LIFE MIDMACC

Mid-mountain adaptation to climate change

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Monitoring protocol of C1 action

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Executive summary

This deliverable describes the monitoring protocol of C1 action: scrubland clearing carried out in La Rioja and Aragón.

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 presents the design of the monitoring network including a description of the monitoring program/design carried out in La Rioja and Aragón. The third section presents the monitoring variables and all the protocols established to realize the environmental monitoring of the C1 action (scrubland clearing), including a table with a summary of all the measured variables, methods and timing.

This deliverable explains the monitoring protocol that will be carried out during the entire LIFE MIDMACC project related to action C1, fundamental in the project. The main objective of these protocols is to evaluate the effects of scrubland clearing and livestock management in different environmental variables. We have described in detailed 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) pasture variables (biodiversity, production and quality), (iii) hydrogeomorphological response (runoff, infiltration rates, sediments, times to response), and (iv) site meteorological conditions (air moisture and temperature, rainfall).

Content

1. Introduction

The main objective of LIFE MIDMACC is to promote the adaptation of marginal mid-mountain areas of Mediterranean environments to climate change, through the implementation and testing of different landscape management measures, while improving their socioeconomic development.

The first landscape management measure to be implemented is **scrubland clearing**, based on the elimination of scrubland in an area to stimulate pasture regeneration, extensive livestock farming and fire risk reduction.

After the implementation of pilot experiences carried out in 2019-2020, monitoring tasks have started during spring and summer 2020. It should be highlighted that even scrubland clearing has been carried out periodically in some mountain areas since the end of the 1980s, there is no overall experimentation framework to assess the environmental and socioeconomic effects of this measure, and only few studies have evaluated some of these effects recently (Lasanta et al., 2016, 2018, 2019). Thus, it is necessary to establish well-controlled experiments to explore all the environmental implications of the scrubland clearing measure.

The **main objective** of this report is to describe the **monitoring protocol** of action C1. related to the implementation of extensive livestock farming measures in scrubland areas, implemented in San Román de Cameros (calcareous) and Ajamil de Cameros (siliceous) in La Rioja, and La Garcipollera Research Station (calcareous) in Aragón. First of all, we will briefly describe the design of the monitoring network, and then we will present the monitoring variables and different protocols used.

2. Design of the monitoring network

The monitoring network includes a protocol for monitoring and the installation of monitoring plots. A set of variables 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 variables measured 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). This experimental farm is dedicated to the study of mountain agriculture and livestock. It has about 14 hectares of meadow, and all kinds of livestock facilities, as well as two experimental herds, one of about 200 heads (cows) and the second one about 300 sheep.

As mentioned in Deliverable 6, the clearing activities were carried out at the end 2019 and at the beginning of 2020 at “La Garcipollera” Research Station. Two areas of **3.3 ha** and **0.24 ha** have been cleared, but only one has been selected to carry out the monitoring program (Figure 1), due to the better accessibility and facilities provided by La Garcipollera Research Station. The study area is public and the Government of Aragón allows us the experimentation in the different cleared areas. Animals are provided by La Garcipollera Research Station.

Among the cleared areas, one was selected in calcareous soils to create 12 sub-plots (100 m^2) for the monitoring experiments with different livestock loads (3 replicates for each load): no livestock, low, medium and high load. In addition, one plot with no intervention has been selected close to the managed area to monitor the site evolution with no actuation (control plot) (Figure 1).

