲	×
Medium livestock intensity	▲	▲▲▲	×	▲▲	×
High livestock intensity	▽	▲▲▲	×	▲▲	×

PRODUCTION AND QUALITY OF PASTURES

Both the previous uses of the land and its edaphic conditions determine the coverage and abundance of the pastures. Thus, on degraded soils, herbaceous cover is scarcer than on more fertile soils or those previously used for livestock, which will be able to support higher livestock intensities.

Furthermore, the presence of livestock involves greater coverage of herbaceous plants, including a greater proportion of leguminous plants, as well as less coverage of grasses compared to land without livestock.

Regarding production and quality, the data analysed corresponds only to the first year of sampling. Therefore, the effect of the intensity of livestock farming cannot be validated, but only the effect of clearing, comparing the control plot with the clearing without livestock. In this case, the results obtained indicate a tendency to increase the production of pastures after eliminating the scrub.

WEATHER CONDITIONS

The annual climatic conditions are a determining factor in the supply of pastures and the livestock intensity. In dry years, the soils will have little vegetation cover and, therefore, a low livestock intensity will be necessary. On the contrary, in wetter years, there will be increased production and the same pastures will be able to support higher intensities.

EFFICIENCY OF CLEARING

To maintain clearing actions, it is necessary for the flocks to graze. Without livestock action, the scrub recolonises the cleared lands in a period between 3 and 4 years. Mainly, herbaceous and bush species dominate with a predominance (>20%) of *Genista scorpius* in calcareous soils and *Cistus laurifolius* in silicic soils. However, in order to guarantee good grazing for the flocks, it is necessary to eliminate the scrub by the roots. If this practice is not carried out, the sheep do not consume the regrowth and, over time, these shoots colonise the land again.

III. ECONOMIC ANALYSIS

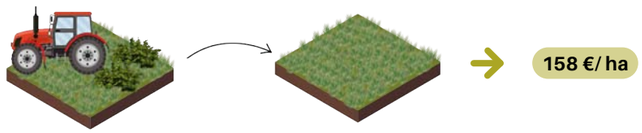
ECONOMIC ANALYSIS OF CLEARING ACTIONS

With the final objective of obtaining a useful tool so that the different actors involved in the management of the territory can assess the possibilities of applying the adaptation measures to climate change described above, the following analysis is carried out on the economic costs and the characteristics that influence its variability (*for more information see Deliverable no.21*):

The costs of clearing activities can range from approximately €150/ha, if simple mechanised clearing is considered, to €5,100/ha, if a more complete activity is carried out (manual clearing, thinning, pruning, management of plant remains and planting), enabling the area to provide grazing for animals.

Maintenance of an existing pasture

Maintenance review on a grass plot with a slight slope and low density of forest cover.



Tractor clearing *Natural revegetation*

158 €/ ha

Recovery of old pastures and crops

Scrub clearing actions to recover flat land with high density of scrub.

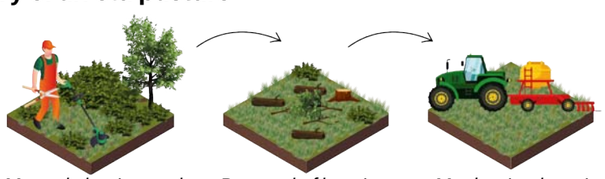
Manual clearing *Natural revegetation*

1.458 €/ ha
Public administration

2.238 €/ ha
Private company

Complete recovery of an old pasture

Complete management with several clearing and forestry actions for the recovery of an old pasture.



Manual clearing and felling *Removal of logging remains* *Mechanised sowing*

5.100 €/ ha

Note: the prices shown do not take into account VAT or the cost of renting the machinery or its transportation. Data extracted from public companies such as TRAGSA (Transformation Agraria, S.A.), SARGA (Sociedad Aragonese de Gestión Agroambiental, S.L.U.) and Forestal Catalana, S.A., and from the costs incurred in the LIFE MIDMACC project for clearing and forest management actions.

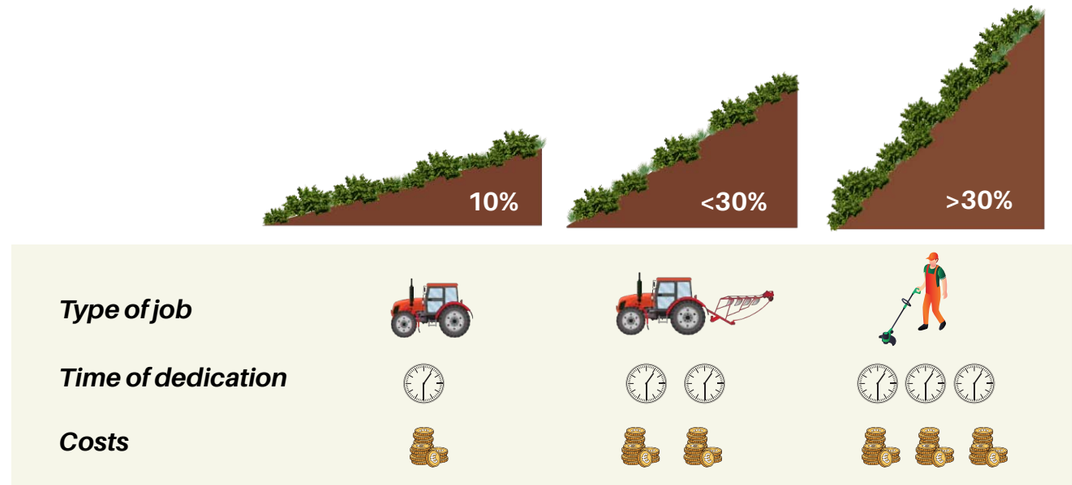
CONDITIONING FACTORS OF COSTS

The costs for carrying out this action are mainly associated with the volume of work to be carried out. This volume depends, on the one hand, on the surface of the clearing and its characteristics, and, on the other, on the type of action carried out and the time spent. Although the average cost of clearing is €2,000/ha, great variability is observed in the real cost, which ranges between €150 and €5,100/ha.

This variation is due to the fact that the different characteristics of the terrain and other aspects directly determine the hours of labour dedicated to executing the task, which is subsequently transferred to its costs. Below are the aspects that influence the hours of dedication, increasing or decreasing the volume of work and, therefore, the cost:

Slope of the terrain

The greater the slope of the terrain, the greater the difficulty of execution and, therefore, the longer the time spent. The use of machinery reduces the number of labour hours. However, it is necessary to adapt the machinery depending on the slope.



Relationship between the different slope of the terrain, the amount labour used, the time spent and the costs invested.

Scrub cover

The amount of surface area covered by scrub has an impact on the work to be carried out. The more covered area there is, the more labour will be required, as well as material and machinery.

Cost of transportation

The location and accessibility of the land determines the cost of transportation along with the volume of product to be extracted, since it may involve the use of more vehicles and trips.

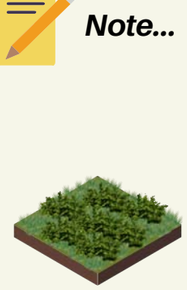
Management of plant remains

Depending on the quantity and type of plant remains to be extracted and managed, costs increase significantly and may even exceed the cost of the clearing action.

Hours of dedication

The slope of the terrain significantly influences the number of hours of dedication. A slope of 50% multiplies the number of hours of action by 7, while, on flat terrain, a single day is enough.

Note...



- ✓ The characteristics of the terrain directly condition the hours dedicated to labour: the greater the slope and the greater the amount of scrub, the more hours of dedication and labour.

- ✓ Mechanise clearing actions whenever possible to reduce time and labour.

- ✓ Maintaining clearing with extensive livestock farming is beneficial for livestock farmers and, in turn, allows reducing the risk of fire and the resulting costs.

ECONOMIC ANALYSIS OF EXTENSIVE LIVESTOCK FARMING

The use of extensive livestock farming in the management of pastures and forests is relevant to reduce the revegetation process and, therefore, allows the effects of forestry and clearing actions to be prolonged over time.

Despite the importance of livestock in the maintenance of forests and pastures, in recent years a reduction in its economic value and the number of livestock farmers has been observed due to the notable abandonment of rural areas.

With the objective of knowing the viability of applying extensive livestock farming as an adaptation measure, given the lack of resources and livestock farms in the mid-mountain area, the following analysis has been carried out on the socioeconomic situation of three privately managed livestock farms and one of public management, where the product for sale corresponds mainly to cows, sheep or goats for fattening (*for more information, see Deliverable no.21*):

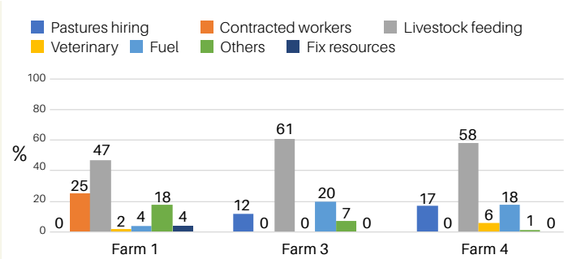
	Farm 1	Farm 2	Farm 3	Farm 4
				
Management type	Private	Public	Private	Private
Pastures/forests	In ownership	Experimental zone	Hiring	Hiring
Area (ha/MLU)	0,49	22,8	1,76	0,88
Contracted workers (public and private)	✓	✓	✗	✗
Total costs (euros/MLU)	905,94	_	451,38	172,13

MLU: major livestock unit
The total costs of livestock farm 2 are not shown because it is an experimental farm managed by the public administration.
Total costs have been estimated as the sum of pasture rental expenses, the salary of hired workers, food supplementation, health and transportation expenses, other expenses (professional services, electricity and facilities) and fixed capital.

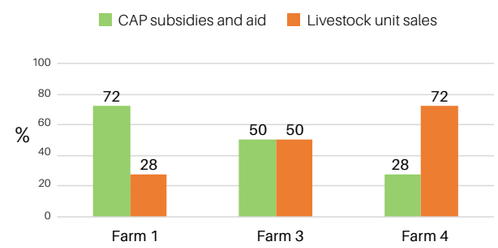
Economic characterisation

The extensive livestock farms analysed have difficulties in being economically viable. The most notable expense is food supplementation, which corresponds to between 50 and 60% of total production costs. Furthermore, the income generated from the sale of products is highly variable.

Consequently, CAP subsidies and aid are key to being able to at least cover production costs.



Production costs (%) in the different livestock farms.



Income (%) of the different livestock farms.

On the other hand, and according to the economic - but also social - assessment of the livestock farms that have participated in the analysis, the following factors are determined as conditions for their viability in the application as an adaptation measure:

Livestock feeding

Feeding their animals becomes one of the most expensive costs for livestock farmers, corresponding to 50% or 60% of the total costs per livestock unit. Therefore, it is essential to reduce supplementation costs and increase the availability of pastures and forests where animals can feed freely and this does not entail high costs for farms.

CAP subsidies and aid

CAP aid is essential for all livestock farms evaluated to be able at least to cover production costs. However, many livestock farmers are not satisfied with these aid and subsidies, even though they are key to their survival. They consider that they are poorly managed and often dismiss them due to the high bureaucracy involved in the procedures.

Pasture availability

Having pasture areas is relevant for the viability of the farm; therefore, it is important that the administration ensures access to these areas. It must also be taken into account whether the pasture areas are located on rented or owned land.

Marketing of the flocks

The main income product is the animal for fattening. Through the sale of calves and lambs for this purpose, production income is generated. However, prices fluctuate a lot and vary depending on the area, season and market. In the case studies, livestock farms earn between €200 and €500 per livestock unit sold. These sales usually account for between 28% and 72% of income depending on the livestock farm.

Cost of labour and generational change

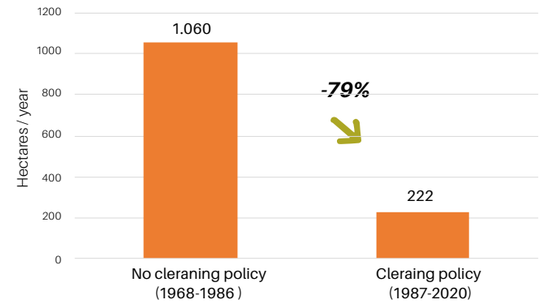
Often, the labour is provided by family members and is unpaid. Hiring external workers is difficult due to the low profits obtained from this operation. Furthermore, the level of population retention – whether due to generational change or newcomers – is low due to deficient infrastructure and services, poor accessibility and little or no telephone coverage in rural towns and mountain areas.

ECONOMIC ANALYSIS OF THE APPLICATION OF SCRUB CLEARING IN THE REDUCTION OF FIRE RISK AND POPULATION RETENTION

The analysis was carried out in La Rioja, one of the autonomous communities that has been a pioneer in clearing management and is compared with the neighbouring community of Castilla y León (control area) where, for the most part, prescribed burning is applied to reduce biomass and create a mosaic landscape (*for more information see Deliverable no.21):*

Forest fires

Since the application of the La Rioja Clearing Plan in the late 1980s, the hectares burned per year have been reduced by 79%. This type of management is based on the mechanical clearing of bushes combined with livestock grazing, thus reducing forest biomass and also creating a mosaic landscape, with forests alternating with scrub and grassland areas. In this way, it is possible to reduce biomass burning carried out by livestock farmers, a possible origin of fires due to accidents or negligence.



Hectares burned per year before (1968-1986) and after (1987-2020) the entry into force of the clearing policy in La Rioja

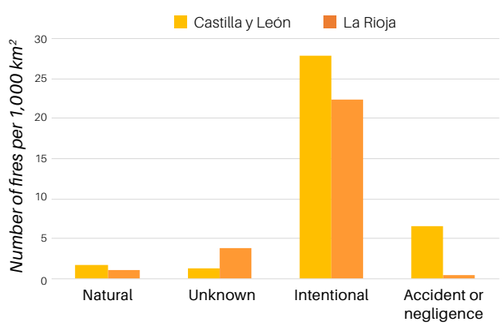
- Create a mosaic landscape
- Extensive livestock farming

- Forest biomass
- Prescribed burning
- Risk of fire

- Create a mosaic landscape
- Risk of fire due to accident or negligence
- Risk of soil loss

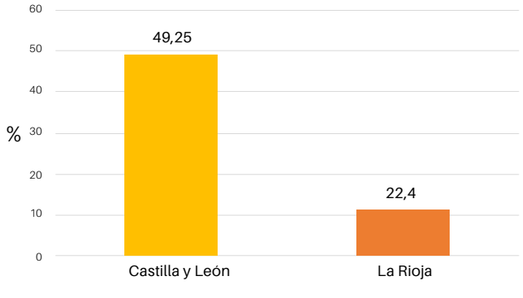
- Forest biomass
- Risk of forest fires due to other causes

The application of clearing significantly contributes to reducing the probability of a forest fire (between 67 and 77%) in the area examined (La Rioja) compared to the control area (Castilla y León), where prescribed burning is carried out. Likewise, a reduction of 86.2% in burned forest area is also achieved.



Number of fires per 1,000 km² by type of cause of outbreak in the communities of Castilla y León and La Rioja between 2001 and 2015.

