LIFE MIDMACC

Mid-mountain adaptation to climate change

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Monitoring protocol of C2 action

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Authors

Diana Pascual, Eduard Pla, Estela Nadal Romero, Teodoro Lasanta, Javier Zabalza, Yolanda Pueyo, Ana Foronda, Ramón Reiné, Olivia Barrantes, Noemí Lana-Renault, Purificación Ruiz.

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Executive summary

This deliverable gives an in deep description of the monitoring tasks and network developed to assess and compare the evolution of the pilot experiences in comparison with the initial conditions, with the control plots and with the experiences in other areas of the project. This deliverable explains the monitoring protocol developed for one of the climate change adaptation measures applied in the project: forest management for fire risk prevention and maintenance with extensive livestock farming. These measures, designed and deployed together with local stakeholders, were implemented by the end of 2019 and beginning 2020 in Aragón and Catalonia. An in deep description of the location of the experiences can be consulted at Nadal-Romero et al (2019, Deliverable 1). The description of the adaptation measures implemented can be consulted at Pascual et al. (2020, Deliverable 5).

The first section is a short introduction to the deliverable, with a briefly description of the pilot experiments and the main objectives of this deliverable. The second section describes the monitoring design implemented in both sites, Aragon and Catalonia. The third section details the monitoring variables that will be measured in each plot, the frequency of the monitoring and the methodology employed to measure the variables. Finally, the fourth section summarizes all the monitoring tasks implemented in the forest management pilot experiences.

This deliverable presents the activities carried out to monitor the action C2, fundamental in the LIFE MIDMACC project. We have tried to define accurately all the activities that have been carried out this year and that will be carried out in the following four years before evaluating the adaptation measures implemented. We have described all the environmental variables that are going to be measured, with different methodologies, timings, and protocols: (i) soil properties (soil analysis and soil moisture), (ii) forest variables (forest structure, forest fuel continuity, forest health status, fuel moisture), (iii) pasture variables (biodiversity, production and quality), (iv) hydrological and sedimentological response (infiltration rates, sediments, times to response), and (v) site meteorological conditions (air moisture and temperature, rainfall).

Content

1. Introduction

The main objective of the LIFE MIDMACC project is to promote adaptation to climate change through the implementation and testing of different landscape management measures in mid-mountain areas of Spain: scrubland clearing, forest management and different assays in vineyards in three study areas (Aragon, La Rioja and Catalonia).

The demonstrative activities have been performed in different pilot sites representative of Mediterranean mid-mountain areas. Once the demonstrative activities have been installed, a **monitoring network has been designed, implemented and started**. The objective of the monitoring is to **evaluate the efficiency of the demonstrative activities** to **improve the adaptation capacity to face climate change threatens** and to **improve the socioeconomic development of the mid-mountain areas** where the landscape management measures have been implemented.

In this report, we present the monitoring network related to forest management activities to diminish forest fire risk and improve livestock grazing, carried out in Aragón and Catalonia. Forest adaptive management has consisted on the thinning of trees and scrubland clearing in wooded areas in Aragon (La Garcipollera) and Catalonia (Requesens-l'Albera). In this case, the **monitoring network implies the establishment and monitoring of a set of permanent monitoring plots and monitoring instrumental** with a triple objective:

- To **assess the adequacy of the actions** implemented to achieve the objective of improving the adaptation capacity of forest masses.
- To **evaluate the consequences derived from its application on several key functions of the ecosystem**: the regulation of the water regime, the production of soil erosion, the effects on soil quality and soil organic stocks, soil moisture and air moisture and temperature and the changes in pasture quality and biodiversity.
- To **evaluate the impacts of the actions in the socioeconomic development of the extensive farms.**

This report presents the monitoring action, a description of the monitoring variables that will be measured in each plot, the frequency of the monitoring and the methodology employed to measure the variables in both regions (Aragon and Catalonia).

2. Design of the monitoring network

The monitoring network includes the installation of monitoring plots and the design of a protocol for monitoring. The protocol includes a set of variables that will be periodically measured to assess the evolution of pilot experiences, in comparison with plots without landscape intervention (control plots). The monitoring design and the measured variables will be explained in the next sections.

2.1. Monitoring design in Aragon

The pilot experience has been implemented in La Garcipollera Research Station (Central Pyrenees, Huesca, Spain). Before explaining the monitoring design in the experimental plots in La Garcipollera, we include a summary of the forest adaptive management finally implemented to facilitate the explanation of the monitoring network. A more detailed description of the implemented actions can be consulted in Pascual et al. (2020). The pilot experience consists of:

- The application of adaptive forest management in in two plots: a 0.58 ha plot in a reforestation forest of *Pinus nigra* and 1.3 ha on a *Fraxinus* forest, consisting of high intensity scrubland clearing selective thinning and scrubland clearing.
- An area with no actuation of 0.55 ha. This area is close by the managed area and show similar condition in location, altitude and orientation. This area will not be neither managed nor pastured, with the objective to monitor the site evolution with no actuation

Based on the implemented actions, the **experimental design** of the monitoring network consist on creating **three typologies of monitoring plots with a surface of 400 m^2**:

- control plots, without neither forest management nor the entry of livestock (BC);
- managed plots with livestock (BS);
- managed plots without livestock (BN).

For each of these monitoring plots, we have performed **three replicates**, except in the control area where there were only space for two replicates (B1S-3S-5S, B2N-4N-6N, and BC1-2). With three replicates we can perform statistical analysis to confirm if differences among the plots are significant. Therefore, the experimental design includes three plots of 400 m^2 with its replicates, **eight monitoring subplots of 400 m^2** in total (Figure 1).