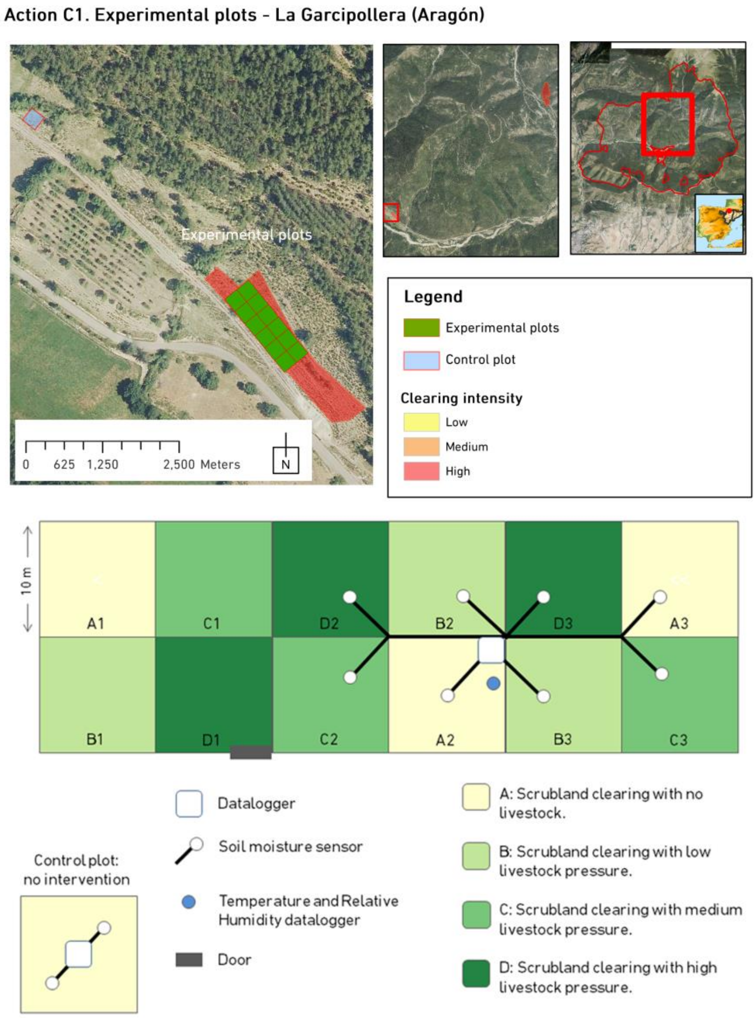

Figure 1. Location of the control and experimental plots (up) and diagram of the livestock and monitoring subplots (down)

Figure 1 shows the control plot and the twelve subplots defined for the monitoring experiments, and a diagram of the livestock and monitoring subplots, together with the location of the different measurement equipment.

2.2. Monitoring design in La Rioja

The pilot experience has been implemented in the Leza river basin (La Rioja). Two study areas have been selected, located in the municipalities of **San Román de Cameros and Ajamil de Cameros**. The reason to select two areas in the same valley is based on the different lithologic conditions: calcareous (San Román de Cameros) and siliceous (Ajamil de Cameros).

The cumulative area of scrubland cleared zones during winter 2019-2020 by the Government of La Rioja has been **20.1 ha** in San Román de Cameros and **8.61 ha** in

Ajamil, with different clearing intensities: two areas with high intensity, two areas with medium intensity and two with low intensity (Figure 2 A and B). In addition, the LIFE MIDMACC project has carried out similar scrubland activity in two private areas due to the better accessibility to carry out the experimentation: 0.7 ha in San Román and 3.6 ha in Ajamil 3.6 ha. In total, **scrubland clearing has been applied in a surface of 33 ha in La Rioja**.

In each (private) area, 12 sub-plots were created for the monitoring experiments with different livestock loads (3 replicates for each load): no livestock, low, medium and high load. In addition, one plot with no intervention has been selected close to the managed area to monitor the site evolution with no actuation (control plot) (Figure 2).

Figure 2 also indicates the clearing intensity of the different plots (determined by the previous vegetation that has been eliminated): low, medium and high.

