LIFE MIDMACC

Mid-mountain adaptation to climate change

LIFE18 CCA/ES/001099

Start date of the project: 1st July 2019

Duration of project: 5 years

Deliverable 27

Report with the 3rd year monitoring results of the implementation action C1

Due date of deliverable: 12-2023

Actual submission date: 12-2023

Beneficiary leading this deliverable: IPE

Dissemination level: Public

Mid-mountain adaptation to climate change

With the support of

LIFE18 CCA/ES/001099

Authors

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

Cite as

Nadal-Romero, E., Zabalza, J., Foronda, A., Lasanta, T., Pueyo, Y., Reiné, R., Barrantes, O., Lana-Renault, N., Ruiz, P. (2023) Report with the 3rd year monitoring results of the implementation action C1. Deliverable 27 LIFE MIDMACC.

Executive summary

This deliverable presents the results obtained from the monitoring of the pilot experiences in scrub clearing during the third year of the monitoring in 2023. The pilot experiences were mainly implemented by the end of 2019 and the beginning of 2020, the setting of initial monitoring variables was performed in 2020, the first monitoring campaign was realized in 2021, the second monitoring campaign was performed in 2022, and the third campaign has been carried out since the beginning at the end of 2023.

Following the monitoring protocol developed in the Deliverable 8 (Nadal-Romero *et al.*, 2020b), this document includes the results obtained in the pilot experiences of scrubland clearing management with extensive livestock farming in Aragon (La Garcipollera) and La Rioja (San Roman and Ajamil).

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 summarises the monitoring protocol, to have a quick overview of the monitored variables. The third, fourth and fifth sections detail the results of the first monitoring campaigns, in both sites of Aragon and La Rioja. Finally, the sixth section summarizes the main outcomes found in the second monitoring campaign.

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: (i) scrubland clearing, (ii) forest management, and (iii) different assays in vineyards in three representative 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** (see Nadal-Romero et al., 2019, 2020a, 2020b). 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 **results of the third monitoring campaign** related to scrubland clearing with livestock grazing, carried out in Aragon and La Rioja. Scrubland clearing has consisted of the scrubland clearing in land abandonment and encroachment areas in Aragon (La Garcipollera) and La Rioja (San Román and Ajamil both located in the Leza Valley). In this case, the monitoring campaign has been accomplished along 2022 and 2023, ending in November. Monitoring results of the soils, pastures, infiltration and erosion, and meteorological variables are shown in the following chapters.

2. Summary of the monitoring protocol

Deliverable 8 (Nadal-Romero *et al.*, 2020b) collects all aspects related with the monitoring of pilot experiences. Following, Table 1 summaries the monitored variables in the scrubland clearing management pilot experiences in Aragon and La Rioja. A more detailed description of each variable, the means to measure, frequency and specifications can be consulted at Nadal-Romero *et al.* (2020b).

	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	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 starting from 2021 (only the first 10 cm)
	Soil moisture	Soil water content (SWC)	Humidity sensors and data-loggers	Continuous (2020-2024)
Pastures	**Biodiversity**	Plant community composition (species richness, diversity and plant functional types)	Vegetation surveys / sampling	Annual survey (spring or summer 2020-2022-2023) Final (2023)
	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 2020-2022-2023) Final (2023)
Rainfall simulation	**Hydrological response and soil erosion**	Runoff coefficient Time to runoff Wetting front Sediment concentration Sediment production	Rainfall simulation experiments	After clearing (2020) Annual simulations (2020-2021-2022-2023)

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
	Precipitation	Daily rainfall amount	Rainfall gauges	Continuous

Table 1. Summary of the monitored variables in the scrubland clearing management pilot experiences in Aragon and La Rioja.

3. Results of the 1st, 2nd and 3rd monitoring campaign in Aragon

The pilot experience has been implemented in La Garcipollera Research Station (Central Pyrenees, Huesca, Spain) in a representative land abandoned area that was cleared at the beginning of the LIFE MIDMACC project (hereafter scrubland clearing area). This chapter includes the results of the results of the 1st, 2nd and 3rd monitoring campaigns.

Following, we include a summary of the implemented pilot experience and the experimental design of the monitoring network, to facilitate the understanding of the monitoring results. A more detailed description of the implemented actions can be consulted in Nadal-Romero *et al.* (2019, 2020a, 2020b).