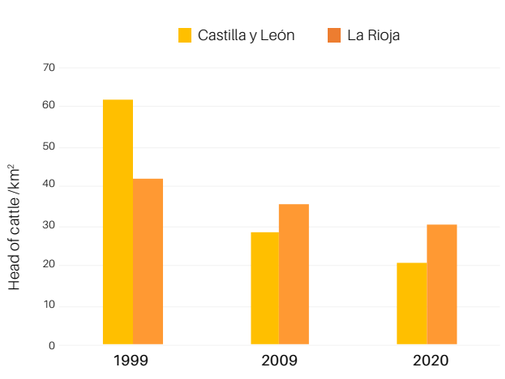
Forest fires can start due to natural causes (lightning), unknown origin, or they can be due to intentional acts, accident or negligence. The decrease in the number of fires due to accident or negligence in La Rioja could be related to the reduction in biomass burning, which is usually the origin of fires of this type.



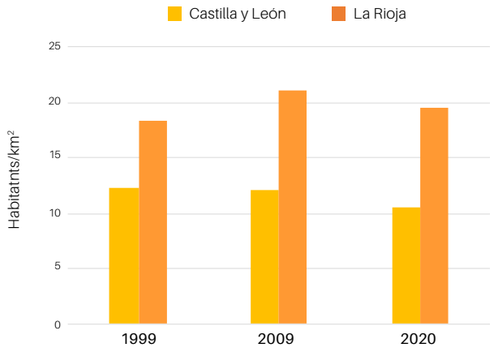
Percentage (%) of fires between 2001 and 2015 in the communities of Castilla y León and La Rioja between 700 and 1,000 m altitude

Population retention

Through the application of prescribed burning and clearing, the aim is to manage the land for environmental purposes (fire reduction) – but also socio-economic purposes – based on promoting extensive livestock farming and retaining population in the territory. Regarding the relationship with the promotion of livestock, there has been a decrease in the amount of livestock in Castilla y León, where scrub clearing and thinning are not carried out. On the other hand, an effect on the population retention in the territory of La Rioja is evident with an increase in the population in rural areas.



Average head of cattle by municipalities and years



Average number of inhabitants by municipalities and years

Extinguishing costs and losses resulting from fires

Extinguishing costs and losses resulting from fires become higher in the control area, where management is carried out based on prescribed burning. On the other hand, in the area of La Rioja – where clearing has contributed to reducing the risk of fire – the losses per hectare burned are significantly lower, around €240/ha burned. Thus, the management of the territory allows us to avoid losing around €1.036/ha burned in addition to reducing extinguishing costs per hectare.

	Extinguishing costs per hectare burned	Losses per hectare burned
Castilla y León	1.292,87 €	1.274,03 €
La Rioja	917,67 €	237,57 €
Difference (direct cost/hectares)	375,20 €	1.036,46 €

ANALYSIS OF WATER RESOURCES IN RELATION TO CLEARING AND FOREST MANAGEMENT MEASURES

The progressive rural abandonment of recent decades has caused the expansion of unmanaged forest areas, which are responsible for the increase in water interception and evapotranspiration. This vegetation growth has affected hydrological dynamics, and has led to a reduction in available water resources at the basin scale. In order to determine whether clearing and adaptive forest management can lessen this reduction in "blue water", the impact is analysed at the basin scale in the Aísa Valley (Aragon) and in the basins of the Anyet River (Catalonia) and Leza River (La Rioja) (*for more information* *see Deliverable no.21*):

Adaptive measures and water availability

Several studies relate the actions of scrub clearing or thinning with an increase in water flows. For example, clearing and cleaning of bushy areas and abandoned pastures that represent 15.7% of the surface in the Arnás basin – in the Central Pyrenees – can reduce evapotranspiration by 7.1% and improve flow annually by up to 24% depending on the intensity of the actions applied. The measures analysed in Aínsa (Aragón), Anyet (Catalonia) and Leza (La Rioja) confirm an improvement in the water balance derived from management and within the framework of the different climate change scenarios (*for more information* *see page 67*).

Impacts on the economy derived from the increase in water resources

Generally speaking, the increase of 1 hm^3 of water resources has an impact of €3,5 million, of which €275,424 correspond to the direct impact on the agricultural sector, and €3.204.230 to the indirect impact on all economic sectors thanks to the knock-on effect of increased agrarian production. Specifically, it would allow a direct increase of 52% for vegetable, fruit and nut crops. Regarding the net present value of the benefits derived from the increase in water availability, it is observed that, in the area of Aísa (Aragon), it ranges between €51,29 to €199,16 per hectare affected after the clearing and thinning actions in the different scenarios that contemplate the effects of climate change on exported water resources. In the Anyet River basin (Catalonia) and in the Leza Valley (La Rioja), the benefits are more notable and are between €7.000 and €4.500/ha affected on average in the different scenarios considered.

Net present value of the benefits derived from the increase in water availability

	Aísa (Aragon)	Anyet (Catalonia)	Leza (La Rioja)
Without climate change	-37,87 €/ha	4.891,98 €/ha	7.529,08 €/ha
Ssp 2.6	51,29 €/ha	4.580,02 €/ha	7.673,00 €/ha
Ssp 4.5	39,28 €/ha	4.518,67 €/ha	6.732,61 €/ha
Ssp 7.0	146,04 €/ha	4.454,94 €/ha	6.824,58 €/ha
Ssp 8.5	199,16 €/ha	4.056,45 €/ha	6.861,89 €/ha

SSP Shared Socioeconomic Pathways, future scenarios on alternative socioeconomic development

In relation to the cost of exported water derived from agro-livestock and forestry management actions, notable differences are observed as a function of location and proposed actions. In the Leza River basin (La Rioja), the costs of exported water are €0,06/m^3 (€0,07/m^3 with climate change), while those of the Anyet River basin are between 0,23 and 0,42 €/m^3 (0,24-0,50 €/m^3 with climate change); a range of values lower than the current cost of desalination (0,6-1 €/m^3) and of the same order as the cost of reused water (€0,45/m^3). In the Aísa Valley, the costs of provision are much higher. These results highlight the potential of the actions applied as a good alternative when aiming to reduce pressure on water resources, and suggest that, when well designed, they can become cost-efficient measures.

Cost of exported water derived from management actions

	Aísa (Aragon)	Anyet (Catalonia)	Leza (La Rioja)
Without climate change	-	0,23 – 0,42 €/m^3	0,06 €/m^3
Ssp 2.6	22,09 – 41,29 €/m^3	0,24 – 0,45 €/m^3	0,06 €/m^3
Ssp 4.5	28,85 – 53,92 €/m^3	0,24 – 0,45 €/m^3	0,07 €/m^3
Ssp 7.0	7,76 – 14,50 €/m^3	0,25 – 0,46 €/m^3	0,07 €/m^3
Ssp 8.5	5,69 – 10,63 €/m^3	0,27 – 0,50 €/m^3	0,07 €/m^3

SSP Shared Socioeconomic Pathways, future scenarios on alternative socioeconomic development

Thus, adaptation measures against climate change – such as, for example, clearing and forest management to recover pastures and forested areas – generate positive effects through greater availability of water, which results in greater agricultural production and increased activity in the different economic sectors.

IV RECOMMENDATIONS

Scrub clearing and subsequent maintenance with extensive livestock farming contribute positively to establishing and maintaining mosaic landscapes, improving the environmental and socioeconomic resilience of the territories. Thus, the promotion of a mosaic landscape becomes an essential strategy in the adaptation of the mid-mountain area to climate change.

Despite the low economic profitability and the need for constant help from public policies, below there are some recommendations to promote the scrub clearing-extensive livestock farming dichotomy:

RECOMMENDATIONS FOR SCRUB CLEARING

Scrub clearing plan

In heavily revegetated territories and in the absence of measures to create open spaces, it is recommended to follow a scrub clearing plan based on the technical criteria of the La Rioja Clearing Plan of 1986, or to adapt it to local conditions.

Guarantee financing

It is advisable to be able to guarantee, through public policies, sufficient annual financing for clearing scrub.

Efficient clearing

Clearing actions should serve to regenerate herbaceous grasses, reduce and control fires, and delay the regrowth of the scrub. The use of economically unprofitable animal species (mares and donkeys) can facilitate clearing in inaccessible areas.

Regenerative livestock

Regenerative livestock farming is based on using high livestock density rates for relatively short periods of time combined with long periods of pasture rest, to ensure productivity and soil quality, as well as the well-being of the animals. The use of this system is recommended to recover forage potential and delay the regeneration of scrub.

Management for efficient clearing

It is advisable to adapt the livestock intensity depending on the potential of the pastures and climatic conditions, as well as combining different livestock species. On the other hand, to achieve efficient management, it is also necessary to direct livestock routes with shepherds, water troughs or fences, in addition to generating new routes through the application of selective felling.

RECOMMENDATIONS TO PROMOTE EXTENSIVE LIVESTOCK FARMING

Improving the economic profitability of livestock farms

It is recommended to seek strategies to facilitate the sale of products –mainly meat– with an increased price to achieve an improvement in economic profitability. Among the possible measures, those that stand out are the promotion of mobile slaughterhouses, the promotion of direct sales to the consumer, the promotion of local products and tourism, or the creation of a quality brand associated with extensive livestock farming.

Public aid and subsidies

To improve public aid intended to complement the income of livestock farmers, it is recommended to incorporate all environmental, landscape and climate change-related benefits in the receipt of aid from the Common Agricultural Policy (CAP), apply a payment for environmental services (PSA) and provide aid for possible damage that protected species may cause. Furthermore, it is recommended to promote the modification of the pasture subsidy coefficients (CSP) of the Common Agricultural Policy, to include pastures under tree cover as eligible areas.

Improvements in livestock management

It is advisable to strengthen the perimeter fences to ensure the presence of the animals in cleared areas, encourage the use of GPS to control the movements of the livestock and condition the drinking troughs and salt points to facilitate the tasks of the farmers and improve the management of the livestock.

PASTURE RECOVERY

Visual guide to the impacts of the experimental actions carried out within the framework of the LIFE MIDMACC project

MIDMACC Mid-mountain adaptation to climate change — LIFE18 CCA/ES/001099

CHARACTERISTICS OF THE AREAS

	AREA 1	AREA 2	AREA 3
Region	Aragon	La Rioja	La Rioja
Climate	Continental Mediterranean with Alpine influence	Continental Mediterranean with Atlantic influence	Humid Mediterranean
AAT	10ºC	12ºC	14ºC
AP	1.000 mm	500 mm	600 mm
Altitude	932 m a.s.l.	1039 m a.s.l.	850 m a.s.l.
Soil	Calcareous	Calcareous	Silicic
Previous load	Not pastured	Non-intensive pastures	Non-intensive pastures
Condition	Degraded and abandoned land	Degraded and abandoned land	Degraded and abandoned land

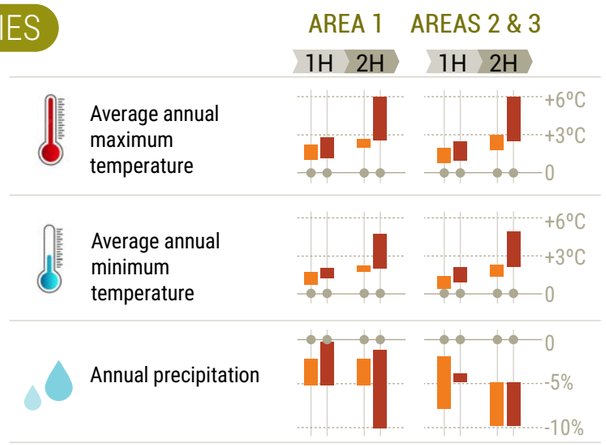
AAT = *average annual temperature;* **AP** = *annual precipitation*

PRESSURES AND VULNERABILITIES

Climate change

Legend

- *Starting point (2020)*
- *Range of forecasts for the most moderate scenario (RCP 4.5)*
- *Range of forecasts for the most pessimistic scenario (RCP 8.5)*
- 1H *First horizon (2020-2050)*
- 2H *Second horizon (2051-2100)*



Changes in the territory

- ▲ Raising the upper limit of the forest
- ▲ More abundant forest stands
- ▲ Increased fire risk
- ▼ Reduction in pastures
- ▼ Loss of biodiversity in open spaces
- ▼ Rivers carrying less water
- ▲ Increased risk of flooding

Socioeconomic changes

- ▼ Loss of profitability of pastures
- ▲ Increased risk of depopulation

IMPACTS OF ADAPTATION MEASURES

Legend

Control = no clearing or livestock
Without pasture = with clearing and without livestock
Low load = with clearing, livestock 72 hours, 1 time/year
Moderate load = with clearing, livestock 72 h, 2 times/year
High load = with clearing, livestock 72 hours, 3 times/year

☺ *Favourable situation for the adaptation of the mid-mountain area to global*

☹ *Unfavourable situation for the adaptation of the mid-mountain area to global change*

Effects of treatments on variables:

- *Not evaluated*
- *No change*
- *Small increase*
- *Moderate increase*
- *Large increase*
- *Very large increase*
- *Small reduction*
- *Moderate reduction*
- *Large reduction*
- *Very large reduction*

C/N = *Carbon/nitrogen ratio;* org. C = *Organic carbon;* B.soil = *Bare soil;* Rich. herb. = *Richness of herbaceous species;* Cov. herb. = *Covering of herbaceous species;* Prod. = *Pasture productivity.*

RECOMMENDATIONS

To carry out scrub clearing

- ☑ Guarantee clearing each year with public financing
- ☑ Combine grazing with different livestock species
- ☑ The use of regenerative livestock farming to recover forage potential and delay scrub regeneration.
- ☑ Adapt clearing to the potential of pastures and livestock routes

Encourage extensive livestock farming

- ☑ Promote mobile slaughterhouses and local direct sales, and create quality brands
- ☑ Incorporate payment for environmental services in public aid
- ☑ Strengthen perimeter fencing, the use of GPS, watering troughs and salt points to control the flocks
- ☑ Include pastures under tree cover as eligible area for the Common Agricultural Policy (CAP)

FOREST MANAGEMENT

The forests of the Mediterranean mid-mountain area are especially vulnerable to climate change.

Adaptive forest management based on the selective treatment of the understory and tree thinning aims to promote combustible material discontinuity with the aim of reducing the risk of forest fire, increasing the generation of pastures and reducing water stress in the forest.

I. METHODOLOGY

Pilot tests have been implemented in representative forested areas of the mid-mountain, such as, for example, a black pine forest (*Pinus nigra*) and a poplar tree forest (*Populus nigra*) on the experimental farm La Garcipollera, in **Aragon**, and a holm oak forest (**Quercus ilex**) on the Requesens estate (L'Alt Empordà) in **Catalonia**.

With the objective of evaluating forestry and livestock management as climate change adaptation measures, the following steps have been carried out:

1 *Adaptive forest management*

Before managing the forest, it is necessary to know the initial state of the forest in order to be able to design the relevant forest management measures. Therefore, it is necessary to carry out an initial forest inventory, based on the following variables:

- Forest structure: determines the density of the forest (number of trees per hectare) and diameter and height of the trees
- Continuity of combustible material: evaluates the risk of fire and crown fire
- Understory biovolume: determines the cover of scrub species
- Regeneration: analyses the ability for regrowth
- Health status: evaluates the state of decline of the forest

The forest management actions applied are mainly based on selective thinning treatments and scrub clearing, to reduce tree density and promote mature structures with larger trees. In this way, the aim is to reduce continuity of combustible material and the risk of fire, promote the development of pastures through greater soil irradiation and promote an improvement in livestock management.