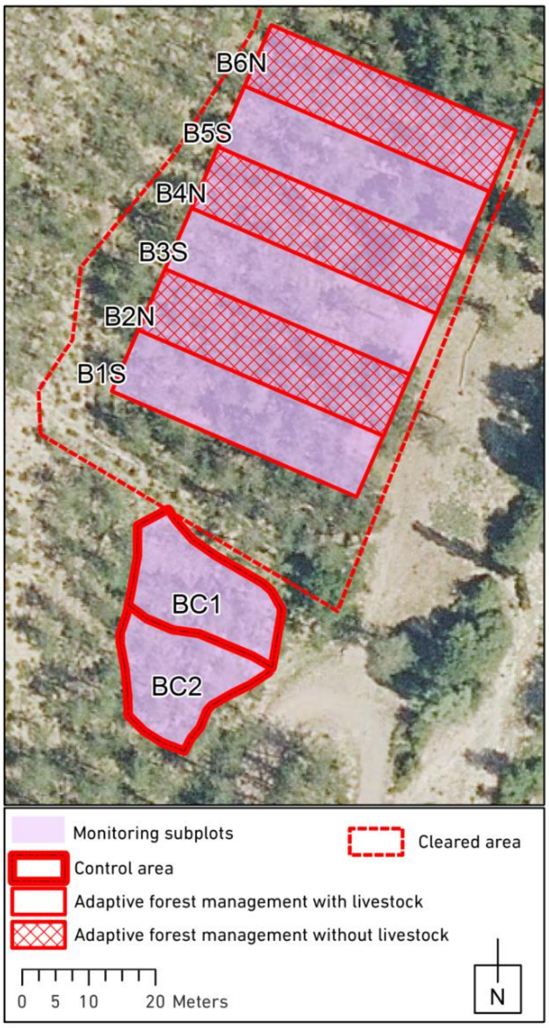

Figure 1. Location of the monitoring plots and replicates of the experimental design.

The following diagram shows a summary of the monitoring network installed in La Garcipollera Requesens experimental area. We can distinguish the three typologies of monitoring plots with its replicates (colour square and rectangles). In each monitoring subplots, we have installed a set of instruments and a set of forest inventory subplots for the monitoring of different variables, explained in the following chapter.

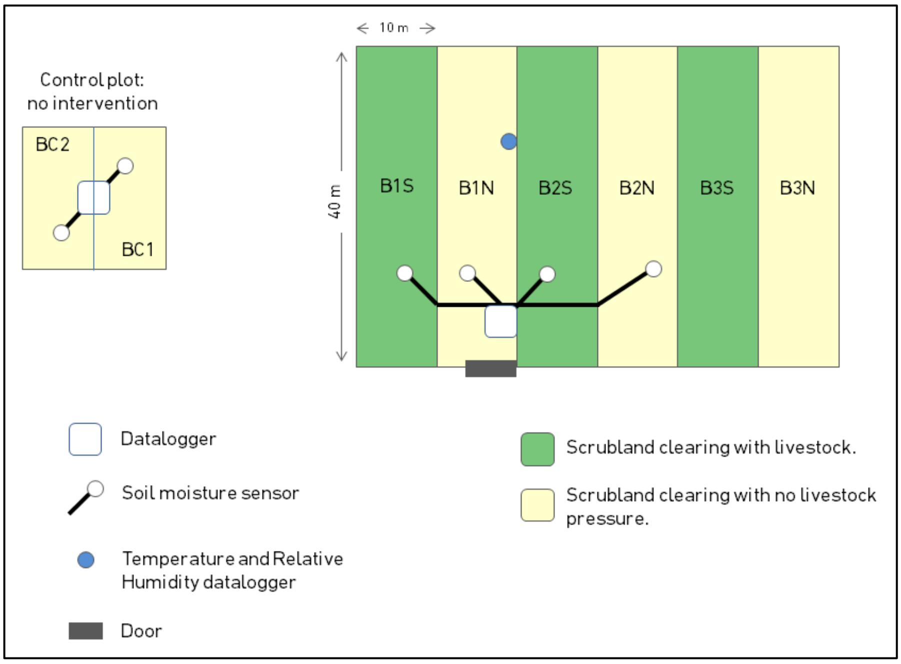

Figure 2. Diagram of the livestock and monitoring subplots.

2.2. Monitoring design in Catalonia

The forest management pilot experience in Catalonia is located in a Holm oak forest in the lower part of the Eastern Pyrenees, specifically, in the Requesens estate. Before explaining the monitoring design in the experimental plots in Requesens, Catalonia, we include a summary of the forest adaptive management finally implemented to facilitate the explanation of the monitoring network. A more detailed description of the implemented actions can be consulted in Pascual et al. (2020). The pilot experience consists of:

- The application of adaptive forest management in a Holm oak forest area of 1.15 ha, consisting of selective thinning and scrubland clearing. This area has been divided in two different sub-areas, depending on the livestock management:
    - A sub-area of 5,520 m^2 where livestock can enter. In this sub-area, some preparation actions were needed, including the removal of all gross logging residues, the entrance of the cows for a couple of days to eat the oak and heather sprouts and the randomly and manually sowing of a specific mixture of pasture seeds.
    - A sub-area of 5,978 m^2 where livestock cannot enter. In this sub-area, the logging residues has been left in the soil.
- An area with no actuation of 1.47 ha. This area is close by the managed area and show similar condition in location, altitude and orientation. This area will not be neither managed nor pastured, with the objective to monitor the site evolution with no actuation

Based on the implemented actions, the **experimental design** of the monitoring network consist on creating **three typologies of monitoring plots with a surface of 1,000 m^2**:

- control plots, without neither forest management nor the entry of livestock (BC);

- managed plots with livestock (BTAR);
- managed plots without livestock (BTSR).

For each of these monitoring plots, we have performed **three replicates** (BC7-8-9; BTAR1-2-3 and BTSR4-5-6). With three replicates we can perform statistical analysis to confirm if differences among the plots are significant. Therefore, the experimental design includes three plots of 1,000 m^2 with its replicates, **nine monitoring subplots of 1,000 m^2** in total (Figure 3).