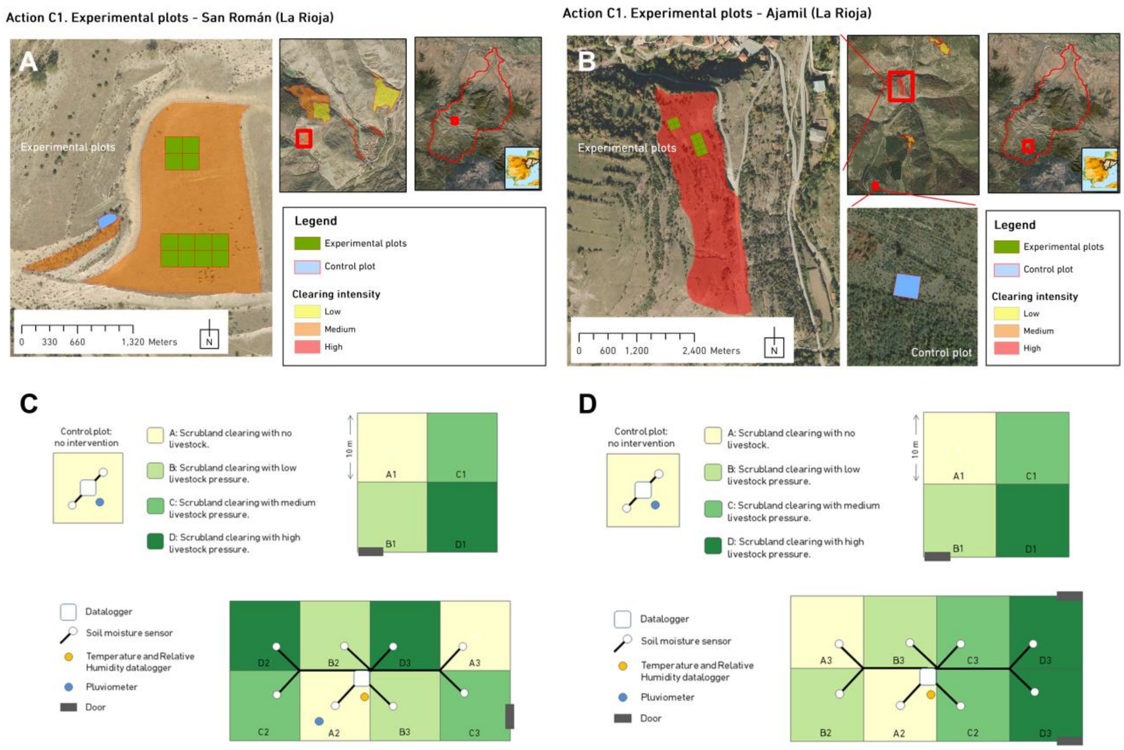

Figure 2. Location of the control plots and replicates of the experimental design and diagram of the livestock and monitoring subplots in La Rioja.

Figure 2 shows the control plots and the twelve subplots defined for the monitoring experiments, and a diagram of the livestock and monitoring subplots, with the location of sensors to monitor soil humidity, air temperature and relative humidity in the different livestock treatments.

3. Monitoring variables and protocols

Table 1 summaries the monitored variables in the scrubland clearing pilot experiences in La Rioja and Aragón. Following, a detailed description of each variable, the means to measure it, the frequency of the measurements and other specifications are included.

	Variable	Description	Methodology	Periodicity
Soil	**Soil analysis**	Field bulk density (BD) pH and electrical conductivity (EC) Total Carbon concentration (Ctotal) Total Nitrogen concentration (N) Carbonate content (CaCO3) Soil organic carbon and nitrogen stocks (SOC and TN) Corg/N ratio % organic matter Grain size distribution (texture) Organic phosphorus (P) Saturated soil moisture (SAT) Field capacity (FC) Wilting poing (WP)	**Soil analysis** A field campaign will be designated to characterize soil properties before the experiment and at the end of the project. In each site, in order to have more variability, three soil samples will be taken in each plot; then, this samples will be mixed to create a composite sample. Four depths will be analysed: 0-10, 10-20, 20-30 and 30-40 cm.	All the variables will be measured twice along the project: at the beginning and at the end of the experimentation. In addition, soil properties related to carbon storage will be analysed yearly (only the first 10 cm)
	Soil moisture	Soil water content (SWC)	Humidity sensors and data-loggers	Continuous
Pastures	**Pasture production and quality**	Pastoral value Pasture nutritive quality	Field sampling Chemical analysis	Yearly in spring or summer

		(protein and fibre content) Biomass productivity		
	Biodiversity	Plant community composition (species richness, diversity and plant functional types)	Field sampling	Yearly in spring or summer
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 and yearly
Site meteorological conditions	**Precipitation**	Daily rainfall amount	Rainfall gauges	Continuous
	Temperature and relative humidity	Temperature and relative humidity	Temperature and relative humidity data loggers	Continuous

Table 1. Monitored Variables: variables, description, methodology and periodicity

3.1. Soil

Soil is the main reservoir for organic carbon in terrestrial ecosystem. 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 scrubland clearing and livestock management in soil properties and soil organic carbon dynamics.