The initial sampling of the monitoring variables was carried out in June 2020 and the monitoring campaigns were carried out in November 2021, 2022, and 2023, once the animals entered three times in the experimental plots (spring, summer, and autumn). In winter 2021-2022 and 2022-2023, during the 1st and 2nd-year monitoring campaigns, superficial soil samples (0-10 cm) have been taken to analyse the changes in carbon and nitrogen. In this deliverable, we present the results of 2021, 2022 and 2023.

Implemented pilot experience:

- Adaptive scrubland management of abandoned fields in 0.24 ha plot consisting in scrubland clearing.
- Control plot: an area with no actuation of 100 m^2.

Monitoring network:

- Four classes of monitoring subplots (surface of 100 m^2):
  - control subplots, without neither scrubland management nor the entry of livestock;
  - managed subplots with three different livestock density:
    - A no livestock,
    - B low pressure,
    - C medium pressure,
    - D high pressure.
- For each of the monitoring subplots, three replicates were selected, except in the control area where there was only space for two replicates.

The monitoring network includes twelve monitoring managed subplots of 100 m^2, and two subplots in the control area.

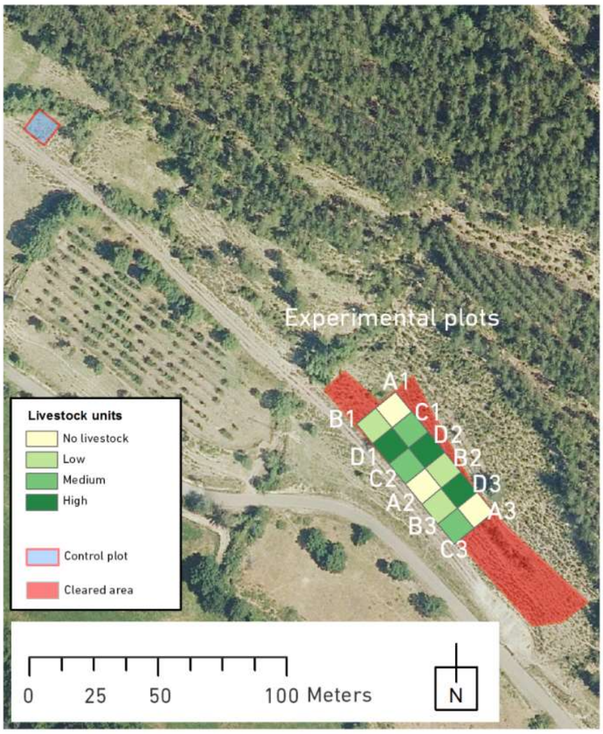


Figure 1. Location of the monitoring plots and replicates of the experimental design.

3.1. Monitoring results of the Soil

3.1.1. Soil characteristics

The initial sampling of the monitoring variables was carried out in June 2020 and the first year and second year monitoring campaigns were carried out in November 2021 and November 2022 once the animals entered three times in the experimental plots (spring, summer, and autumn 2021 and 2022). In winter 2023-2024, during the third-year monitoring campaign, soil samples (0-40 cm) are being taken again to analyse the changes in carbon and nitrogen content and stocks in the complete soil profile. In this deliverable, we present the results of the 2021 and 2022 campaigns (the last results about soil properties will be presented in the final deliverable).

At each monitoring subplot, three soil subsamples were sampled in a depth of 0-10 cm. In each site, 45 points were selected, and subsamples were recorded and later combined into one soil composite sample per plot and depth (0-10 cm). In total 15 composite samples were created in La Garcipollera.

The samples have been analysed by the Pyrenean Institute of Ecology (IPE-CSIC), evaluating the following soil variables: total carbon concentration (Ctotal), total nitrogen concentration (N), organic matter (OM), bulk density (BD), and soil organic carbon (SOC). It should be noted, that during this year the calculation to determine SOC and N stocks have been slightly modified, and consequently some data may differ from previous deliverables.

The following tables and figures present the mean values at the initial conditions, after the first and the second years of monitoring, and the change occurred in percentage for the main variables (0-10 cm) measured in the experimental plots during the 2021 and 2022 monitoring campaigns in La Garcipollera Research Station. Statistical results did not show significant differences between the management plots and the control plots at the third year of monitoring, neither between the initial conditions and the present values. However, some changes could be highlighted. Related to SOC values (and Figure 2) (i) higher SOC stocks are observed after the first and second monitoring year, although these changes are not significant; (ii) the higher increase in SOC stocks are observed in the B plots in the second year, and higher SOC values are observed in the B and C plots (low and medium livestock pressure); and (iii) the lowest increases are recorded in the A and D plots (no grazing and high livestock pressure).