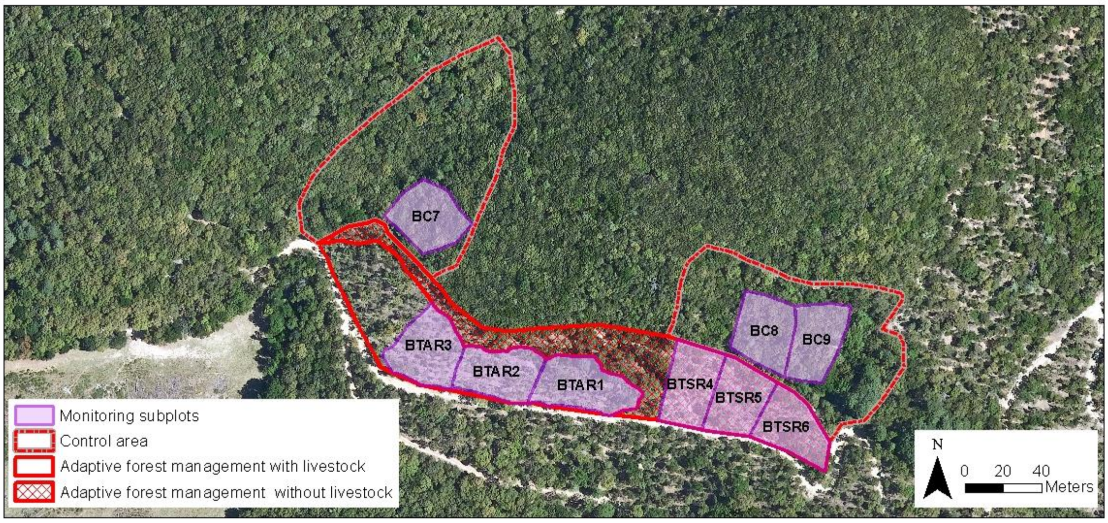

Figure 3. Location of the monitoring plots and replicates of the experimental design.

The following diagram shows a summary of the monitoring network installed in the Requesens experimental area. We can distinguish the three typologies of monitoring plots with its replicates (colour square and rectangles). In each monitoring subplots, we have installed a set of instruments and a set of forest inventory subplots for the monitoring of different variables, explained in the following chapter.

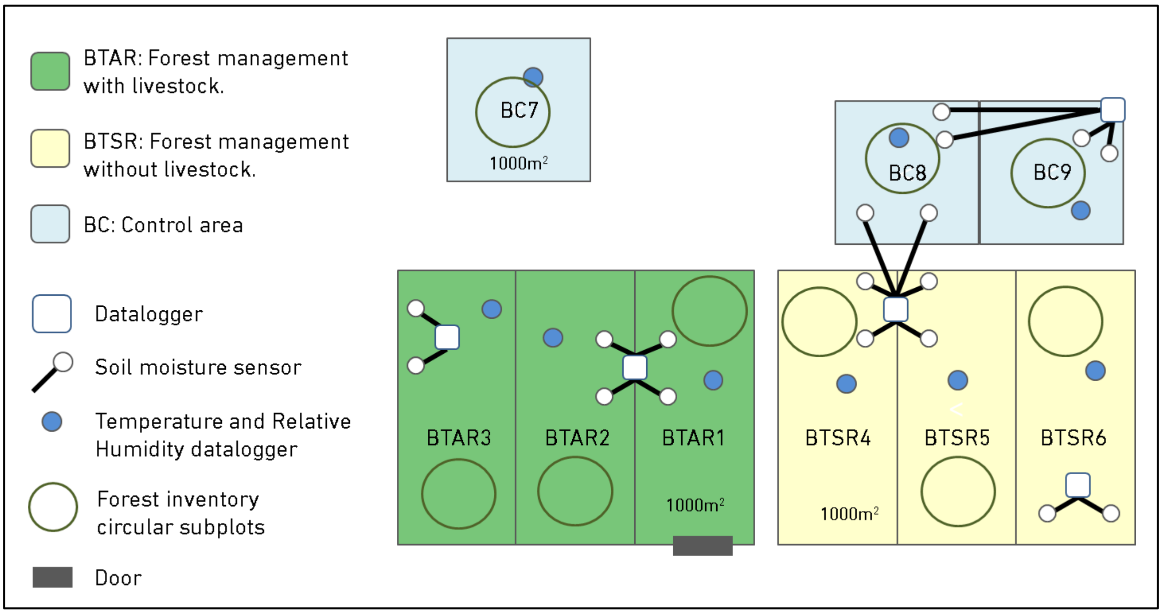

Figure 4. Diagram of the livestock and monitoring subplots.

3. Monitoring variables and protocols

Table 1 summaries the monitored variables in the forest management pilot experiences in Aragon and Catalonia. Following, a detailed description of each variable, the means to measure, frequency and specifications is included.

	Variable	**Measured variables**	**Methodology**	**Periodicity**
Soil	**Soil characteristics**	Field bulk density pH and electrical conductivity Total carbon concentration Total nitrogen concentration Carbonate content Organic carbon Soil organic carbon and nitrogen stocks Organic matter ¡ Grain size distribution Organic phosphorus Saturated soil moisture Field capacity Wilting point CN ratio	Soil sampling Soil analysis	Initial (2020) Final (2024)

	Variable	Measured variables	Methodology	Periodicity
	Soil moisture	Soil water content (SWC)	Humidity sensors and data-loggers	Continuous (2020-2024)
Forest	**Forest structure**	Tree density (trees/ha) Diametric class distribution Tree height (m) Resprouting Canopy cover (%)	Forest inventory	Initial (2020) After implementing the adaptation measure (2020) Final (2024)
	Forest fuel continuity	Crown fire hazard Fuel type cover (%) Fuel height (m) Distance between fuel types (m) Understorey biovolume	Fuel identification and classification Strip biomass transects	Initial (2020) After implementing the adaptation measure (2020) Annual survey (autumn 2021-22-23) Final (2024)
	Forest health status	Forest decline (%) Tree mortality (%) Defoliation (%) Decolouration (%)	Forest health sampling	Initial (2020) After implementing the adaptation measure (2020) Annual survey (autumn 2021-22-23) Final (2024)
	Fuel moisture	Relative water content (RWC)	Forest fuel sampling	Nine measures per year during summer during 4 years (2020-2021-2022-2023).
Pastures	**Biodiversity**	Plant community composition (species richness, diversity and plant functional types)	Vegetation surveys / sampling	Annual survey (spring or summer 2020-2021-2022-2023) Final (2024)
	Pasture production and quality	Pastoral value Pasture nutritive quality (protein and fibre content) Biomass productivity	Vegetation surveys Sample processing Chemical analysis	Annual survey (spring or summer 2020-2021-2022-2023) Final (2024)
Rainfall simulation	**Hydrological response and soil erosion**	Runoff coefficient Infiltration rate Time to runoff Ponding time Wetting front Sediment concentration Sediment production Sediment detachment	Rainfall simulation experiments	After clearing (2020) Annual simulations (2021-2022-2023) Final (2024)

	Variable	Measured variables	Methodology	Periodicity
Site meteorological conditions	**Precipitation**	Precipitation	Pluviometers (only in La Garcipollera, Aragon)	Continuous (2020-2024)
	Temperature and relative humidity	Temperature Relative humidity	Temperature and relative humidity data loggers	Continuous (2020-2024)
	Meteorological variables	Maximum temperature Minimum temperature Precipitation Radiation Wind speed	Meteorological station (only in Requesens, Catalonia)	Continuous (2020-2024)

Table 1. Summary of the monitored variables in the forest management pilot experiences in Aragon and Catalonia.