3.1.1. Soil analysis

Soil samples will be carried out twice along the project: at the beginning and at the end of the experimentation. In addition, soil properties related to carbon storage (only in the top soil, 0-10 cm) will be analysed yearly.

The first soil samplings were carried out in June 2020 in all the scrub clearing plots. At each monitoring subplot, three soil samples were diagonally sampled with an auger at 10 cm increments: 0 cm, 0-10 cm, 10-20 cm, 20-30 cm and 30-40 cm. In each site, 45 points were selected and 225 subsamples were recorded and later combined into one soil composite sample per plot and depth. In total 75 composite samples were created in each study site (in San Román, Ajamil and La Garcipollera) (total soil samples to be analysed, n=225) (Figures, 3, 4 and 5). In addition, bulk soil samples were collected to test soil moisture and bulk density values. These 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. Soil samples are air dried and sieved through a 2 mm mesh sieve in the laboratory.

(i) 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);

(ii) pH is measured in a deionized water suspension (1:2.5) using a pH meter;

(iii) electrical conductivity using a conductivity meter;

(iv) total carbon and total nitrogen are measured by dry combustion in an elemental analyser (LECO CNS 928);

(v) carbonate content is measured with the Bernard calcimeter method;

(vi) 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);

(vii) 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;

(viii) organic matter is determined using the Walkley-Black chromic acid wet oxidation method;

(ix) Corg/N ratio is calculated using Corg and total nitrogen;

(x) grain size distribution is determined using a particle size analyser (Mastersizer 2000) after oxidizing the organic material with peroxide;

(xi) organic phosphorus is determined by the Bray method;

(xii) 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).

Figure 3. (a) Soil sampling in San Román (Calcareous soils), and (b) detailed undisturbed soil sample.

Figure 4. Soil sampling in the Control plot in Ajamil (Sileceous soils).

Figure 5. (a) Soil sampling in La Garcipollera and (b) detailed soil sampling site.

3.1.2. Soil moisture

A sensor network has been designed in which two soil moisture samples are obtained for each treatment related to the different livestock load. As shown in Figure 6, a U30-NRC Meteorological Station HOBO USB datalogger has been installed with different S-SMC M 005 humidity probes: 8 in the experimental plots and 2 in the control plots.

The dataloggers were programmed to take measurements hourly. Although the analysis of the data will be carried out on a daily basis, it is important to have detailed time lapse to observe the different responses of the treatments after a rain event. Thus, having the hourly information can help us to understand the small differences between the different treatments. As detailed in the Deliverable 6, the sensors were nailed in a vertical position at a depth of 20 cm, as recommended in the installation manual.

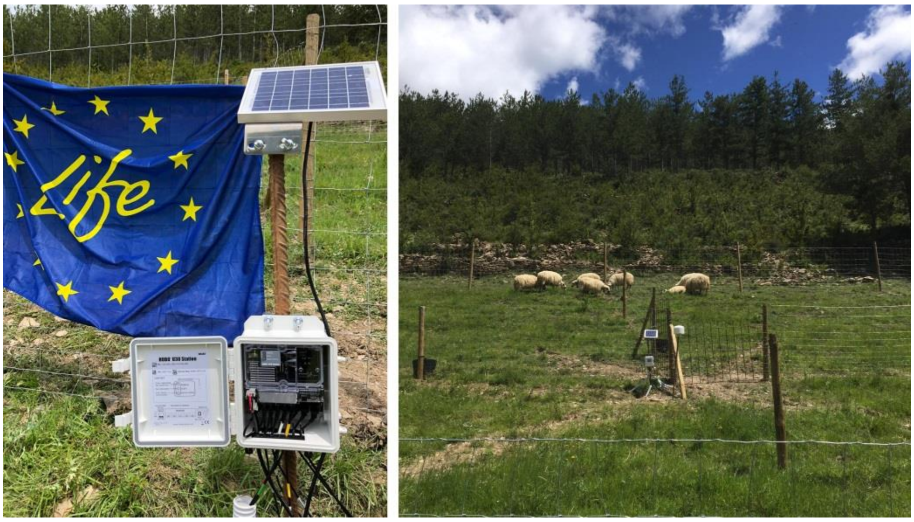

Figure 3. Soil Humidity (detail on the left side) and Termometer/Hygrometer dataloggers installation in La Garcipollera experimental plots.