Black pine forest (*Pinus nigra*) in La Garcipollera - Aragon

- Low density (470 trees/ha, dominant diameter classes 20 and 30)
- Low fire risk
- Median basal area >24.2 m²/ha

- Forest treatments have been applied mainly to the understory, leading to changes in the cover and biovolume of the understory. It has not been necessary to act in the tree layer

Poplar forest (*Populus nigra*) in La Garcipollera - Aragon

- Very low density (75-175 trees/ha, dominant diameter classes 25 and 40)
- Median basal area 9.5 m²/ha

- Forest treatments have been applied mainly to the understory, leading to changes in the cover and biovolume of the understory. It has not been necessary to act on the structure of the trees.

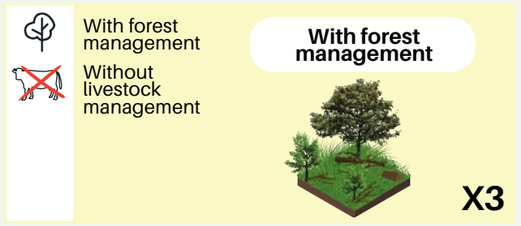
Holm oak forest (*Quercus ilex*) in Requesens - Catalonia

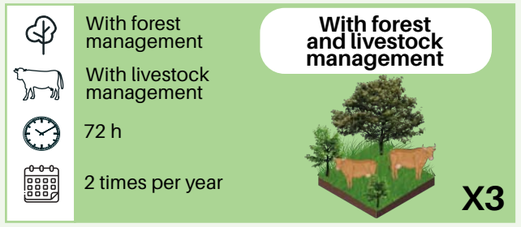
- Very dense and irregular (>1,700 trees/ha, dominant diameter classes 10 and 15)
- Moderate fire risk
- Median basal area >30 m²/ha

- Medium density (700 trees/ha, lower diameter classes alternating with large ones)
- Moderate fire risk
- Median basal surface 13.8 m²/ha

2 *Installation of monitoring plots*

After forest management, monitoring plots are delimited. The study area is divided into an area where the described forest management actions are applied and a control area, without any type of forestry or livestock action, which allows the evolution of the space to be compared. In this context, the managed area contains two scenarios of different livestock pressure (active and zero). For each of the areas, three replications (x 3) are carried out, achieving a total of 9 monitoring subplots.

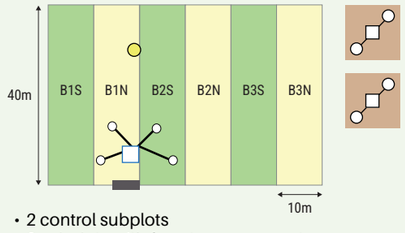




The surface area of the subplots is determined based on the available surface area in each area and study area, as well as according to the conditions imposed by the ownership of the livestock action, carried out with cows.

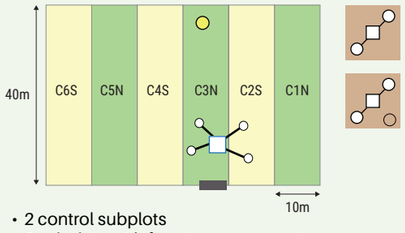
Experimental design of the monitoring plots and location of the devices for monitoring environmental variables:

Pinus nigra forest in La Garcipollera (Aragon) 400 m²



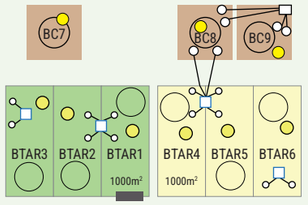
- 2 control subplots
- 3 subplots with forest management
- 3 subplots with forestry and livestock management

Populus nigra forest in La Garcipollera (Aragon) 400 m²

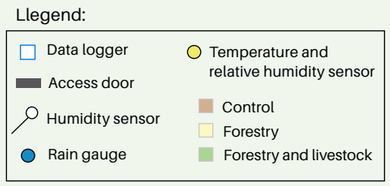


- 2 control subplots
- 3 subplots with forest management
- 3 subplots with forestry and livestock management

Quercus ilex forest in Requesens (Catalonia) 1000 m²



- 3 control subplots
- 3 subplots with forest management
- 3 subplots with forestry and livestock management



3 *Protocol and monitoring variables*

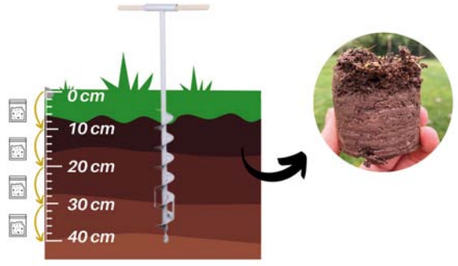
In order to evaluate the effects of adaptive forest management and livestock management on the reduction of forest fires and the regeneration of pastures, the following environmental variables are monitored (*for more information, see Deliverable no.9*):

A Soil properties

The characteristics of the soil (carbon/nitrogen ratio and organic matter, among others) are analysed at the beginning of the monitoring, to know the initial conditions of the soil, and at the end of it, to determine the effects of the actions on the soil. On the other hand, an annual monitoring of the variables related to carbon storage is carried out as a key element to mitigate the effects of climate change, as well as a continuous monitoring of soil humidity as an indicator of the availability of water for vegetation in the different treatments.

B Forest characteristics

In order to demonstrate and quantify how the applied management can reduce the vulnerability of forests to climate change, a forest inventory is carried out in the monitoring plots in initial conditions, which analyses the structure and health status of the forest and also the continuity of combustible forest material. This analysis is repeated at the end of the experiments. Forest health, and the continuity and moisture of combustible material are also analysed to varying degrees once a year.

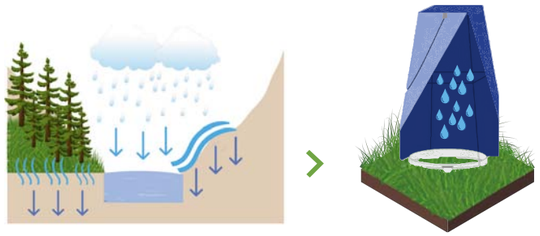


(C) Pastures

The effect of grazing with cows on the production and quality of pastures is evaluated through the analysis of the abundance and composition of plant species, and also the nutritional quality, biomass and pastoral value. All sampling is carried out at the end of spring, before grazing begins and coinciding with the growth of the vegetation and the flowering peaks typical of the Mediterranean mountains. In this way, the correct identification of plant species is ensured.

(D) Hydrological response and erosion

To evaluate the effect of forest management and grazing on hydrological response and soil erosion, rainfall simulations are carried out, which analyse how adaptive forest management actions and the introduction of livestock ranching affect the runoff coefficient and infiltration depth, as well as erosion and sediments.



(E) Local weather conditions

A continuous record of meteorological conditions is made throughout the duration of the project in order to interpret the evolution of the monitored environmental variables.

II. RESULTS

MONITORING RESULTS AT LANDSCAPE SCALE

Below, the effects, at a landscape scale, of the application of forest management as an adaptive measure against climate change are shown in the studies carried out in Aragon and Catalonia to reduce the risk of forest fires and other vulnerabilities presented by forests in the mid-mountain area, especially vulnerable spaces due to their climatic sensitivity and their territorial extension:

a Reduction of forest vulnerability

- Reduction of the risk of fire and improvement of the health status of forests where complete forest management is carried out, with clearing of the understory and actions on the tree cover.
- Better response of Mediterranean forests to adaptive forest management.

b Adaptive forestry practices

Increased robustness against climatic events through the application of adaptive management. Three silvicultural practices have been tested:
1) Reduction of tree density
2) Understory management
3) Promotion of heterogeneity

RESULTS OF MONITORING AT PLOT SCALE

Below, the effects of adaptive forest management and its subsequent maintenance through the use of extensive livestock farming are shown on a more detailed scale. The managed plots correspond to a *Pinus nigra* forest and a *Populus nigra* forest in Aragon, while, in Catalonia, they correspond to a *Quercus ilex* forest (*for more information, see Deliverable no.31*):

Interpretation of the results

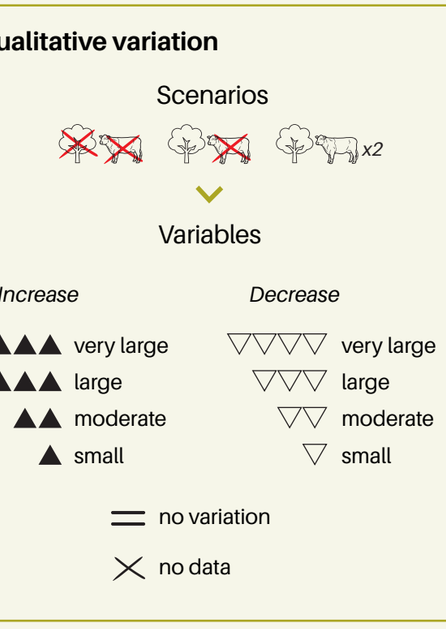
The results obtained from monitoring the different forestry and livestock management scenarios are shown through qualitative interpretation tables.

The values measure the magnitude and direction of the change. In this way, you can see if a variable is unchanged, increases or decreases, as well as the intensity with which it does so. Those cases in which data are not available are also indicated.

It should be remembered that the results shown indicate a trend, but are not conclusive given the short study period (3-4 years) as well as the effects of climate variability and differences between the study areas.

Livestock pressure scenarios

Qualitative variation



EVOLUTION OF SOIL QUALITY

Soil moisture tends to increase seasonally in those plots with forest management. During the spring and summer months, this increase is positively correlated with an improvement in tree growth and health. In turn, the use of livestock in managed forests favours water retention in the soil, largely due to the presence of good herbaceous cover.

	Humidity	Carbon/ nitrogen ratio	Organic carbon
Pinus nigra			
Control	▲▲▲▲	▲▲▲▲	▲
Forest management	▲▲▲	▲▲▲	▽▽
Forestry and livestock management	▲▲	▲▲	▲▲▲
Populus nigra			
Control	▲	▲▲▲▲	▽▽▽
Forest management	▲▲	▲	▽
Forestry and livestock management	▲▲	▲	▽▽
Quercus ilex			
Control	▲	×	×
Forest management	▲▲	×	×
Forestry and livestock management	▲▲▲▲	×	×

EFFECTS ON RUNOFF AND EROSION

In the plots with *Pinus nigra* and *Populus nigra*, a greater production of water and sediment is observed when there is forestry and livestock management than when there is no type of management or only forestry management. This effect is not observed in the plots with *Quercus ilex*, in which both the understory and the tree cover are affected. On the other hand, erosive processes increase significantly in plots with *Quercus ilex* and in areas without livestock and without pasture establishment.

	Runoff	Erosion
Pinus nigra		
Control	▲	▲
Forest management	=	=
Forestry and livestock management	▲▲	▲▲
Populus nigra		
Control	▲	▲
Forest management	=	=
Forestry and livestock management	▲▲▲	▲
Quercus ilex		
Control	▲▲▲	▲▲▲
Forest management	▲▲▲▲	▲▲▲▲
Forestry and livestock management	▲▲	▲

FOREST CHARACTERISTICS

Complete forest management where action is taken both in the understory and in the tree layer leads to an increase in the water content of the vegetation in periods of high fire risk, thus reducing flammability and combustibility, as observed in the *Quercus ilex* plot compared to the *Pinus nigra* and *Populus nigra* plots, where only the understory is managed.

The same happens with the state of health of the forests, where the management of the tree layer involves less loss of leaves and colouring compared to those plots in which it is not applied.

Regarding vulnerability to crown fire, all managed plots have low vulnerability after carrying out the treatments. However, the role of livestock farming is key to reducing and maintaining this new forest structure.

	Vegetation humidity	Risk of crown fire	Defoliation/ Discolouring
Pinus nigra			
Control	▲▲	=	=
Forest management	▲▲	=	=
Forestry and livestock management	▲▲	=	=
Populus nigra			
Control	▲▲	=	=
Forest management	▲▲	=	=
Forestry and livestock management	▲▲	=	=
Quercus ilex			
Control	▲	=	▲▲
Forest management	▲▲▲	=	▲
Forestry and livestock management	▲▲▲▲	▽▽	▽

PRODUCTION AND QUALITY OF PASTURES

During the first stages of monitoring, in all the study plots, forest management is relevant for the establishment of herbaceous pastures under tree cover, since good forest management allows increasing the cover of herbaceous plants and reducing the cover of bare soil. However, we must take into account the effects of the drought in recent years (2022-2023), which directly affects the recovery of herbaceous cover.

	Bare soil	Herbaceous coverage	Production	Abundance of herbaceous plants	Quality
Pinus nigra					
Control	▲	▲	▲	▲	▲▲
Forest management	▲▲	▲▲	▲▲	▲	▲▲
Forestry and livestock management	▲▲▲	▲▲	×	▲▲	×
Populus nigra					
Control	▲▲	▲	▲	▲	▲
Forest management	▲	▲▲▲	▲	▲▲	▲
Forestry and livestock management	▲▲▲	▲▲	×	▲▲	×
Quercus ilex					
Control	▲▲	▲	▲	▲	▲▲
Forest management	▲	▲	▲▲	▲	▲
Forestry and livestock management	▲▲	▲▲	×	▲	×

WEATHER CONDITIONS

The decrease in rainfall and the notable increase in temperatures in recent years have a direct effect on the herbaceous cover, causing it to decrease drastically and for the covering of bare soil to increase. Consequently, livestock farming is also affected since its entry is restricted due to lack of herbaceous pastures.

EFFECTS OF FOREST AND LIVESTOCK MANAGEMENT

Livestock management a posteriori of forestry actions allows their maintenance, avoiding severe revegetation of the area.

However, although livestock farming exercises control over woody species by slowing the expansion of scrub, in some cases, despite the entry of herds, the scrub once again gains cover due to the regrowth of the bushes and trees that the cattle tend to reject, as has been observed in the experimental plots of Catalonia.

III. ECONOMIC ANALYSIS

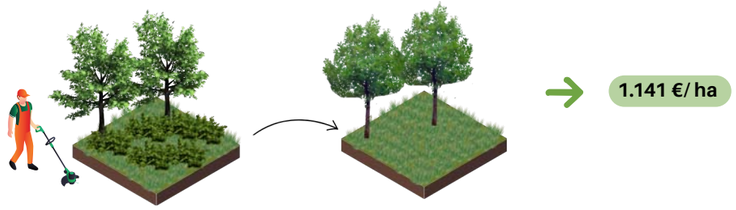
ECONOMIC ANALYSIS OF ADAPTIVE FOREST MANAGEMENT

So that the different managers of the territory can assess the possibilities of applying adaptive forest management and, thus, prevent and reduce the risk of fire in the mid-mountain area in the face of climate change, the economic costs involved in its application are analysed and, also, the different factors that influence the variability of its cost (*for more informatio, see Deliverable no.21*):

The application of adaptive forest management can have an initial value of approximately €1,140/ha considering low workload conditions, increasing to €2,200/ha for medium loads, and up to €5,100/ha considering a very complete activity (clearing, thinning, pruning, management of plant remains and planting), enabling the area to provide grazing for animals.