3.1. Soil

Soil is the main reservoir for organic carbon in terrestrial ecosystems. Land uses and land management changes, modified the composition of plant cover, and these changes affect the content and quality of soil properties, especially organic matter and soil organic carbon. The soil organic carbon conservation and its sequestration is of great interest to mitigate the effects of climate change. In that sense, the objective of this environmental monitoring is to identify the effects of adaptive forest management and livestock management in soil properties and soil organic carbon dynamics.

3.1.1. Soil characteristics

The first soil samplings were carried out in January and June 2020 in all the forest management plots. At each monitoring subplot, three soil samples were sampled with an auger at 10 cm increments: 0 cm, 0-10 cm, 10-20 cm, 20-30 cm and 30-40 cm in Aragón and two samples per monitoring subplots, at two different depths: 0-10 cm and >10cm in Catalonia. These analyses will allow to set the initial conditions of the soil.

- In Aragón, 21 points were selected and 105 subsamples were recorded and later combined into one soil composite sample per plot and depth. In total 45 composite samples were created.
- In Catalonia, 15 points were selected and 90 subsamples were recorded and later combined into one soil composite sample per plot and depth. In total 30 composite samples were created.

In total, 75 soil samples will be analysed. In addition, bulk soil samples were collected to test soil moisture and bulk density values. Those analyses will allow to set the initial conditions of the soil. Before the end of the project, the same procedure will be carry out in the different subplots to know the effect of the different treatments on the following soil variables: Field bulk density (BD), pH and electrical conductivity (EC), total carbon concentration (Ctotal), total nitrogen concentration (N), carbonate content (CaCO3), organic carbon (Corg), soil organic carbon (SOC) and nitrogen (TN) stocks, organic matter (OM), grain size distribution, organic phosphorus (P), saturated soil moisture (SAT), field capacity (FC), wilting point (WP) and CN ratio. Once per year, top soil samples (only the first 10 cm) will be taken and soil properties related to carbon storage will be analysed.

The analyses are being carried out in the Pyrenean Institute of Ecology (IPE-CSIC) following the protocols established in the laboratories. The following methodologies are used:

- Soil samples are air dried and sieved through a 2 mm mesh sieve in the laboratory.
- Bulk density is estimated from undisturbed soil samples that were oven-dried at 105ºC for 24-48 h. When missing these values, BD values were calculated by pedotransfer equations proposed by Guo and Gifford (2002) and Post and Kwon (2000).
- PH is measured in a deionized water suspension (1:2.5) using a pH meter, and electrical conductivity using a conductivity meter.
- Total carbon and total nitrogen are measured by dry combustion in an elemental analyser (LECO CNS 928).
- Carbonate content is measured with the Bernard calcimeter method.
- Organic carbon is calculated by subtraction of total inorganic carbon from the total carbon or using the van Bemmelen factor of 0.58 (using as universal conversion factor in the absence of CaCO3).
- SOC and N stocks is expressed in Mg ha^{-1}, calculated weighting each organic carbon and total nitrogen values by the respective depth range (10 cm) and the value of bulk density.
- Organic matter is determined using the Walkley-Black chromic acid wet oxidation method.
- The ratio Corg/N is calculated using Corg and total nitrogen.
- Grain size distribution is determined using a particle size analyser (Mastersizer 2000) after oxidizing the organic material with peroxide.
- Organic phosphorus is determined by the Bray method.
- Soil hydraulic properties (saturated soil moisture (SAT), field capacity (FC) and wilting point (WP)) are estimated using pedotransfer functions (from texture data and organic matter values; Rawls et al., 1992).

Before the end of the project, the same sampling collection and analysis, with the same procedures, will be carry out in the different subplots to know the effect of the different treatments on the identified soil variables.

Figure 5. Soil sampling in the control plot in La Garcipollera, Aragon.

Figure 6. Soil sampling in the treatment plot in Requesens, Catalonia.

3.1.2. Soil moisture

A sensor network has been designed to monitor the evolution of the water in the first 20 cm of the soil, as indicator of water availability for the vegetation and recovery of soil functioning. The sensor network measures two soil moisture samples for each treatment related to the different livestock load. We have used two complementary instruments in this network:

- U30-NRC Meteorological Station HOBO USB datalogger. The datalogger allows to record the data for a long period. The dataloggers were programmed to take measurements hourly. Although the analysis of the samples will be carried out on a daily basis to observe the different responses of the treatments after a rain event, having the hourly information can help us to understand the small differences between them.

- S-SMC M 005 humidity probes. These probes are buried in the soil, take the soil moisture measures and is connected to the datalogger where the information is recorded. The probes are, buried at 20 cm depth, are inserted in a corrugated tube for protection, mainly to avoid being bitten by livestock. The sensors are nailed in a vertical position at 20 cm depth, as recommended in the installation manual.

The distribution of this sensor network is graphically shown in previous Figure 2 and Figure 4, and explained following:

- In Aragón, we have installed 2 dataloggers, one in the treatment plots and another in the control plot. Those dataloggers are connected to two soil moisture sensors in the managed area with livestock, two in the managed area without livestock and two in the control area. In total, we have installed 2 dataloggers and 6 soil moisture sensors (Figure 7).
- In Catalonia, we have installed 5 dataloggers, four in the treatment plots and one in the control plot. We needed more dataloggers than in Aragon because the monitoring plots were higher in surface and there was not the possibility to connect 1 datalogger to 4 plots, as in Aragon. We could maximum connect one datalogger to the sensors of two plots. Moreover, in Catalonia we installed two soil moisture sensors per treatment and replica. In total, we have installed 6 dataloggers and 18 soil moisture sensors (Figure 8).