SOC Mg ha^{-1} (10 cm)	YEAR 0	YEAR 1	YEAR 2	Change 1 %	Change 2 %
A	46.1	49.9	53.5	*+ 8.2*	*+ 16.0*
B	40.9	53.2	64.0	*+ 30.1*	*+ 56.6*
C	41.9	52.4	54.2	*+ 25.1*	*+ 29.3*
D	34.4	58.7	40.6	*+ 70.8*	*+ 18.2*
CONTROL	34.8	55.3	53.9	*+ 59.1*	*+ 55.1*

Table 2. Soil organic carbon (SOC) stocks of soil samples for the initial conditions and first and second years of monitoring (at depth of 0-10 cm) and in the different plots (A, B, C and D and control plots).

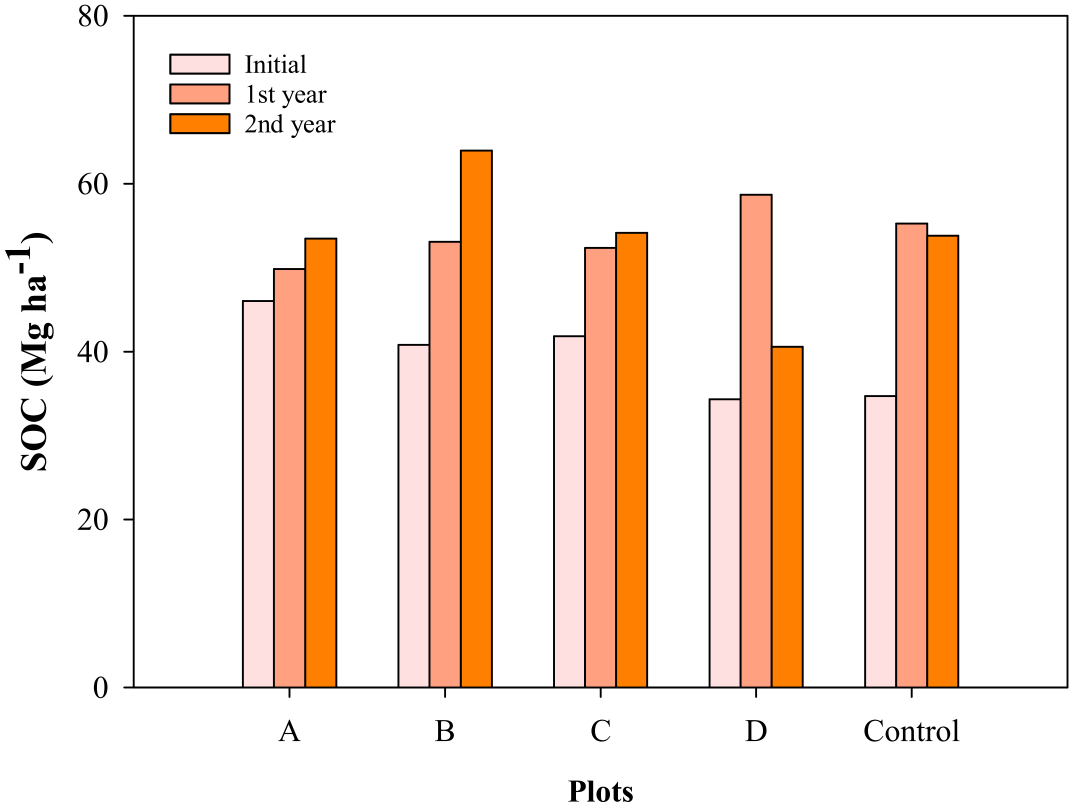


Figure 2. Soil organic carbon (SOC) stocks of soil samples for the initial conditions and first and second years of monitoring (at depth of 0-10 cm) and in the different plots (A, B, C and D and control plots).

Related to N stocks (Table 3 and Figure 3): (i) all the plots show decrease in N stocks during the first year. In the second year an increase is observed in B, C (low and medium livestock density) and control plots; and (ii) the highest increases are recorded in the B and control plots.

N Mg ha^{-1} (10 cm)	YEAR 0	YEAR 1	YEAR 2	Change 1 %	Change 2 %
A	3.7	2.7	3.6	*- 26.8*	*- 2.5*
B	3.6	2.9	4.6	*- 18.0*	*+ 30.0*
C	3.7	3.2	3.8	*- 15.4*	*+ 1.1*
D	3.2	2.5	3.1	*- 24.4*	*- 4.1*
CONTROL	3.3	2.4	4.0	*- 27.3*	*+ 20.7*

Table 3. Nitrogen (N) stocks of soil samples for the initial conditions and first and second years of monitoring (at depth of 0-10 cm) and in the different plots (A, B, C and D and control plots).