Maintenance of an existing pasture

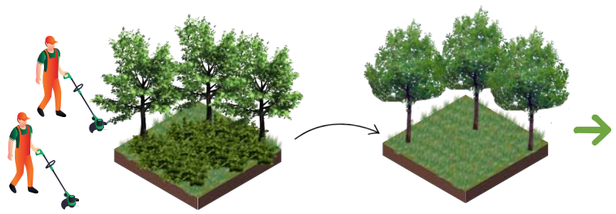
Clearing, pruning and thinning actions in a forested area with a low workload



1.141 €/ ha

Forest management with medium workload

Clearing, pruning and thinning actions in a forested area with a medium workload



2.213 €/ ha
a
5.100 €/ ha

Note: the prices shown do not take into account VAT, the cost of renting the machinery or its transportation. Data extracted from public companies such as TRAGSA (Transformation Agraria, S.A.), SARGA (Sociedad Aragonese de Gestión Agroambiental, S.L.U.) and Forestal Catalana, S.A., and from the costs incurred in the LIFE MIDMACC project for clearing and forest management actions.

CONDITIONING FACTORS OF COSTS

The average price of forestry activities per hectare has a similar cost to that of clearing activities, around €2,000/ha. However, when applying forest management actions, there is also variability in the real cost that can range up to €5,000/ha. This variation is due to various aspects that influence the number of hours of labour and, consequently, the cost. These aspects are detailed below:

Slope of the terrain

As indicated in the clearing actions, the slope of the terrain is a relevant factor. The greater the slope, the more expensive it is to work, the greater the limitation of mechanised processes and the longer the execution time.

Scrub cover

The height of the bush layer and the surface covered by scrub determine the efforts to carry out the work. The greater the amount of understory, the more labour, more material and more machinery is necessary.

Presence of obstacles

Carrying out forest management in rocky terrain, with the presence of lianas, climbing plants and other species that can make actions difficult increases the time spent.

Management of logging residues

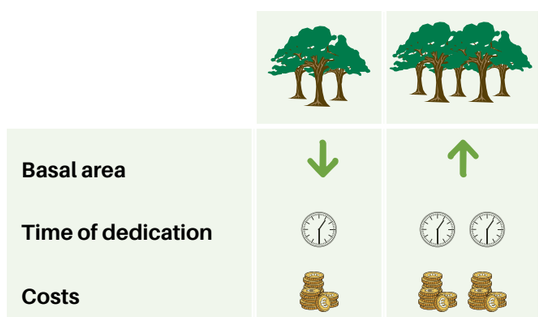
It often entails high expenses that can exceed the cost of pruning and thinning. However, in some cases, it can be compensated through the sale of the product.

Diameter of the trees

A very large normal diameter can lead to an increase in hours and efforts dedicated to felling: the larger the diameter, the more the cost.

Basal area

The basal area refers to the forest stand of a space and can be decisive when executing forestry actions. The larger the basal area, the more hours and, therefore, a greater economic investment is necessary.



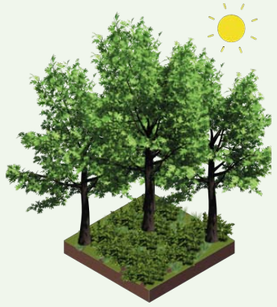
Cost of transportation

The costs in being able to carry out forestry actions also depend on the location and accessibility to the forest stands. The type of transport that can access the site of action and the type of road – whether it is paved or mountain road – directly influence the costs.

Hours of dedication

The time it takes to extract the logging residues resulting from pruning and thinning determines the costs. A forest stand with a normal diameter greater than 6 cm increases the number of hours dedicated to both logging and the extraction of logging residues up to three times.

Note...



- Among the economic conditions that determine the variation in costs, the slope, the diameter of the trees and the density of the forest stand out.

- The mechanisation of forestry actions reduces time and labour.

- Extensive livestock farming acts as a maintenance tool for forestry actions, reducing both costs and the risk of fire.

IV. RECOMMENDATIONS

Adaptive forest management with subsequent maintenance through extensive livestock farming makes it possible to reduce the vulnerability of forests to climate change. Consequently, the application of this binomial achieves an improvement in fire prevention and risk, soil quality, pastoral resources, biodiversity and water resources. At the same time, it also contributes to local development and improves the viability of mid-mountain area farms.

Below are some recommendations that can encourage the use of the forest management-extensive livestock binomial:

RECOMMENDATIONS FOR ADAPTIVE FOREST MANAGEMENT

Design of the actions

To generate pasture areas in forests, it is recommended to carry out a prior analysis of the structure of the forest (tree and bush cover), the herbaceous species present, characteristics and slope of the soil, etc., which allows evaluating the potential of the forest in the establishment of pastures.

Forest vitality and growth

It is advisable to prioritise forestry actions in highly vulnerable forests in order to improve their growth and vitality.

Actions in the understory

Among forestry actions, it must be taken into account that those that focus on the understory have a lower effect on the vitality and growth of the forest than those that include a reduction in tree density. However, actions focused on the understory has clear effects on reducing the risk of crown fire.

Actions in the tree cover

In case of intense thinning, the derived processes such as greater sun exposure, or greater risk of erosion, must be taken into account.

Morphology of the terrain

It is not advisable to apply forest management interventions on land with a marked slope since they have a greater risk of soil loss after treatment, which may be worsened by the effect of the livestock.

Management of logging residues

It is recommended to shred the logging residues, since they favour the integration of the plant remains with the soil and drastically reduce their combustibility after treatment. In addition, it contributes to the development of pastures. However, it must be considered that this action has a higher economic cost.

Herbaceous cover management

It is advisable to plant herbaceous species typical of pastures where their spontaneous appearance after silvicultural actions is difficult, since the cover has protective effects on the soil and facilitates management by livestock. Likewise, it is recommended to protect initial sowings from wild ungulates through the use of fencing or electric fences. It must be taken into account that both actions – sowing and protection – have an added cost.

Weather conditions

The effects of drought condition the effectiveness of initial plantings and can compromise the timeliness of replanting practices. They also condition the expected initial frequency of entry of the animals. Therefore, it is recommended to readjust the livestock intensity to the availability of pastures depending on climatic conditions.

RECOMMENDATIONS TO PROMOTE EXTENSIVE LIVESTOCK FARMING

Regenerative livestock

Regenerative livestock farming is based on using high livestock densities for relatively short periods of time combined with long periods of pasture rest. This rotational grazing allows the recovery of pastures and prevents soil compaction. However, the availability of trained shepherds and the necessary infrastructure are key elements to carry out this type of management.

Type of livestock

Sometimes, the appropriate combination of different types of animals is advised to stop the expansion of scrubland, due to the different consumption patterns of each species.

Animal welfare

The presence of pastures under tree cover in Mediterranean climates is key for animal well-being during the warmer months since they find shaded areas to take shelter.

Improving the economic profitability of livestock farms

In order to achieve an improvement in the economic profitability of these livestock farms, it is advisable to promote a brand that allows them to identify their contributions to adaptation to climate change. Likewise, mobile slaughterhouses are needed to facilitate and reduce the costs of marketing and distribution of livestock products.

Public aid and subsidies

It is necessary to modify the CAP pasture subsidy coefficients to include pastures in wooded areas and also study the application of payments for environmental services (PES).

Specific training

In order to improve livestock management, it is recommended that both livestock farmers and owners receive training in extensive regenerative or rotational livestock farming, as well as silvopastoral techniques.

FOREST MANAGEMENT

CHARACTERISTICS OF THE AREAS

	AREA 1	AREA 2	AREA 3
Region	Aragon	Aragon	Catalonia
Climate	Mediterranean with alpine influence	Mediterranean with alpine influence	Mediterranean coastal climate
AAT	10ºC	10ºC	12,5ºC
AP	1.000 mm	1.000 mm	840 mm
Altitude	932 m a.s.l.	932 m a.s.l.	500 m a.s.l.
Forest type	*Pinus nigra*	*Populus nigra*	*Quercus ilex*
Density	Low	Very low	Very dense and irregular
Risk of crown fire	Low	Low	Moderate
Density reduction	Not applicable	Not applicable	700 trees/hectare

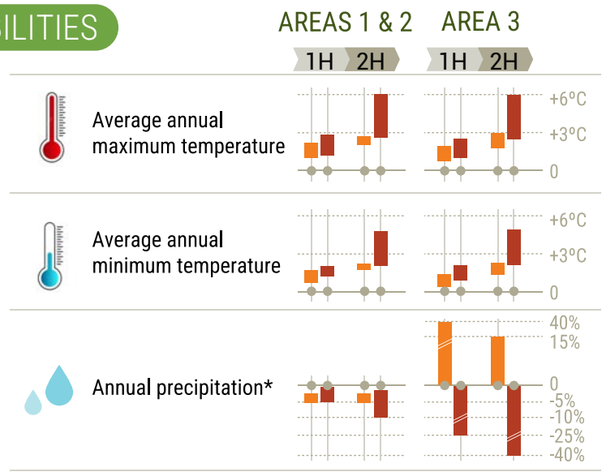
AAT = *Average Anual Temperature*; PA = *Anual Precipitation*

PRESSURES AND VULNERABILITIES

Climate change

Legend

- *Starting point (2020)*
- *Range of forecasts for the most moderate scenario (RCP 4.5)*
- *Range of forecasts for the most pessimistic scenario (RCP 8.5)*
- 1H *First horizon (2020-2050)*
- 2H *Second horizon (2051-2100)*
- *Jump in the range*



*In Catalonia, the great rainfall variability is due to the uncertainty in the projections for the first half of the century. However, projections in the summer months indicate statistically significant reductions in precipitation.

Changes in the territory

- ▲ The forest expands
- ▲ The forest stands grow a lot
- ▲ Increases the risk of fires
- ▼ Increases wildlife access to crops
- ▼ Loss of biodiversity in open areas
- ▼ Rivers carry less water
- ▲ Flood risk increases

Socioeconomic changes

- ▼ More uncertainty in the quality of the crops
- ▲ Increased risk of depopulation

IMPACTS OF ADAPTATION MEASURES

Legend

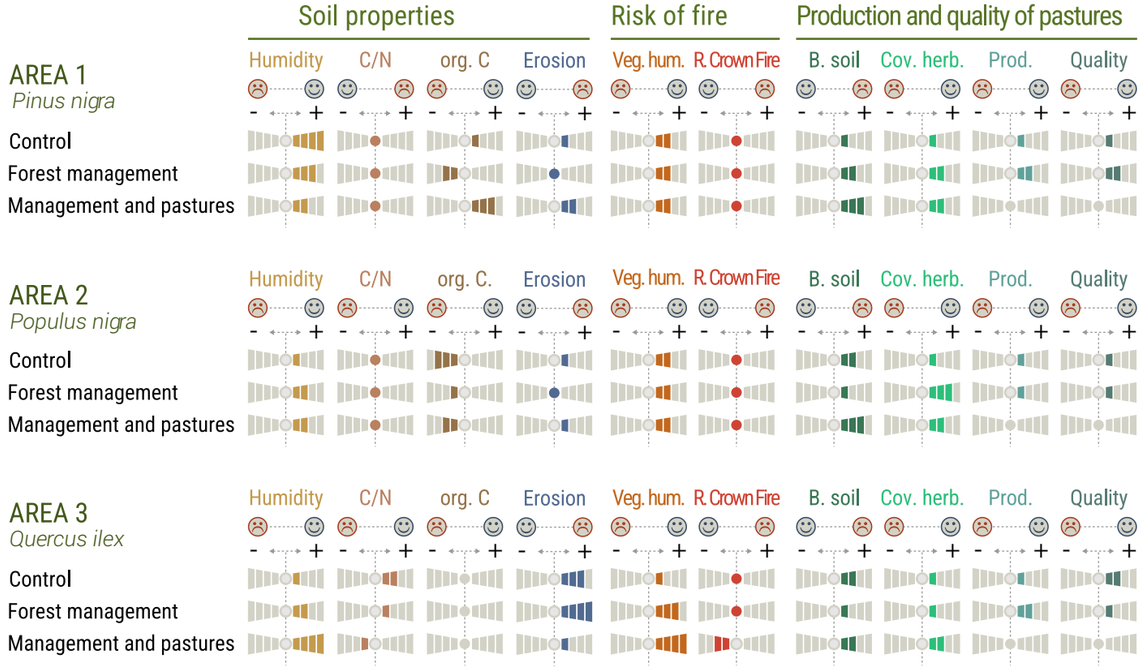
Control = without forest management or livestock
Forest management = with forest management and without livestock
Forest and livestock management = forest management, livestock 72 hours, 2 times/year

Favourable situation for the adaptation of the mid-mountain area to global

Unfavourable situation for the adaptation of the mid-mountain area to global change

Effects of treatments on variables

- *Not evaluated*
- *No change*
- *Small increase*
- *Moderate increase*
- *Large increase*
- *Very large increase*
- *Small reduction*
- *Moderate reduction*
- *Large reduction*
- *Very large reduction*



C/N = *Carbon/nitrogen ratio*; org.C = *Organic carbon*; Veg. hum. = *Vegetation humidity*; R. Crown Fire = *Risk of crown fire*; B. soil = *Bare soil*; Cov. herb. = *Covering of herbaceous species*; Prod. = *Pasture productivity.*

RECOMMENDATIONS

To carry out adaptive forest management

- ☑ Prioritise highly vulnerable forests
- ☑ Do not prioritise places with steep slopes and risk of erosion
- ☑ Shred the logging residues, evaluating the economic cost
- ☑ If necessary, sow herbaceous grasses and make initial fencing

To encourage extensive livestock farming

- ☑ Promote mobile slaughterhouses and direct and local sales, and create quality brands
- ☑ Combine different types of livestock to limit scrubland
- ☑ Include pastures under tree cover as an eligible area for the Common Agricultural Policy (CAP)
- ☑ Carry out rotational grazing to ensure pasture regeneration
- ☑ Receive training in extensive rotational livestock farming and silvopastoral techniques

OPTIMISATION OR INTRODUCTION OF VINEYARDS

One of the landscape management measures consists of promoting vineyards in mountain agriculture. Through the conversion of scrub into vineyards and the adaptation of agricultural practices to climate change, an environmental and socioeconomic improvement of agriculture in mid-mountain areas is intended to be achieved.

I. METHODOLOGY

Five pilot tests are implemented in a gradient that covers different environmental conditions and agronomic practices to determine which are the most important factors for the adaptation of this crop to the mid-mountain. In Catalonia, in the vineyards of the Celler Cooperatiu d'Espolla winery, the Finca de Mas Marès d'Espelt Viticultors (Roses) and Llivins (Llívia) and, in La Rioja, in the Dinastía Vivanco (Tudelilla) and Mont Laturce (Clavijo) wineries.

The objective is, on the one hand, to improve the adaptation of the mid-mountain to climate change and, on the other, to determine which practices best contribute to the cultivation of vineyards in these areas and what limitations they may present.

In addition to the climatic gradients and the different soil characteristics, throughout the five pilot tests, the following gradients are considered:

a) Altitude above sea level: between 100 m above sea level (hereinafter "a.s.l.") and 1,200 m a.s.l.

b) Age of the vines from 1 to over 50 years.

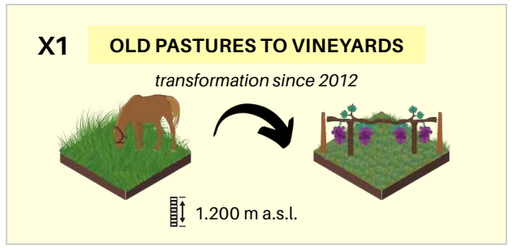
c) Slope of the plot: hillside land.