Figure 7. Soil moisture dataloggers and sensors installed in La Garcipollera experimental plots (left) and control plot (right) (Aragon).

Figure 8. Soil moisture dataloggers and sensors installed in Requesens experimental plots (Catalonia).

3.2. Forest

One of the objectives of the forest management pilot experiences is to demonstrate and quantify how management can make forest less vulnerable to climate change impacts. This quantification is done through the **design of a network of forest indicators or variables that will be monitored during four years**. The comparison of these indicators along the time and among the treatment/control plots or the location of the plot will allow us to quantify the adequacy of these action to improve the adaptation capacity of the forest masses and the consequences on the actions in the provision of functions of the ecosystems.

The monitoring of the forest variables is done through the **installation of permanent inventory subplots**. The inventory subplots are randomly distributed in the study area, but with the premise of installing one subplot per treatment/control plot and replica. In the control plots the same monitoring will be carried out as in the intervened plots, in order to be able to assess both quantitatively and qualitatively the consequences of the actions by comparing different indicators. Attending the characteristic of each are of study, two kind of inventory subplots have been installed:

- **Six rectangular subplots with an area of 400 m^2 in Aragon** (Figure 1). The shape and the surface of the inventory subplot is determined by the size of the monitoring plots. The forest inventory subplots occupy the whole surface of the monitoring plots.
- **Nine circular plots (radius 10 m) with an area of 314 m^2 in Catalonia** (Figure 9). Plot location in each treatment area is uniformly distributed, pre-assigned in a map and redefined with GPS in the field. The central point of these plots will remain marked for periodic surveys.

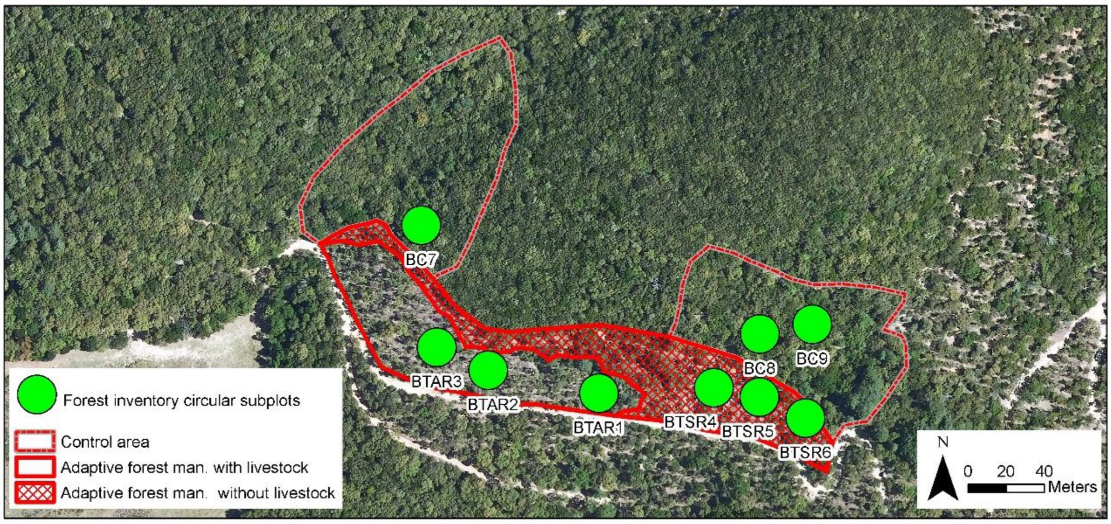

Figure 9. Location of the circular inventory subplots in Catalonia.

The forest inventory subplots are permanent. The centre of the plots will be permanently marked with a 40 cm wooden stake and the upper part of the stake will be spray painted in a striking colour. In this way, the centre will be more easily located in future inventories and a well-defined reference point will be available. In addition, the marking is made to the tree closest to the centre. The bark is scraped off and an inverted T is drawn with paint. This tree cannot be cut down at any time. The horizontal line marks the normal diameter (Dn, diameter at 1.3m high) and the vertical one faces the centre of the plot (Figure 10).

Figure 10. Two examples of forest inventory subplots. The centre of the subplot is marked with a 40 cm wooden and orange-painted stake. The closest tree to the centre is painted with an orange-inverted T.

In each forest inventory subplot, some general information is recorded:

- The distance and angle from the centre of the subplot to the nearest tree that is permanently marked.
- The UTM coordinates (ETRS89H31) of the centre of the subplot with GPS and a precise sketch of the subplot location.
- Orientation (degrees), altitude (meters) and slope (degrees) of the subplot.
- Visual characterization of the soil depth: deep, medium depth, shallow
- Visual characterization of the position of the slope: crest, upper part, middle slope, lower part, skirt (point of union between the valley and the lower part) and valley bottom.
- Photographs of the subplot (from the centre of the plot towards south and north; from the south to the centre, and a circular sweep of the plot).
- Other characteristics that condition the forest or the possible actions to be carried out: percentage of stones, erosive processes, previous forest management …

This **network of forest inventory subplots will be constant along the project duration**, and several different monitoring inventories will be performed to characterise the forest and evaluate the changes. A **first forest inventory was carried out on May and June 2020 in Catalonia and Aragon respectively**. The objective of this first forest inventory was to set the initial conditions of the forest stand, to follow up its evolution on time. In each forest inventory subplot, several variables are measured, as explained following.