3.2. Pastures

We aimed to assess the effect of different livestock stocking rates 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 activity and matching with both the vegetation growth and flowering peaks in Mediterranean mountains to ensure species identification.

3.2.1. Biodiversity

First vegetation surveys were carried out at each study site (La Garcipollera in Aragon, Ajamil and San Román in La Rioja) 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 scrubland clearing, we set three sub-plots (10*10 m) per sheep stocking rate (low, medium and high), 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 clearing intervention nor grazing. Specifically, we recorded the cover per species growing inside four randomly arranged quadrats (1*1 m) at each sub-plot in the clearing area and also in 9 randomly arranged quadrats in the control area (n=45 quadrats per study site) (Figure 7).

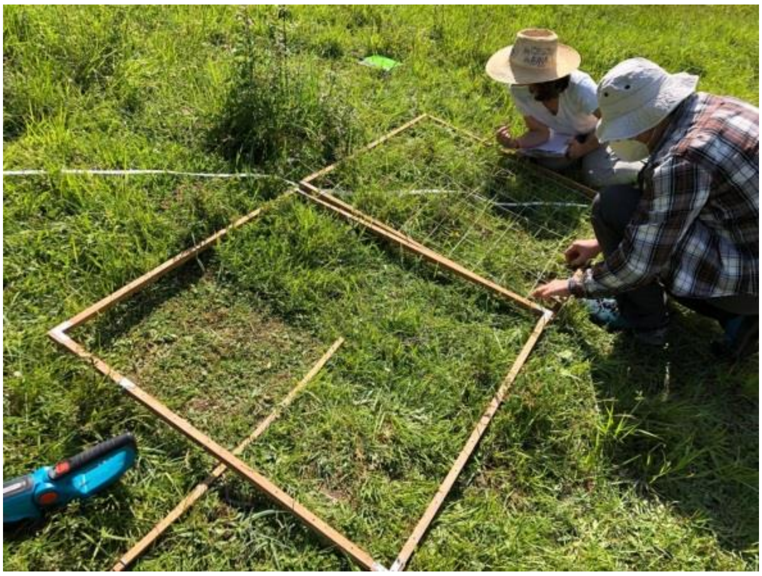

*Figure 7. Vegetation sampling point in La Garcipollera: study of the cover per species growing inside a quadrat (1*1).*

3.2.2. Pasture production and quality

a) Sample collection

To assess the pasture's production and quality, we collected systematically the plants growing in 60 x 60 cm areas close to each of the previously surveyed quadrats (n=45 samples per study site) (Figure 8).

Figure 8. Sample collection to estimate pasture production and quality.

We cut the plants to the ground level using mechanical scissors (Gardena mod. 8895). Samples were put into properly labelled plastic bags and, once in the laboratory, they were stored in a freezer (-18 ºC) until being processed to avoid their rotting and drying. During the first field campaign (June 2020), vegetation sampling was not feasible in Ajamil because the plants were parched. However, sample collection is planned for the following field campaigns.

b) Samples processing

Once in the laboratory, samples were thawed at room temperature and ensuing cleaned. Samples cleaning consisted 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 were oven dried at 65ºC during 48 hours. Afterwards, they were weighed to estimate the dry biomass production (t/ha) (Figure 9). Next, previous to chemical analyses to assess pasture's feed quality, samples were ground in a mill (IKA MF10, IKA-Werke, Staufen, Denmark) and sieved to a fine particle size (<1 mm).