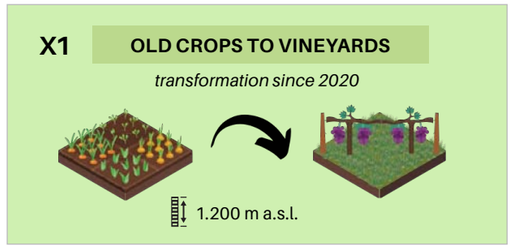
d) Use of plant cover: from completely conventional management with continuous tillage and use of herbicides to managed and well-implemented permanent cover.

e) Formation in goblet-pruning or espalier.

1 *Transformation of old crops and pastures into vineyards: Llívia*

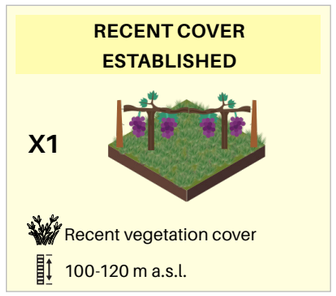
The migration of the vineyard to high altitude (1,200 m a.s.l.) presents a series of challenges. In this case, a change in land use from pasture to vineyard (2012) and from cultivation to vineyard (2020) of espalier vineyards with managed permanent vegetation cover, without slope and with low temperatures.

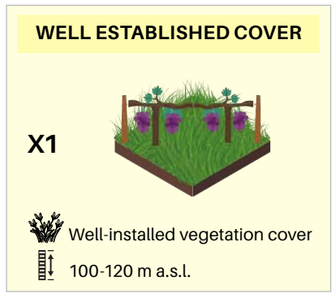




2 *Implementation of vegetation cover in old vineyards: Espolla*

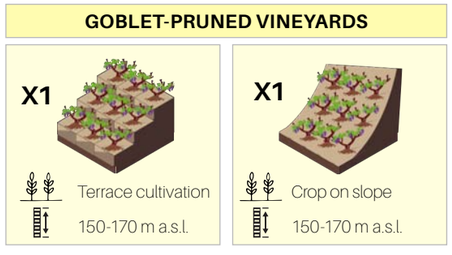
This case study has the objective of seeing the effect of the implementation of a permanent vegetation cover, compared to conventional soil management with frequent tillage and use of herbicides. In three adjacent plots between 100 and 120 m a.s.l., with a very slight slope and a goblet-pruned formation more than 50 years old. A long-term conventional management plot, one with a well-installed cover (2016) and one with a newly installed cover (2019).

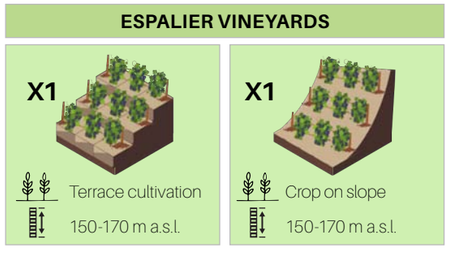




3 *Terrain morphology and vineyard formation system: Roses*

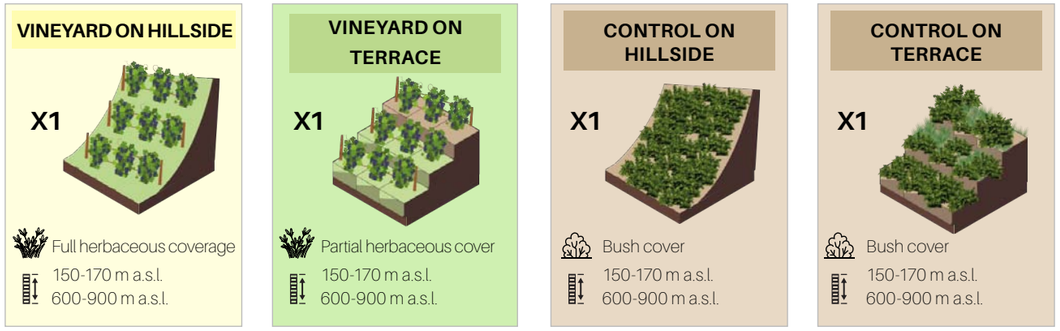
Despite being at a low altitude, the slope of the terrain is an added difficulty to the cultivation of the vineyard, which can be done by terracing the land, as was traditionally done to prevent erosion and facilitate management. The more traditional system of training grape vines with goblet pruning – or, in a more modern form, espalier– has implications for efficiency, the use of water in the vines, growth, yield and quality of the grapes obtained. Both variables have implications for the costs of establishing and managing the plot. On the Mas Marès estate (Roses) at 150-170 m a.s.l., all plots have temporary vegetation cover and vines planted in 2002, reconstructing old terraces.





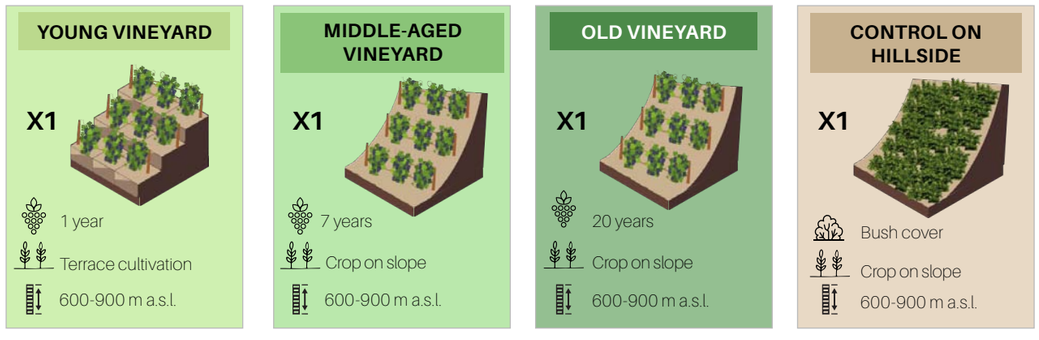
4 *Terrain morphology, altitude and vegetation cover: Clavijo*

This plot combines the altitude (600-900 m a.s.l.) with the slope of the terrain, on a terrace, with total or partial cover, and also compares it with the adjacent scrubland on a terrace to illustrate the change in land use.



5 *Implementation of the vegetation cover in vineyards of different ages: Tudelilla*

This plot combines the altitude (600-900 m a.s.l.) with the slope of the terrain, on a terrace or slope, with a gradient of the ages of the vineyard, planted in the year 2000, 2012 and 2020, providing a time series perspective. It is also accompanied by an adjacent patch of scrubland.



6 Protocol and monitoring variables

In order to know the vulnerabilities of the vineyard in mid-mountain areas against the impacts of climate change and to be able to assess the adaptation of agricultural practices and their effects on the environment and on the production and quality of the wine, monitoring has been carried out the following environmental variables (*for more information, see Deliverable no.10*):

Soil properties

The effects of planting vineyards and the implementation of different agronomic practices over time (age) and space (location and altitude) on the physical-chemical properties of the soil (10-20 cm depth) are evaluated: texture, pH, organic matter and nutrients. Continuous monitoring of the water content in the soil is also carried out, which is of utmost importance for adaptation to climate change.

Hydrological response and erosion

With rainfall simulation experiments, the hydrological response of vineyard implementation and the implementation of different adaptive practices to erosion, runoff and infiltration of rainwater in crops and adjacent vegetation are studied. Soil loss is a serious structural problem, but it also involves the loss of nutrients and organic matter, which impoverishes soils and increases management costs.

Grape production and quality

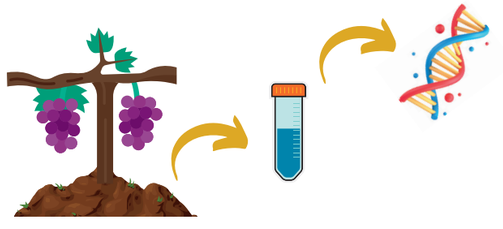
To determine the viability of establishing vineyards in the mid-mountain as a measure of adaptation to climate change, the production (kg grapes/ha) and the quality of the grapes at harvest (acidity, pH, colour and alcoholic strength) are analysed annually.

Local weather conditions

The recording of meteorological conditions is key to understanding the evolution of the variables studied throughout the duration of the project. For this reason, continuous monitoring is carried out through temperature and humidity sensors, as well as weather stations near the study areas.

Soil microbial biodiversity

The abundance and diversity of soil microorganisms contributes to healthier, more sustainable and more resilient soils. With studies of genetic diversity and its relationship with the physicochemical properties of the soil, we analyse how vineyard cultivation and the use of different agronomic practices over time affect soil health. Likewise, indicators of adaptation to different conditions are established.

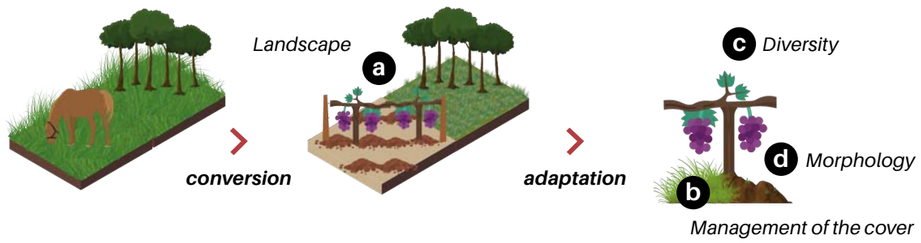


II. RESULTS

MONITORING RESULTS AT LANDSCAPE SCALE

The wine sector is one of the agricultural sectors that is most keenly aware of climate change. Its involvement means that different alternatives to usual agricultural practices are sought as a sustainable and adaptation measure. Viticulture in mountain areas, seeking cooler temperatures, is already an adaptive practice, along with the change of varieties.

Below are the effects, at landscape scale, of the establishment of vineyards and the implementation of the different practices in the study areas of **Catalonia** and **La Rioja**:



a Mosaic landscape

- Becomes a mosaic generating element
- Breaks the continuity of the forest
- Provides biodiversity
- Increases in hunting fauna pressure

b Vegetation cover management

- Prevents erosion
- Improves water infiltration
- Negative influence on vegetative growth and crop yield in the short term

c Soil microbial diversity

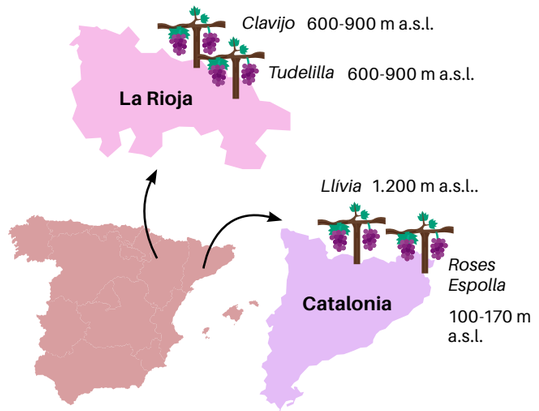
- The microbial diversity of the soil is conditioned by the presence of the crop, goblet-pruned or espalier formation, the age of the vines and the slope of the terrain

d Morphology and slope of the terrain

- There are no productive differences between terraced or hillside land
- Reconstruction of terraces is more economical than implementation from the beginning. Construction from scratch also alters the physical-chemical properties of the soil and microbial diversity
- Lands with less slope or terrace have greater microbial diversity than lands with greater slopes, possibly due to a loss of clay, organic carbon and nitrogen due to soil erosion processes.

RESULTS OF MONITORING AT PLOT SCALE

The adaptation measures analysed aim to improve the restrictive environmental conditions for agriculture in the medium-altitude Mediterranean mountains. Below are the effects of its application in the experimental plots distributed following an altitudinal gradient, to evaluate the adaptation of the vineyard to the mid-mountain area (*for more information, see Deliverable no.32*) :



EVOLUTION OF SOIL QUALITY

- **Coastal plots (from 100 to 170 m a.s.l.):**
  The implementation of a vegetation cover involves an increase, in the short term, of organic matter and micronutrients in the soil. The exception is the terraced plots and the goblet-pruned vineyard, where the levels are reduced.

- **Plots at altitude (from 600 to 1,200 m a. s. l.):**
  Adult vines on terraces show higher levels of organic carbon and nitrogen than vineyards on slopes. The inclination of the land could be correlated with the loss of nutrients, given that the greater the slope, the greater the erosion, producing a loss of clay, organic carbon and nitrogen.

  On the other hand, the implementation of vineyards in old pastures means that the levels of organic matter and micronutrients are lower compared to already established vineyards due to adaptation to the new terrain.

MICROBIAL BIODIVERSITY

- **Coastal plots (from 100 to 170 m a.s.l.):**
  The microbial diversity of the soil is higher in vineyards with vegetation cover than in vineyards with traditional soil management. Recent vegetation cover tends to have greater biodiversity compared to more established cover. The morphology of the land and the vineyard also determines the microbial diversity of the soil, so the alpha* diversity is slightly lower in terrace and goblet-pruned vineyards.

  On the other hand, in plots without vineyards and dominated by scrub, a lower microbial alpha diversity is observed compared to plots with vineyards.

* Alpha diversity is the diversity of species at a local scale

- **Plots at altitude (from 600 to 1,200 m a.s.l.):**
  Hillside plots have lower microbial alpha diversity and a lower abundance of fungi and ammonium-oxidising archaeal bacteria compared to terrace plots, due to the slope of the terrain. The greater the slope, the less diversity. On the other hand, in vineyards implemented in old pastures, the abundance of microorganisms in the soil seems to present higher levels compared to the preceding pastures.

HYDROLOGICAL PROPERTIES OF THE SOIL

- **Coastal plots (from 100 to 170 m a.s.l.):**
  The elimination of the vegetation cover on the vineyard floor leads to a decrease in infiltration and less water retention compared to those plots where the herbaceous cover is established. On the other hand, vineyards on hillsides or terraces do not present a clear pattern regarding water retention in the soil or its dynamics, and show differences in erosion and runoff rates, possibly due to good use of vegetation cover.

- **Plots at altitude (from 600 to 1,200 m a.s.l.):**
  Erosion and runoff are more marked on sloping lands, leading to a significant loss of clay, organic matter and nitrogen, as well as a reduction in microbial diversity and abundance. Thus, a greater slope of the terrain has a greater negative impact on soil characteristics and microbial biodiversity. On the other hand, on land with greater vegetation cover, erosion and runoff are less, as observed in higher altitude plots.

VINEYARD PRODUCTION

- **Coastal plots (from 100 to 170 m a.s.l.):**
  The yield of the vineyard tends to increase in the presence of an established vegetation cover, because it allows greater water retention in the soil. In addition, it also influences productivity and the type of vine formation, increasing in espalier formations.

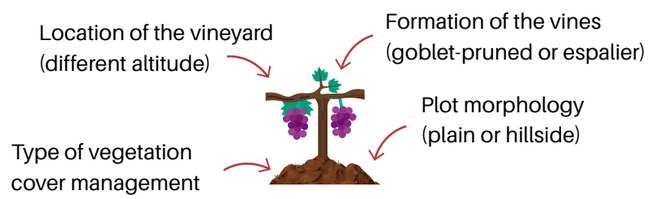
- **Plots at altitude (from 600 to 1,200 m a.s.l.):**
  In the case of young vines, there is a tendency to increase production over the years, according to the age of the plantation and due to the climate conditions and soil types in mountain areas.