3.2.1. Forest structure

Forest structure refers to the distribution and characteristics of the individual trees within the subplot. Forest structure is monitored through a forest inventory, with the following methodologies:

- **Tree density** (number of trees / ha): In each subplot, we count the number of trees or resprouts that are within the 10m radius circumference. The perimeter of the parcel is determined by reduced distance to the centre, and a tree is considered within the parcel if the horizontal projection of the centre of the trunk at the base is only 10 meters or less in the centre of the parcel. Only the inventariable trees (with a diameter at breast height (DBH or Dn) greater than 7.5 cm are counted.
- **Diametric class distribution**: In each subplot, we measure the diameter at breast height (DBH) of all trees with a DBH higher of 7.5 cm, using a pi tape, a diametric tape or a calliper. To re-measure the diameters of the trees in the future, a line will be painted with striking paint, at chest height (1.30 m) of all inventoried trees (with Dn greater than 7.5cm)(Figure 11 Left).
- **Tree height** (m): We measure the total height of 10 trees per subplot, representative of the plot and close to the centre, using a Vertex, a pole, a metric tape or a Christen hypsometer.
- **Resprouting**: In the case of Holm oak (Catalonia), we select three stumps per subplot, close to the centre and identify the stump with a permanent number plate. We count of the number of live sprouts, number of dead sprouts and average height of sprouts (Figure 11 Right).
- **Canopy cover FCC (%):** Fraction of canopy cover, considering all strata (arboreal, shrub and herbaceous), of the subplot, measured visually and in %.

Forest structure is assessed initially, after implementing the forest management and at the end of the project. In this case, as it was explained in Pascual et al (2020), the initial and after implementation inventories were coincident in May (Catalonia) and July (Aragon) 2020, and a final inventory will be done in 2024.

Figure 11. Left: All trees in the subplot (DBH>7.5 cm) are marked with an orange-painted line at chest height (1.30 m) to be re-measured in the future. Right: Three stumps per subplot are marked with a permanent number plate; the number of live sprouts, number of dead sprouts and average height of sprouts are measured.

3.2.2. Forest fuel continuity

Forest fuel continuity refers to the spatial distribution and height of the different strata of the fuel (aerial, ladder or surface cover), which has a direct effect in the vulnerability of the forest to fire risk due to fire propagation. Forest fuel continuity is monitored with the following methodologies:

- **Crown fire hazard**: In each inventory subplot, the risk of crown fire hazard is determined following the methodology of the CVFoC Manual (Piqué et al. 2011). For the estimation of this variable, the following measures are taken:
  - Fuel aerial cover (FCC, %)
  - Fuel surface cover (RCS, %)
  - Fuel ladder cover (RCE, %)
  - Height of surface fuel (m)
  - Distance between surface and ladder fuel (if RCE> 25%) (m)
  - Distance between surface and aerial fuel (if RCE <25%) (m)
  - Distance between ladder and aerial fuel (if RCE> 25%) (m)
- **Understorey biovolume**. We measure fuel coverage making two 10m long strip biomass transects in the direction of maximum slope. The start of the transects is located 2m from the wooden stake that identifies the centre of the plot and following the contour line. The initial and final point of the transects is marked with a wooden stake and painted with permanent spray that allows its later identification. From the upper point of the transect, square polygons of 0.5 x 0.5 m are created towards the outside of the transect where the following information is identified and recorded:
  - Identification of the species of scrub and / or regenerated trees that cannot be inventoried (DBH less than 7.5 cm) present in each square. Square occupancy percentage and average height (m).
  - Percentage (%) of covering of logging residues or dead trees.

- Percentage (%) of moss cover.
- Percentage (%) of herbaceous cover.
- Percentage (%) of litter cover.
- Percentage (%) of stone covering.
- Diagram of the transects that allows reconstructing them in the annual inventories.

Forest fuel continuity is assessed initially, after implementing the forest management, annually (in autumn) and at the end of the project. In this case, as it was explained in Pascual et al (2020), the initial and after implementation inventories were coincident in May (Catalonia) and July (Aragon) 2020. Annually inventories will be done in autumn 2021-22-23 and a final inventory will be done in 2024.

Figure 12. Two examples of the 10m long strip biomass transects.

3.2.3. Forest health status

Forest health refers to the status of the forest decline due to climate change effects (mainly droughts) or other related threatens (plagues, diseases …). Forest decline is defined by the degree of defoliation, decolouration or mortality of the individuals of the forest. Forest health status is monitored with the following methodology:

- **Forest decline**: Using a field key, the forest decline status is assessed through visual estimation of the percentage of tree mortality (dried crowns), the percentage of defoliation (non-present leaves in relation of leaves present on a healthy tree) and the percentage foliage discoloration percentage (non-green leaves in relation of green leaves on a healthy tree). Forest decline is evaluated at 10 trees per forest inventory plot. The trees are marked and identified with a number plate to follow the evolution of the same trees throughout the project. The field visual identification method is based on the DEBOSCAT project (Banqué et al, 2013) and the Spanish Forest Monitoring Network (Level II www.magrama.gob.es)

Forest health status is assessed initially, after implementing the forest management, annually (in autumn) and at the end of the project. In this case, as it was explained in Pascual et al (2020), the initial and after implementation inventories were coincident in May (Catalonia) and July (Aragon) 2020. Annually inventories will be done in autumn 2021-22-23 and a final inventory will be done in 2024.

3.2.4. Fuel moisture

Fuel moisture refers to the water content present in the vegetation along the dry season (summer). Fuel moisture is related with flammability and combustibility of the vegetation and, as a result, with fire risk. A higher water contents of the vegetation in periods of elevated fire risk, is translated in a lower flammability and combustibility of the vegetation. Fuel moisture is monitored with the following methodology:

- **Forest fuel moisture sampling:** In each treatment (not in each forest inventory subplot, but in each treatment and in the control), samples of branches of 5 random trees and 5 random shrubs are collected, using a Fiberglass Pruning Pole (Jameson JE). The branches are cut from the upper part of the crown and facing north. The samples are conserved in a cold box until processing in the laboratory. In the laboratory, the samples are weighed to obtain fresh weight (W). After this, the samples are oven dried at 80 ° C for 24 hours and weighed to determine the dry weight (DW). This allows the determination of the relative water content through the equation:

  RWC (%) = [(W-DW) / W] x 100

Forest fuel moisture samples are taken about nine times per year, approximately on the following dates: 1/5, 1/6, 15/6, 1/7, 15/7, 1/8, 15/8, 1/9 and 1/10. The sampling will be repeated every year until the end of the project (2020, 2021, 2022 and 2023).

Figure 13. Two examples of fuel moisture sampling using a Fiberglass Pruning Pole.