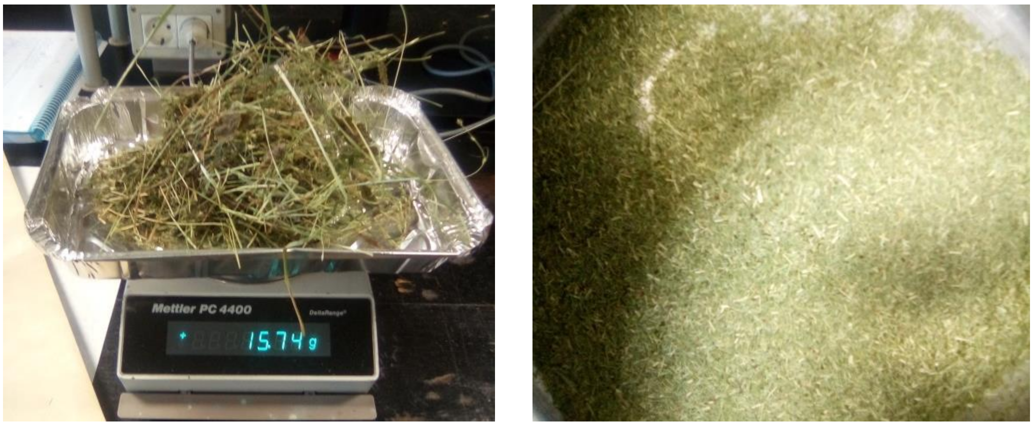

Figure 9. Weighing biomass production (left) and sieve and ground samples in the laboratory (right).

c) Chemical analyses

Ground samples were 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 was obtained by incineration at 550 ºC. Nitrogen content (N) was determined using the Kjeldahl method. Crude protein concentration (CP) was then estimated by multiplying nitrogen content by 6.25. Concentrations of ash-free neutral detergent fiber (NDF) and acid detergent fiber (ADF) were quantified using an Ankom 200 fiber analyzer (Ankom Technol. Corp., Fairport, NY, USA).

After laboratory analyses, we calculated 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.

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

3.3. Rainfall simulations

Land use and land cover determines the relationship between precipitation and both runoff and soil erosion. The implementation of landscape management measurements 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 scrub clearing and different livestock intensities on the hydrological response and soil erosion.

For this purpose, we will 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 will use a portable rainfall simulator designed for rugged terrain (Figures 10 and 12). 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 (return period of 5-10 years in La Rioja). 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 (Figures 11 and 12), located down slope at surface level. In each experiment, several variables characterizing the hydrological and sedimentological response are obtained (See Table 1):

(i) Runoff coefficient (%),

(ii) Infiltration rate (mm h^{-1}),

(iii) Time to runoff (min) andponding time (min),

(iv) Wetting front (cm),

(v) Sediment concentration (mg l^{-1}),

(vi) Sediment production (g),

(vii) Sediment detachment (g m^{-2} h^{-1}).

The first experiments were carried at the end of September and beginning of October 2020 in order to monitor the initial conditions, i.e., in the cleared subplots without grazing and in the control plot. In November 2020, after the livestock grazed for the third time within the year, new rainfall simulations were performed in all the subplots and the control plot. This scheme (i.e., rainfall simulations after the livestock grazes for the third time) will be repeated every year until the end of 2023.

Figure 10. The rainfall simulator used during rainfall simulation experiments in San Román de Cameros (La Rioja).

Figure 11. Collecting water samples during a rainfall simulation experiment in San Román de Cameros (La Rioja).

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Figure 12. Rainfall simulations and plot detailed in La Garcipollera site (Aragón).

3.4. Site meteorological conditions

The registration of the meteorological conditions is a key point to understand and evaluate the evolution of environmental variables (soil properties, pasture and hydro-geomorphological response) during the project duration. With this objective, we have installed air temperature sensors, relative humidity sensors and rain gauges or weather stations to obtain a continuous record of these variables.

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. These instruments have been installed both in Aragón and La Rioja sites.

We have also installed air temperature and relative humidity sensors (HOBO U23 Pro v2), one in each subplot.

Related to rainfall measurements: (i) In Aragón, rainfall is recorded in a pluviometer of the State Agency of Meteorology (AEMET) located in Bescós de la Garcipollera. The CITA will be provided this information; (ii) In La Rioja, in Ajamil data is recorded from a pluviometer managed by AEMET, and we have installed a second pluviometer in the control plot; finally, in San Román a new pluviometer has been also installed (see Figure 13).

Figure 13. Pluviometer, temperature sensor and soil moisture sensors in San Román experimental site.

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.1: Climate change adaptation measure: scrubland clearing in La Rioja and Aragón.

Table 1 summarizes all the variables, briefly describes methods and protocols, and indicates the periodicity of the different monitoring protocols. Physical and chemical soil properties and soil moisture, pasture biodiversity, production and quality, rainfall simulations (hydro-geomorphological response) and meteorological conditions are going to be measure to analysed the effects of scrubland clearing 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 (scrubland clearing)** and data are going to be analysed in the different institutions. 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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