III. ECONOMIC ANALYSIS

ECONOMIC ANALYSIS OF ADAPTIVE AGRICULTURAL PRACTICES WITH VINES

With the aim of offering a guide to the different actors interested in the application of adaptive agricultural practices for vineyard cultivation, the costs involved in their implementation are analysed below and the strengths and weaknesses of each type of practice are highlighted (*for more information consult the corresponding study included in Deliverable no.21*):

The mountain vineyard has different characteristics compared to that of flatter areas, where it is the majority. These characteristics mean that the mountain vineyard has high costs, and that an environment and services are necessary to sustain the crop. For this reason, a comparison is made between the different adaptive practices and the territorial characteristics (location and climatic and soil conditions).

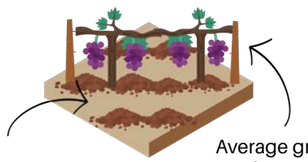


- **Vineyard vegetation cover management**

The removal of vegetation cover on conventionally managed plots entails higher costs (> €590/ha) compared to those with vegetation cover. On the other hand, the management of vineyards with established or recently implemented vegetation cover does not present differences in total costs.

Regarding grape production (kg/ha), conventional management obtains an average production much higher than management with covers. However, an increasing trend is observed in those plots with vegetation cover (16%), and their quality also increases, using the grapes for high-end wines.

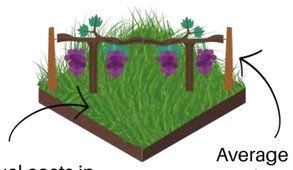
Period 2011-2015



Annual costs in vineyard production
3.567 €/ha

Average grape production
2.211 kg/ha

Period 2016-2021



Annual costs in vineyard production
2.968 €/ha

Average grape production
2.555 kg/ha

Variation in production between the two periods

+343 kg/ha (+16%)

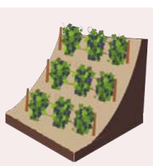
Vine formation system: goblet-pruned or espalier

The implementation of one hectare of espalier vineyard increases total costs by 40% compared to a goblet-pruned vineyard. These costs correspond mainly to the material and labour for the installation of the espalier system. However, when the amortisation of the installations over time is taken into account, no significant differences are observed in the annual cost between both systems. In relation to maintenance and harvest expenses, the goblet-pruned vineyard requires more hours and, therefore, entails a greater expense than the espalier system.

	Goblet-pruned vines	Espalier vineyard
Implementation of the vineyard	8.081 €/ha	13.640 €/ha
Maintenance and annual actions	3.746 €/ha	3.294 €/ha
Annual amortisation of the installation (25 years of life)	✗	223 €/ha
Annual production cost	4.070 €/ha	3.841 €/ha

Terrain morphology: terrace or hillside

Vineyards located on slopes or on narrow terraces entail an increase in costs due to the increase in manual tasks or the need for specific machinery given the morphology of the land. For example, on narrow terraces, manual harvest costs represent 39% of the total vineyard management costs, while, in the case of a mechanisable slope, they only represent 7%. On the other hand, in those vineyards with little slope which can be easily accessed by machinery, a decrease in costs is observed.

		
Slope of the land	↓	↑
Harvest		
Costs		

Vineyard altitude

Vineyards located in mountain areas with a certain altitude are exposed to wild fauna and weather conditions such as hailstorms or frost that can affect them and may lead to an economic loss. The need to use specific material to protect against fauna (fences) and inclement weather (meshes or anti-stone systems) entails an additional increase in total costs.

Difficulties of high mountain vineyards

Those vineyards that are outside a designation of origin (D.O.) do not have a network of services adapted to vineyard cultivation and, therefore, see their costs increase. Cooperation between farmers and the training of specific personnel can help reduce the costs arising from this situation and promote population retention in the mid-mountain areas.

Note...

- ✓ Conventional vegetation cover management entails an increase in costs 
- ✓ The espalier or goblet-pruned vine system of the vineyard does not present relevant economic differences 
- ✓ The slope of the land and the altitude of the vineyard lead to an increase in costs due to the need to use specific machinery and material 
- ✓ Cooperation between farmers helps reduce costs, while the creation of a co-brand of mountain wines facilitates an increase in income 

OPTIMISATION OR INTRODUCTION OF THE VINEYARD

CHARACTERISTICS OF THE AREAS

	AREA 1	AREA 2	AREA 3	AREA 4	AREA 5
Region	Catalonia	Catalonia	La Rioja	La Rioja	Catalonia
Situation	Coastal	Coastal	At altitude	At altitude	At altitude
Climate	Mediterranean	Mediterranean	Continental mediterranean	Continental mediterranean	Mediterranean with alpine influence
AAT	16ºC	16ºC	10ºC	15ºC	9ºC
AP	546 mm	621 mm	843 mm	400 mm	579 mm
Altitude	100-120 m a.s.l.	150-170 m a.s.l.	600-900 m a.s.l.	600-900 m a.s.l.	1.200 m a.s.l.
Methodology	Vegetation cover implementation	Terrain morphology and vineyard formation system	Terrain morphology, altitude and vegeta-tion cover	Implementation of vegetation cover in vineyards of different ages	Transformation of old crops and pastures into vineyards

TMA = *Temperatura mitjana anual*; PA = *Precipitació anual*

PRESSURES AND VULNERABILITIES

Climate change

Legend

- *Starting point (2020)*
- *Range of forecasts for the most moderate scenario (RCP 4.5)*
- *Range of forecasts for the most pessimistic scenario (RCP 8.5)*
- 1H *First horizon (2020-2050)*
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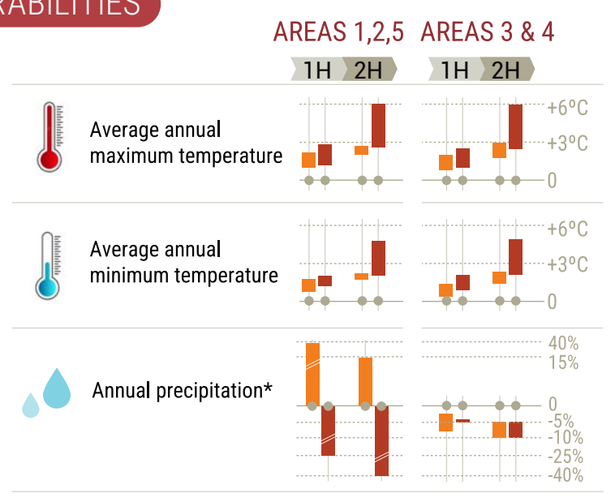


*In Catalonia, the great rainfall variability is due to the uncertainty in the projections for the first half of the century. However, projections in the summer months indicate statistically significant reductions in precipitation.

Changes in the territory

- ▲ The forest expands
- ▲ The forest stands grows a lot
- ▲ Increases the risk of fires
- ▲ Increases wildlife access to crops
- ▼ Rivers carry less water
- ▲ Flood risk increases

Socioeconomic changes

- ▲ More uncertainty in crop productivity
- ▲ More uncertainty in the quality of the crops
- ▲ Increased risk of depopulation

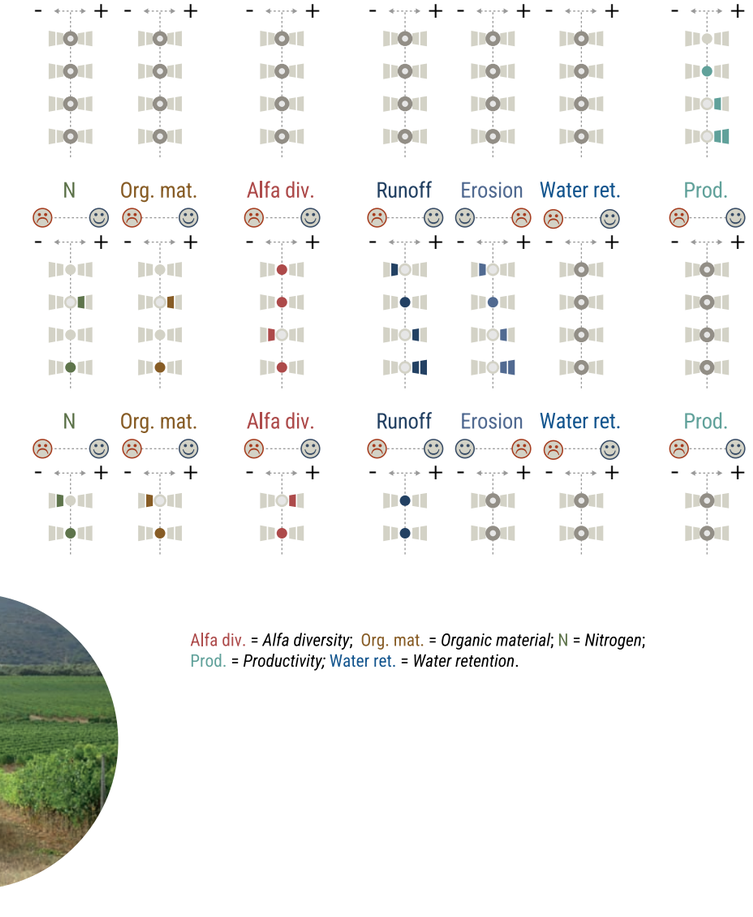
IMPACTS OF ADAPTATION MEASURES

Legend

- ☺ *Favourable situation for the adaptation of the mid-mountain area to global change*
- ☹ *Unfavourable situation for the adaptation of the mid-mountain area to global change*

Effects of treatments on variables

- *Not evaluated*
- *No change*
- *In progress/process*
- *Minor increase*
- *Major increase*
- *Major increase*
- *Major reduction*



Alfa div. = *Alfa diversity*; Org. mat. = *Organic material*; N = *Nitrogen*; Prod. = *Productivity*; Water ret. = *Water retention*.

Analysis at river basin scale

03

Mountain areas play a key role in water production and supply. The decrease in rainfall and the increase in temperature due to climate change, as well as the increase in forest area due to changes in land use, mean that the Mediterranean mid-mountain must face water stress with the consequent decrease of flows and the reduction of water availability.

To predict the evolution of water resources and forest stands, as well as to know the effects of territorial management in the different climate change scenarios, a scaling of the results obtained in the pilot tests in the river basins of the Aísa Valley (**Aragón**), Anyet river (**Catalonia**) and Leza river (**La Rioja**) has been performed.

To carry out this analysis at the river basin scale, an ecohydrological model previously calibrated and validated with historical data is used. Next, future land use and climate change scenarios are designed that, introduced into the ecohydrological model, will allow us to know the effects of these scenarios on the hydrological cycle of the basins.

Furthermore, and to interpret the evolution of the landscape, the dynamics and changes that the study basins have undergone over the last decades are analysed.

SCENARIOS APPLIED AT BASIN SCALE

SCENARIOS ON LAND USE

With regard to future land use scenarios, a new cartography is generated that includes the application of the adaptation measures implemented in the project at basin scale, given the capacity of these measures to modify the characteristics of the soil, vegetation and water availability.

The new cartography of future land uses shows the management of the territory at the river basin scale based on actions to clear scrubland and the reduction of tree density that allow, respectively, the recovery of pasture areas and the management of forest stands.

The criteria used in the clearing performed to create this new cartography are explained below, as well as what changes are implied by the measures with respect to the current situation for each of the basins studied.

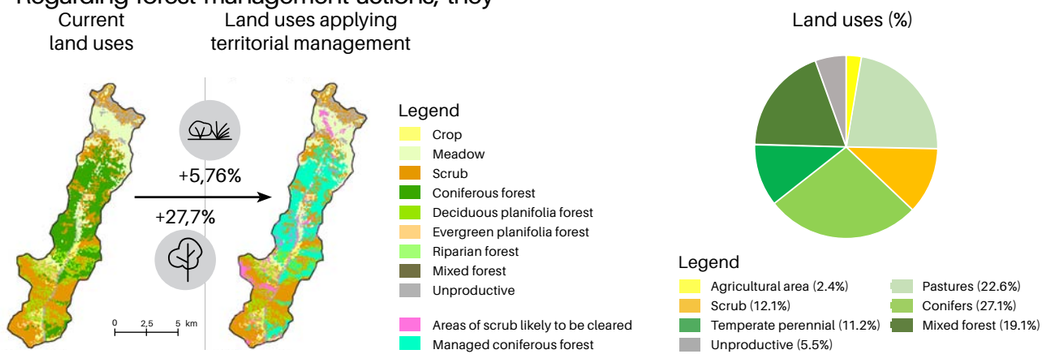
Criteria for the application of clearing at the basin scale as an adaptation measure

- Only clear areas of abandoned scrubland and pasture
- Agricultural areas are excluded
- Exclude riverbank areas and areas with a slope greater than 30% to avoid erosion processes
- Avoid priority habitats
- Delimit the habitats of protected species without action
- Do not apply clearing in areas less than 500 m^2

Aísa Valley (Aragon)

Clearing actions are limited to areas of abandoned scrubland and pasture. Consequently, the target areas for intervention would represent only 5.76% of the valley as a whole, located in two large groups at the headwaters and in the lower part of the basin.

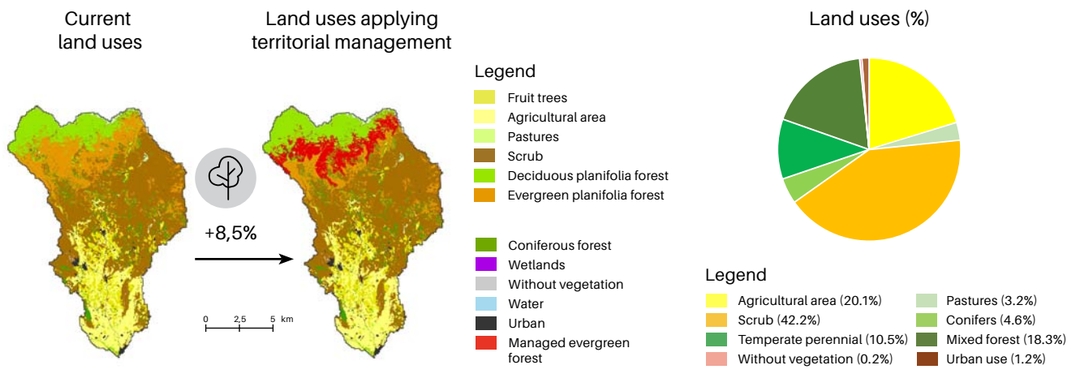
Regarding forest management actions, they are applied to the headwater coniferous stands, which represent 27.7% of the total area of the basin. Forest management consists of reducing tree cover by half, promoting a change in forest structure due, mainly, to management and species replacement.



Anyet River basin (Catalonia)

In the Anyet River basin, forest management only applies to the *Quercus* forests (*Q. suber* and *Q. ilex*) of the headwaters, which represent 8.5% of the basin. Forest management consists of reducing tree cover from the initial 100% to 50%.