3.2.5. Field equipment

To carry out these inventories the following field material is needed:

- 5 wooden stakes per subplot, to locate the centre of the plot and the limits of the biomass transects
- Diameter tape, pi tape or calliper (to measure the diameters of the trees)
- 2 metric tapes (minimum 15 m, to measure distances and make transects)
- Vertex, pole, metric tape or a Christen hypsometer (to measure heights, distances to the centre of the plot and slope)
- Compass
- Tree marking spray

- Permanent number plates to mark trees and nails (13 per plot)
- Camera
- GPS (to mark the centre and know the altitude)
- Carpenter's meter to measure the height of the vegetation in the transects
- Pruning shears and / or pole for vegetation sampling
- Plastic bags for samples
- Portable fridge to store the samples
- Mace

3.3. Pastures

The objective is to assess the effect of cow grazing in the pasture production and quality in terms of biodiversity, biomass productivity and nutritive quality.

Field samplings are done yearly in late spring or early summer (May-June), just before the grazing period and matching with both the vegetation growth and flowering peaks in Mediterranean mountains to ensure species identification.

3.3.1. Biodiversity

Vegetation surveys are carried out at each study site (Requesens in Catalonia and La Garcipollera in Aragon) to assess the pasture's biodiversity (number of species and cover per species in terms of percentage). At each study site, in an area subjected to forest management, we set three sub-plots (10*10 m) submitted to grazing by cows and three sub-plots without grazing. As a control, we considered a nearby area with the same environmental conditions and vegetation structure but with neither a management nor grazing. Specifically, we recorded the cover per species growing inside four randomly arranged quadrats (1*1 m) at each sub-plot in the managed area (12 in the subplots with grazing and 12 in the subplots without grazing) and also in 12 randomly arranged quadrats in the control area (n=36 quadrats per study site) (Figure 14).

Biodiversity samplings are carried out every year in late spring or early summer (May-June). The first sampling was done in July 2020, and will be repeated in 2021, 2022, 2023 and 2024.

*Figure 14. Vegetation surveys in La Garcipollera (left) and Requesens (right): Random quadrats of 1*1 m where we count the number of species and the cover in % per species.*

3.3.2. Pasture production and quality

a) Sample collection

To assess the pasture's production and quality, we collect systematically the plants growing in 60 x 60 cm areas close to each of the previously surveyed quadrats (n=36 samples per study site). We cut the plants to the ground level using mechanical scissors (Gardena mod. 8895). Samples are put into properly labelled plastic bags and, once in the laboratory, they are stored in a freezer (-18 ºC) until being processed to avoid their rotting and drying.

Pasture production and quality samplings are carried out every year in late spring or early summer (May-June). The first sampling was done in July 2020 in La Garcipollera. In Requesens, vegetation sampling was not feasible because the plants were parched. However, sample collection is planned for the following field campaigns. The samplings will be repeated in late spring or early summer in 2021, 2022, 2023 and 2024.

Figure 15. Sample collection for pasture production and quality in La Garcipollera.

b) Samples processing

Once in the laboratory, samples are thawed at room temperature and ensuingly cleaned. Samples cleaning consists of discarding the litter, mosses, rocks and soil and then dividing the vegetation into herbaceous and woody species separately (differentiating among shrub species). When cleaned, they are oven dried at 65ºC during 48 hours. Afterwards, they are weighed to estimate the dry biomass production (t/ha). Next, previous to chemical analyses to asses pasture's feed quality, samples are grounded in a mill (IKA MF10, IKA-Werke, Staufen, Denmark) and sieved to a fine particle size (<1 mm).

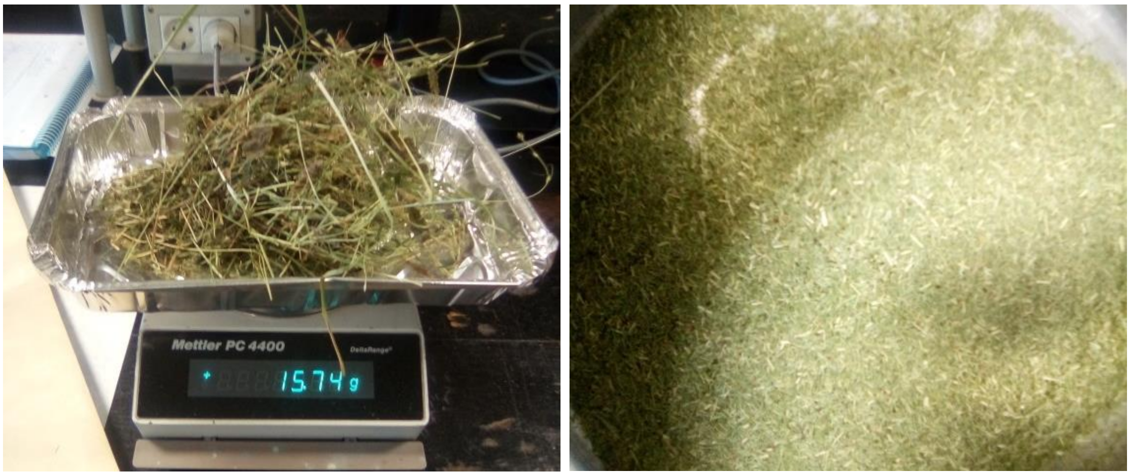

Figure 16. Process of simple to estimate pasture production and quality.

c) Chemical analyses

Ground samples are analyzed in the laboratory to estimate the pasture's feed quality. Specifically, we analyzed the ash concentration (mineral content), nitrogen content, crude protein, and fiber concentrations (neutral detergent fiber and acid detergent fiber). Ash concentration is obtained by incineration at 550 ºC. Nitrogen content (N) is determined using the Kjeldahl method. Crude protein concentration (CP) is then estimated by multiplying nitrogen content by 6.25. Concentrations of ash-free neutral detergent fiber (NDF) and acid detergent fiber (ADF) is quantified using an Ankom 200 fiber analyzer (Ankom Technol. Corp., Fairport, NY, USA).

After laboratory analyses, we calculate the relative feed value (RFV), which is an index that combines important nutritional factors (potential intake and digestibility) into a single number, providing a quick and effective method for evaluating feed value or quality. The RFV is calculated using the estimates of digestible dry matter (DDM %) and potential dry matter intake (DMI % of body weight) of the forage based on the ADF and the NDF fractions, respectively:

$$RFV = (DDM * DMI)/1.29$$

3.4. Rainfall simulations

Land use and land cover determines the relationship between precipitation and both runoff and soil erosion. The implementation of landscape management measures affects the vegetation cover, which in turn affects interception and evapotranspiration of the plants, and also the soil properties, with significant consequences for runoff and soil erosion. The objective of this environmental monitoring is to assess the effect of forest management and grazing on the hydrological response and soil erosion.

For this purpose, we carry out rainfall simulation experiments in all monitoring subplots, several times along the project. Rainfall simulations are widely used to compare and assess runoff and sediment production by rain splash because they enable initial conditions to be established and provide for control over rainfall characteristics (Iserloh et al., 2012). We use a portable rainfall simulator designed for rugged terrain (Figure 17 Left). The simulator consists of a metallic structure with telescopic metal legs, and is covered with plastic to protect the experiments from wind. On the top of the structure a nozzle is installed. In our experiments, we use a rainfall intensity ranging from 30 to 45 mm h-1, which corresponds to a moderate-to-high rainfall intensity event. Rainfall is registered in each experiment with two pluviometers. The experimental plots are defined by a circular ring with an area of 0.25 m^2. Each plot has a drain pipe outlet for collection of runoff samples (Figure 17 Right), located down slope at surface level. In each experiment, several variables characterizing the hydrogeological and sedimentological response are obtained: Runoff coefficient (%), Infiltration rate (mm h-1), Time to runoff (min), Ponding time (min), Wetting front (cm), Sediment concentration (mg l-1), Sediment production (g) and Sediment detachment (g m-2 h-1).

The first experiments (initial conditions) were carried at in October 2020: in Aragón, in the cleared forest subplots (without grazing) and in Catalonia in all the subplots. In December, new rainfall simulation experiments were performed in all the subplots and the control plot in Aragón.

Figure 17. Left: The rainfall simulator used during the experiments in Requesens (Catalonia).Right: Collecting water samples during a rainfall simulation in La Garcipollera (Aragón).

3.5. Site meteorological conditions

The registration of the meteorological conditions is key to understand the evolution of previous variables along the project duration. With this objective, we have installed air temperature sensors, relative humidity sensors and rain-meters or weather stations to record in continuum these variables:

- Aragon: We have installed air temperature and relative humidity sensors (Tinytag Plus 2 - TGP-4500) with measurement ranges of -25ºC-85ºC and 0-100%, respectively. In order to have different replicas of both measurements, they were installed inside the experimental plots, control plots and outside them, in shady and well ventilated sites. The rainfall in La Garcipollera is collected in a pluviometer of the State Agency of Meteorology (AEMET) located in Bescós de la Garcipollera (Figure 18).

- Catalonia: We have installed air temperature and relative humidity sensors (HOBO Pro v2 (U23-001) by Onset Computer Corporation), one in each subplot. These HOBO loggers are located 130 cm above the ground and were set to a recording interval of 60 min. We have installed 9 HOBOS: 3 in the control subplots, 3 in the managed subplots with livestock and 3 in the managed subplots without livestock (Figure 19 Left).

In Catalonia, we have an automatic weather station installed with a previous LIFE project (Figure 19 Right). Daily values of meteorological variables, including maximum temperature, minimum temperature, rainfall, radiation and wind speed are calculated through hourly data recorded by an automatic weather station, a Vantage Pro2 Station (Davis Instruments, Hayward, California, USA).

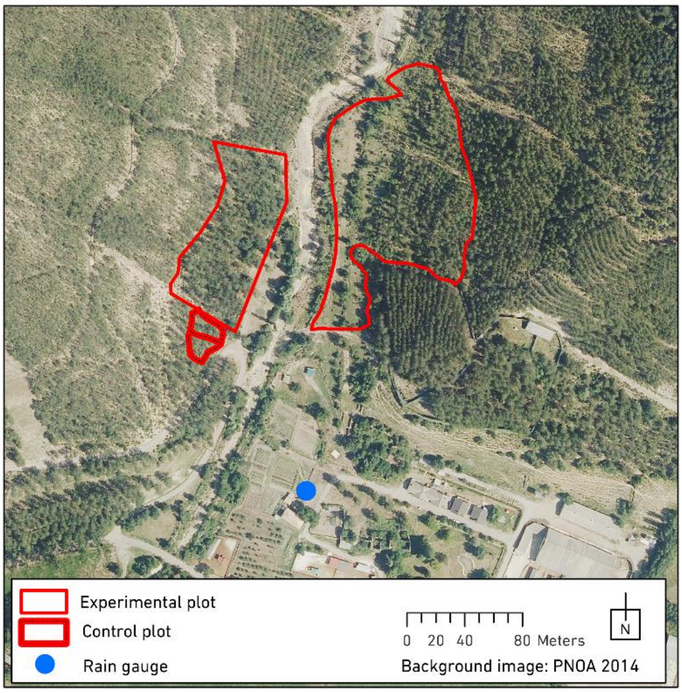

Figure 18. Location of the pluviometer of the State Agency of Meteorology (AEMET) located in Bescós de la Garcipollera.

Figure 19. HOBO Logger (left) and weather station (right) installed in Requesens (Catalonia).

4. Conclusions

The main objective of this deliverable is to present the **design of the monitoring network and describe the monitoring variables and protocols** of the action C.2: Climate change adaptation measure: Forests management in Aragón and Catalonia.

Table 1 summarizes all the variables, briefly describes methods, and indicates the periodicity of the different monitoring protocols. Physical and chemical soil properties and soil moisture; forest characteristics; pasture biodiversity, production and quality; rainfall simulations and meteorological conditions are going to be measure to analyse the effects of adaptive forest management and livestock management.

Finally, it should be highlighted that the **all the monitoring variables have been already measured at the beginning of the implementation activity (2020)** and data are going to be analysed by different project partners. Consequently, **all the activities and the periodicity defined in the proposal have been successfully completed** and it is a perfect starting point for the future monitoring network defined in the LIFE MIDMACC project.

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