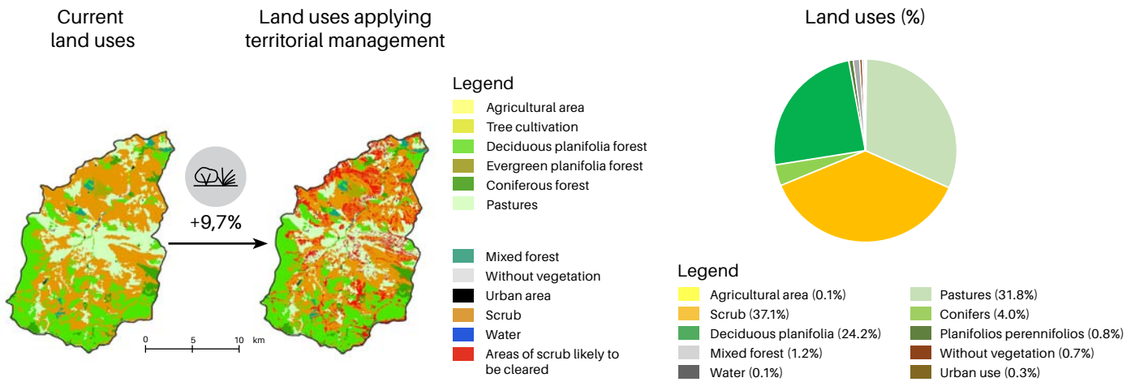
This management, located in the northern area and in the headwaters, is expected to have a relevant impact on the hydrology of the basin, since they are the areas with the greatest generation of water resources.



Leza River basin (La Rioja)

The scrubland areas likely to be cleared in the Leza River basin would lead to an increase in pastures by 9.7%, mainly located in the northeast.

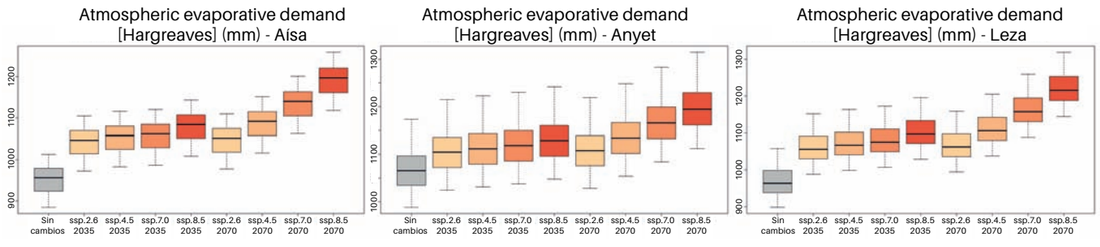
Given that most of the action areas are located in the lowest area of the basin, it would have fewer hydrological implications compared to the headwater areas.



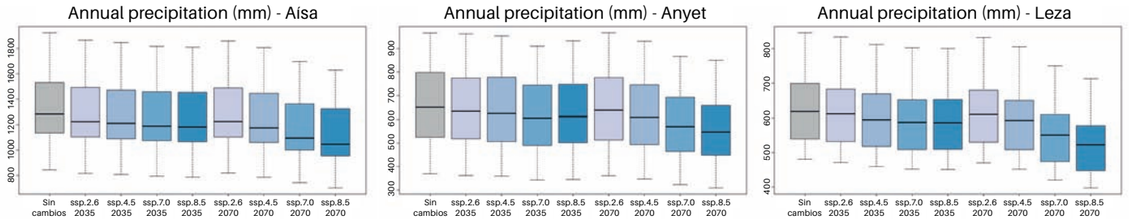
CLIMATE CHANGE SCENARIOS

In order to analyse the evolution of temperature and precipitation in the three basins according to the different projected climate change scenarios (SSP 2.6, 4.5, 7.0 and 8.5), monthly time series of maximum and minimum temperature, as well as precipitation are obtained.

The monthly differences obtained between the control period (1989-2018) and the periods chosen as future scenarios (2035-2064 and 2070-2099) show how the evolution of the evaporative demand of the atmosphere (DEA) tends to increase due to the increase in temperatures, while annual precipitation decreases in all three basins.



Trend of evaporative demand of the atmosphere (DEA) for climate projections (SSP 2.6, 4.5, 7.0 and 8.5) and future periods (2035-2064 and 2070-2099) in the river basins of Aisa (Aragon), Anyet (Catalonia) and Leza (La Rioja)..

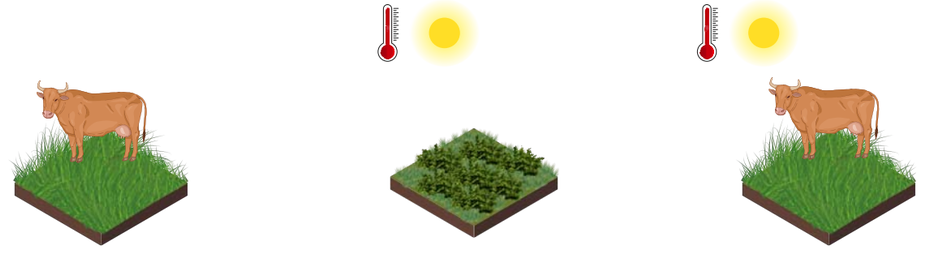


Annual precipitation trend for climate projections (SSP 2.6, 4.5, 7.0 and 8.5) and future periods (2035-2064 and 2070-2099) in the river basins of Aísa (Aragon), Anyet (Catalonia) and Leza (La Rioja).

COMBINED SCENARIOS: LAND USE AND CLIMATE CHANGE

With the aim of knowing the effects of territorial management at the river basin scale in different climate change scenarios, an ecohydrological model, called RHESSys, has been implemented, calibrated and validated with historical data in the basins of the Aísa Valley (**Aragon**) and the Anyet River (**Catalonia**) and Leza River (**La Rioja**).

Next, future simulations have been generated for each of the basins with land use and climate scenarios, to evaluate the effect of these scenarios on relevant variables at the basin scale, such as flow and net primary production of vegetation. The scenarios evaluated were:



The results obtained from the simulations considering the period 2035-2064 with the SSP 4.5 climate projection – chosen because it is the most plausible of the four projected future scenarios – are shown below *(for more information on the rest of the projected scenarios, see Deliverable no. 17)*.

Aísa Valley (Aragon)

Change of land uses due to territorial management (LUC)

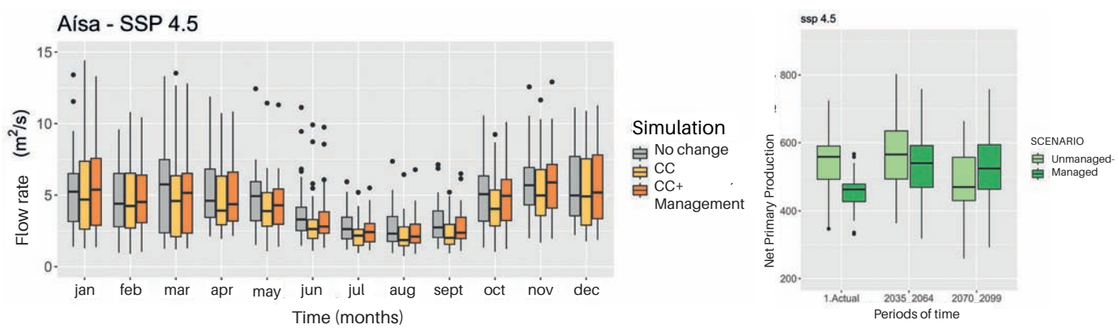
Forest management and the recovery of pastures in the Aísa Valley under current environmental conditions would lead to an increase of 4% in the average monthly flow.

Climate change (CC)

In climatic conditions such as those of the SSP 4.5 projection and without applying any territorial management, a 12% decrease in the average monthly flow would be expected.

Combined action (CA)

In a combined scenario, in which the management measures were applied under climate change conditions, it would lead to a 3% decrease in the average monthly flow. Despite this decrease, it is considered that territorial management could increase the availability of water resources in valleys similar to the Aísa Valley, in a situation of climate change. A combined action would lead to an increase in net primary production, an indicator that forest management would improve the resilience of forests under conditions of climate change.



Anyet River basin (Catalonia)

Change of land uses due to territorial management (LUC)

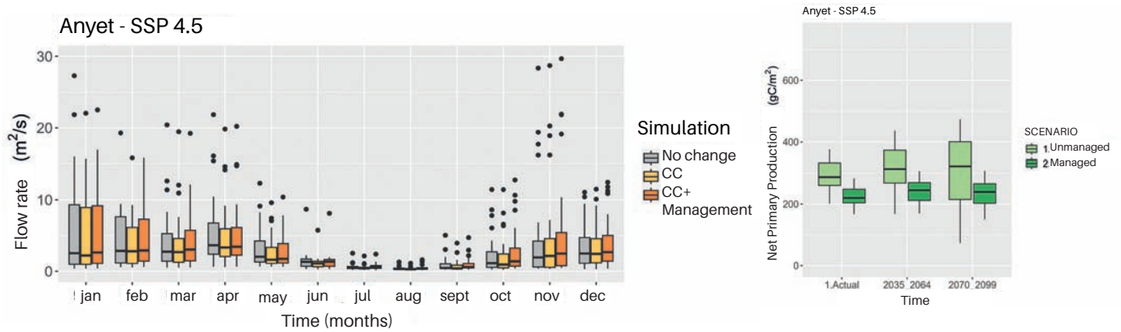
Carrying out forest management in the Anyet River basin under current environmental conditions would lead to an increase of 18% in the average monthly flow.

Climate change (CC)

Under climatic conditions such as those of the SSP 4.5 projection and without adaptive forest management, a 9% decrease in the average monthly flow would be expected.

Combined action (CA)

The application of forest management in climatic conditions such as those of the SSP 4.5 projection would mean an increase in the average monthly flow of 7%. Therefore, it is considered that, in basins similar to that of the Anyet River, forest management would mitigate the loss of water resources or even increase their availability. Furthermore, in this case, a combined action would lead to a trend of decreasing net primary production that suggests the need for less intense management that could allow us to find a balance between the natural dynamics of the forest and the generation of flow.



Leza River basin (La Rioja)

Change of land uses due to territorial management (LUC)

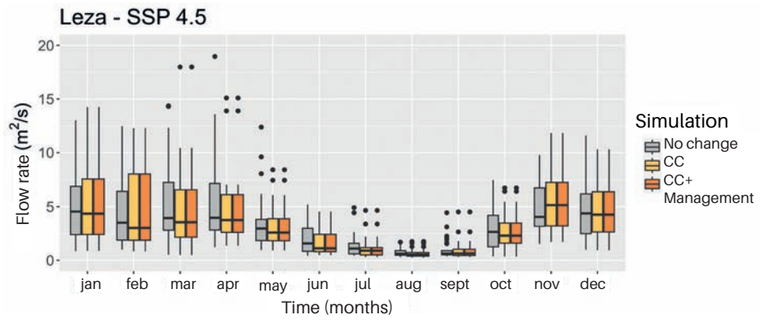
The recovery of pastures through scrub clearing in the Leza River basin under current environmental conditions would mean an increase in the average monthly flow of 10%.

Climate change (CC)

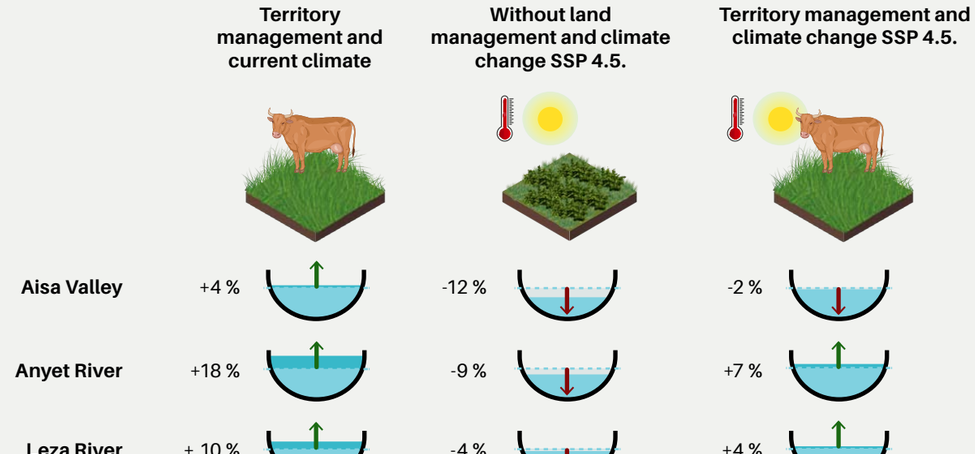
In climatic conditions such as those of the SSP 4.5 projection and without clearing the scrub areas, a 4% decrease in the average monthly flow would be expected.

Combined action (CA)

If clearing actions are applied to eliminate scrub under climatic conditions such as those of the SSP 4.5 projection, it would entail an increase of 4% in the average monthly flow. Thus, it is considered that actions to recover pastures could increase the availability of water resources in valleys similar to that of the Leza River under conditions of climate change. In relation to forested areas, since no actions have been carried out on forest areas, it has not been possible to assess the effects of land management or climate change.



Thus, a lack of territorial management would mean that, under conditions of climate change (SSP 4.5), the average monthly flow would decrease in the three basins in the study. On the other hand, the application of management measures, both in the current and future climate conditions, would mean that this situation would tend to revert, producing, in many cases, an increase in the average monthly flow as observed in the basins of Aísa Valley and the Anyet and Leza Rivers.



Summary table of the variation of the average monthly flow in the study basins according to the territorial management and climate change scenarios

The variability observed between basins is a consequence of the great differences between them, both in the environmental field and in territorial management. The particularity of each basin means that the managed area varies from one basin to another. Thus, the area of scrub cleared for the recovery of pastures is greater in the Leza River basin compared to that of the Aísa Valley. On the other hand, the area allocated to forest management is greater in the Aísa Valley – and is located in the central area – while, in the Anyet River, it is smaller and is concentrated in the headwater area.

Aisa Valley	5,76%	27,12%
Anyet River	-	8,5%
Leza River	10,7%	-

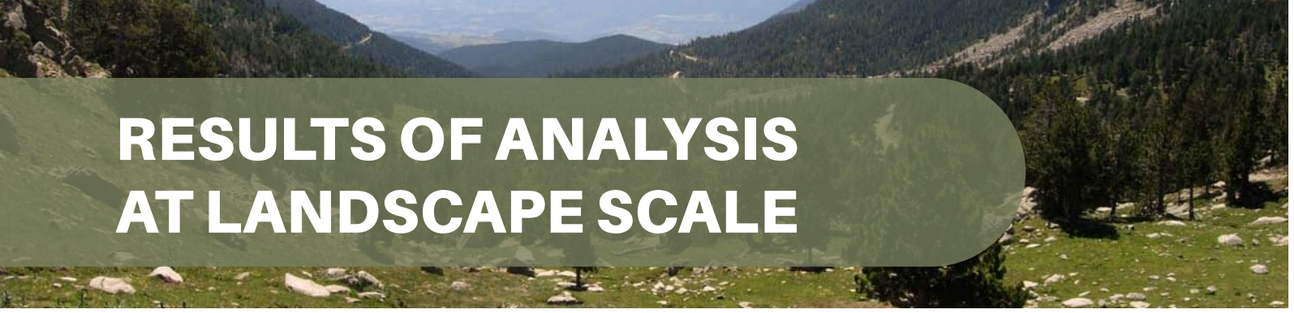
Estimated area (%) for pasture recovery and forest management in each basin.

Despite these differences, a common trend is observed in the three basins, which is a decrease in annual flow as climatic conditions become more severe and, on the contrary, an increase in water resources if territorial management is applied.

In relation to forest stands, the variability observed in the simulation results is linked to the capacity of different forest species to adapt to climate change. Consequently, a higher net primary production is observed in the coniferous forests of Aísa compared to the *Quercus* forests in the Anyet basin, possibly due to greater variability in rainfall and better adaptation of species to climate change conditions.

The simulations obtained determine that both the managed area and the climatic conditions determine the circulating flow and net primary production.

However, it is shown that **territorial management could mitigate the flow loss expected in situations of climate change in the river basins of the Mediterranean mountains.**



RESULTS OF ANALYSIS AT LANDSCAPE SCALE

In order to understand the structure and changes that the landscape has undergone over the last decades in the river basins of the Aísa Valley (Aragón), the Anyet River (Catalonia) and the Leza River (La Rioja), we has analysed the evolution of the landscape in three stages (initial, intermediate and current) distributed over time using V-LATE software (for more information, see the Deliverable no. 17).

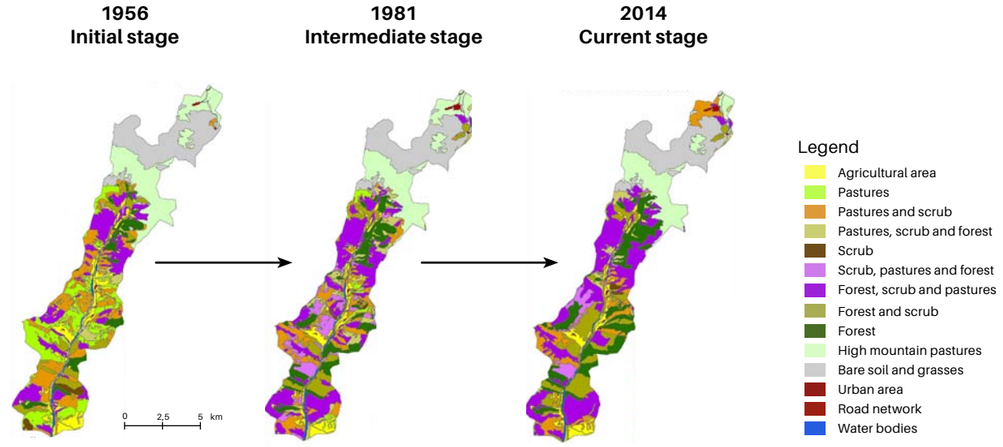
In the initial stage, in 1956, the landscape was mainly formed by cultivated areas or abandoned spaces, while, in the intermediate stage, a landscape in transition dominated with the presence of some elements from the initial and current phases. The abandonment process in the Aísa Valley began in 1981, much earlier than in the Anyet and Leza Rivers, which began in 1993 and 2001, respectively. Finally, in the current stage – year 2014 for the Aísa Valley and the Leza River, and 2017 for the Anyet River – the landscape is dominated by revegetation or renaturalisation processes.

Initial stage (1956) | Intermediate stage (1981, 1993, 2001) | Current stage (2014, 2017)

The results obtained are shown:

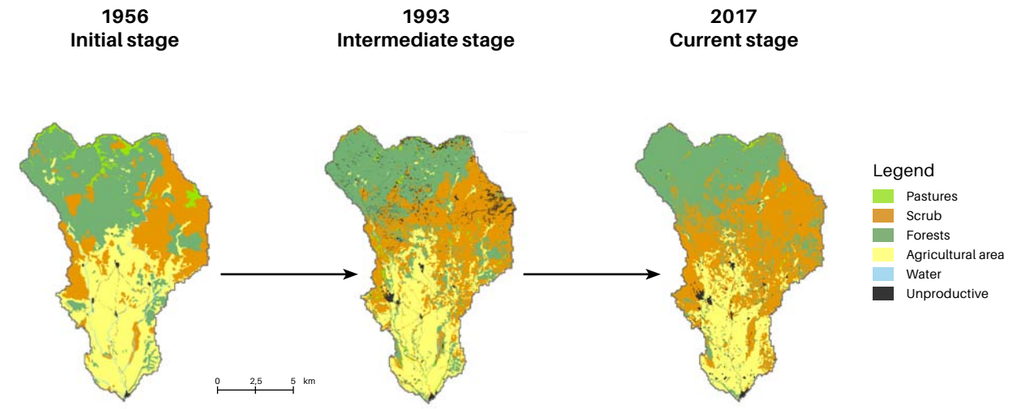
Aísa Valley (Aragon)

In the Aísa Valley, the landscape maintains a fragmented structure during the evolution towards the intermediate stage (period 1956-1981). However, this trend changes in the period 1981-2014, losing the mosaic structure and becoming a more homogeneous landscape in the current stage. Changes in land use become more relevant in the montane stage than in the alpine and subalpine stage, with a loss of montane pastures of 63% and a decrease in crop fields of 42% in the current stage.



Anyet River basin (Catalonia)

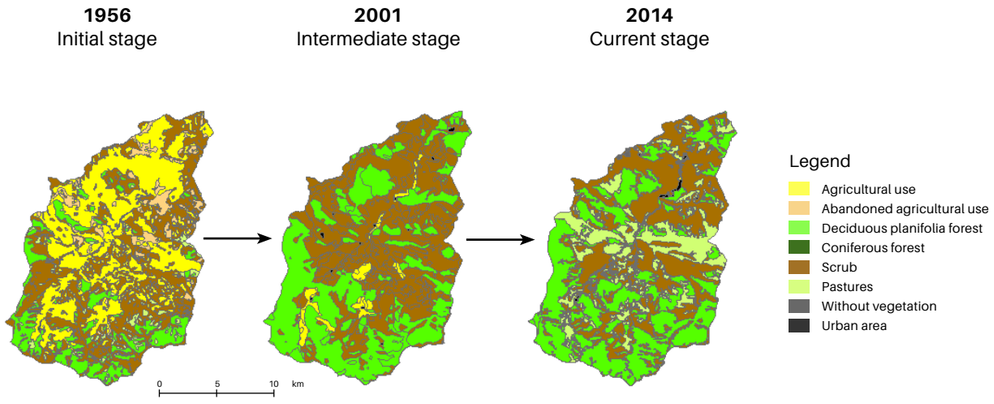
The Anyet River basin presents the same trend: during the initial stage (1956), the landscape is dominated by crop fields, but, over time, an increase in scrubland areas is observed from 25% (1956) to 43% in the current stage (2017). As for the forest layer, it has suffered a slight decrease over the years (34.5% in 1956 and 33.4% in 1993), and remains at 30.7% in the current stage (2017).



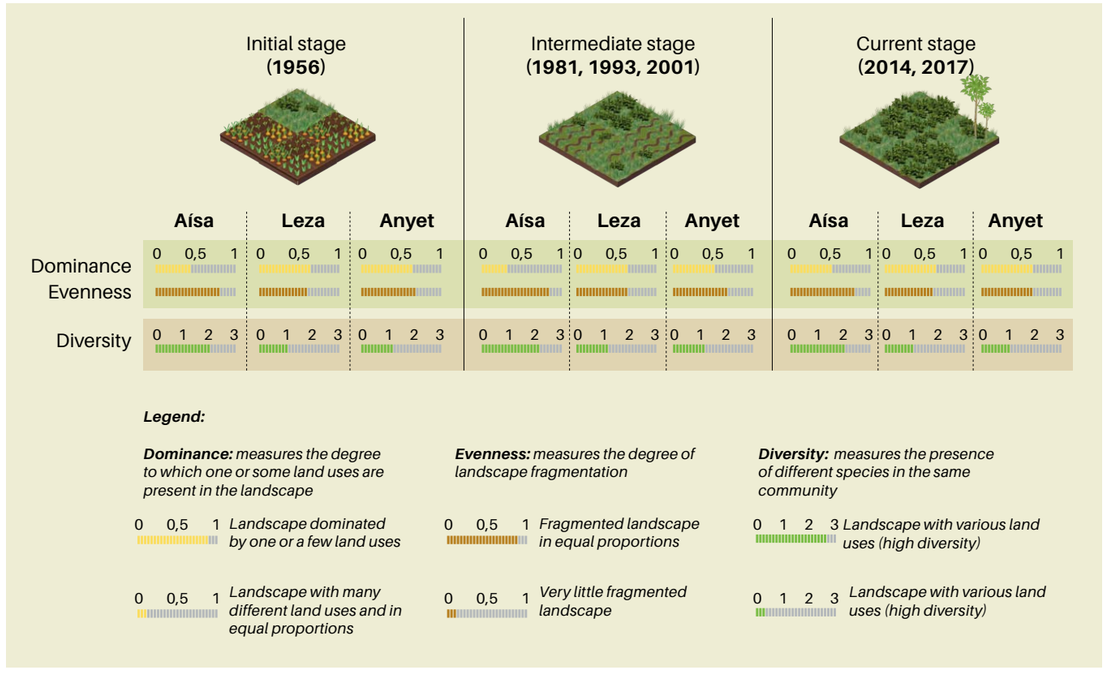
Leza River basin (La Rioja)

Regarding the Leza River basin, in the initial stage (1956), the landscape is dominated by crop fields and greater fragmentation is observed compared to the intermediate stage (2001), in which most of the fields have been abandoned and replaced by scrubland and deciduous forest.

However, in the current stage (2014), the landscape structure becomes more heterogeneous, contrary to what would be expected, due to the clearing actions applied by the government of La Rioja. Consequently, a landscape with more grass surfaces is achieved.



Shannon's dominance, evenness and diversity indices show the same pattern of landscape evolution over time for all three basins. In all cases, in the intermediate stage, high values are observed in terms of diversity and evenness, while dominance decreases, as the landscape transitions between crops and abandoned spaces in the process of revegetation.



However, in recent decades, the landscape in the basins of the Aísa Valley and the Anyet and Leza Rivers has evolved towards homogenisation, progressively losing the mosaic landscape and becoming less resilient to the effects of climate change.

Managing the territory to recover the mosaic landscape contributes to reversing this situation, favouring the heterogeneity of the landscape and improving its resilience to environmental changes.

Other adaptation measures for the mid-mountain area

04

Below, the composition and operation of the participation bodies of the LIFE MIDMACC project are presented, determining bodies in the prioritisation of adaptation measures for the mid-mountain areas of Aragon, Catalonia and La Rioja.

PARTICIPATING BODIES IN THE PROJECT

The LIFE MIDMACC project has had the participation of three regional committees (CR) and a Supraregional Working Group (GT-SR). Next, its importance for the development of the project is explained and its organisation and the tasks carried out are detailed:

REGIONAL COMMITTEES (CR)

The creation of the three committees of regional actors, one for each region in the study, is relevant, since it allows the main managers and actors of the territory to be involved in the design, development and evaluation of the adaptation measures.

Among the actors, there are representatives of the sectors involved in the project (agriculture, livestock and forestry), local and regional administration, research, environmental associations and civil society.

Tasks of regional committees

- Participation in annual meetings organised for the project
- Contribution to the design and implementation of pilot tests
- Contribution to the design of future scenarios through scaling
- Guided tours
- Contribution to the adaptation guide

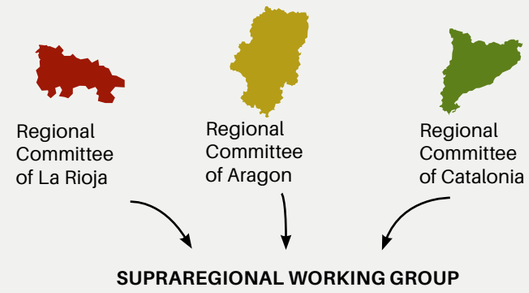
SUPRA REGIONAL WORKING GROUP (GT-SR)

The main objective of the Supraregional Working Group is to involve the regional governments, in this case, of Aragon, Catalonia and La Rioja.

This group has been made up of three or four representative actors from each regional committee, who ensure the representation of the key sectors of the project (vineyards, forests and livestock) and affiliations (public administration, research and productive sector).

Tasks of the Supraregional Working Group

- Review and validation of the results of the regional committees
- Share experiences and resources on adaptation to climate change in the three territories
- Support for the creation of a coordinated political framework for the sustainable use of mid-mountain areas
- Support in the development of a guide with proposals for adaptation to climate change for mid-mountain areas



PRIORITISATION OF MEASURES

Previous chapters of this guide have detailed the adaptation measures implemented and monitored in the project. However, apart from these developed measures, an exhaustive analysis has also been carried out of whatever other adaptation measures were being implemented in the mid-mountain areas of Aragon, Catalonia and La Rioja.

This analysis aimed to understand initiatives that were being carried out in the study regions and that could be transferred to other territories. Based on this work, the most relevant actions for the adaptation of the mid-mountain area were prioritised, in order to make the final recommendations of this adaptation guide.

The first list of existing adaptation measures was made based on the knowledge and experience of the partners of the LIFE MIDMACC project. In total, 53 adaptation measures containing 80 specific actions were compiled. This list was presented at the second meetings of the project's regional committees, in which the 42 participating actors were able to reformulate, refine and validate the compiled measures, and, in addition, they were also able to propose new measures.

In total, once this participatory work was carried out within the framework of the regional committees, 130 adaptation actions were proposed (80 existing and 50 new), many of which were repeated between territories. Next, a grouping and simplification process was carried out by the partners, resulting in a new list of 45 actions, 15 per sector[*].

From this new list, the 10 actors participating in the GT-SR, through collaborative and participatory work, prioritised 17 measures according to the importance and relevance they considered they had for their adaptation to climate change in the three territories.

[*] The complete list of the 45 summary adaptation actions can be consulted in the results document of the second annual meeting of the Supraregional Working Group.

These 17 proposals for action are the main recommendations that this guide proposes to improve the resilience and adaptation of the Mediterranean mid-mountain to climate change. Below are the prioritised measures grouped by theme.

Agriculture and Livestock

- Promote cultural practices that conserve soils and minimise erosion.
- Favour and enhance the eco-schemes of the new CAP related to extensive livestock farming.
- Promote water savings in crops through agronomic measures and efficiency in water use.
- Stimulate the implementation of local food production to achieve sustainable agriculture.
- Promote activities to promote coexistence between the different sectors and activities (vineyards, forests and livestock).
- Prepare a vulnerability map of crops and animal species of productive interest that are most vulnerable to climate change.

Forests

- Recover pasture meadows in recently revegetated areas through ranching for use by livestock, recovering the silvopastoral mosaic and promoting the regeneration and growth of isolated trees that provide shade, improving soil conservation and pasture quality.
- Promote active and adaptive forest management.
- Promote regulatory changes that value forests as a resource for livestock farming; in particular, to influence the CAP to consider forests as grazable resources and to receive the relevant aid.
- Promote the transfer of knowledge to the sector on how management can reduce the effects of climate change.
- Promote joint forest planning and management in different areas and in a complementary way to other planning, in order to promote co-responsibility in the implementation of adaptation actions to climate change.
- Apply forest management models aimed at obtaining greater added value from forest products and promoting local demand.

Population retention

- Encourage generational change through the training of young farmers and shepherds as a group, while also guiding them towards tourism-related activity.
- Improve the viability and competitiveness of small and medium-sized farms with innovative agricultural technologies and sustainable forest managements.
- Guarantee access to energy services, water and high-speed internet to the scattered population.
- Strengthen support for innovation, transfer and markets for local and sustainable products.
- Support companies that have a commitment to the most depopulated territories.

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05

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MIDMACC
Mid-mountain adaptation to climate change

LIFE18 CCA/ES/001099

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