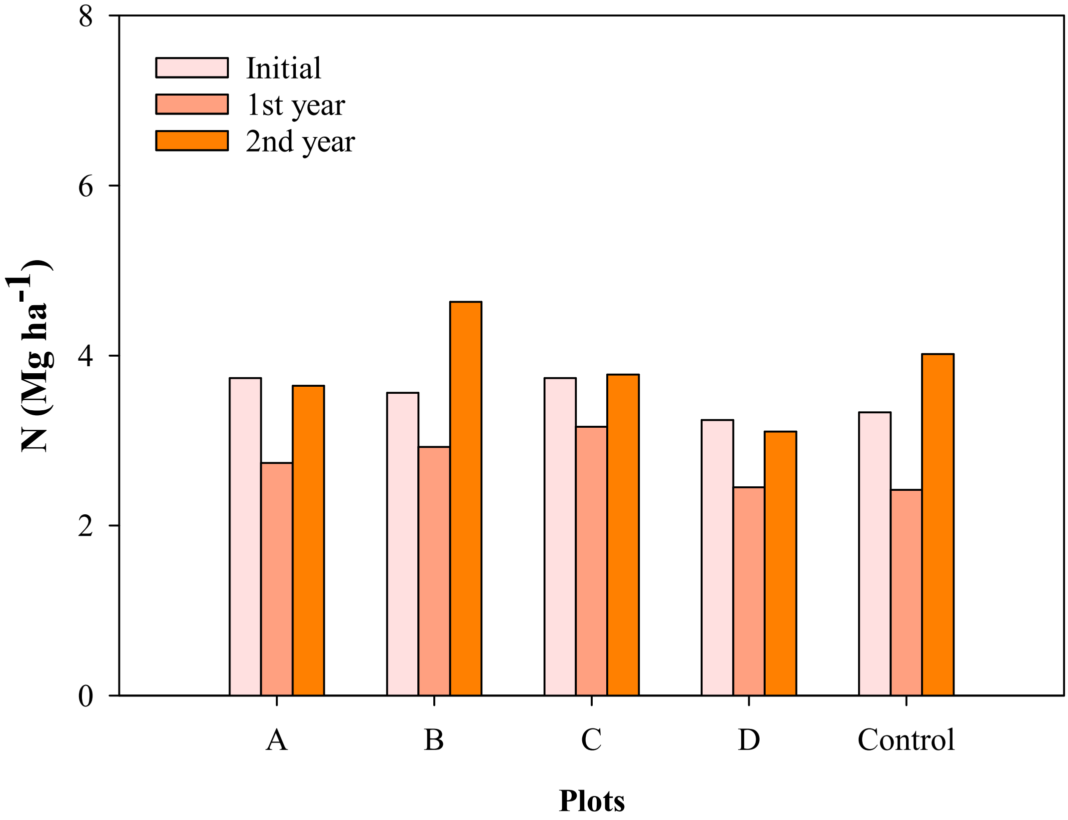


Figure 3. Nitrogen (N) stocks of soil samples for the initial conditions and first and second years of monitoring (at depth of 0-10 cm) and in the different plots (A, B, C and D and control plots).

Related to the Corg/N ratio (Table 4), a sharply increase is observed in all the plots during the first year and a moderate increase is observed at the end of the second year of monitoring considering the initial conditions.

Corg/N ratio (10 cm)	YEAR 0	YEAR 1	YEAR 2	Change 1 %	Change 2 %
A	12.2	20.0	*14.6*	*+ 63.6*	*+ 19.6*
B	11.4	19.7	*13.8*	*+ 72.4*	*+ 21.4*
C	11.1	17.2	*14.2*	*+ 54.2*	*+ 27.8*
D	10.9	27.1	*13.2*	*+ 148.0*	*+ 20.8*
CONTROL	10.4	26.4	*13.4*	*+ 152.9*	*+ 28.2*

Table 4. Corg/N ratios of soil samples for the initial conditions and first and second years of monitoring (at depth of 0-10 cm) and in the different plots (A, B, C and D and control plots).

3.1.2. Soil moisture

The sensor network installed to monitor the evolution of the water in the first 20 cm of the soil has been continuously recording since the installation. In the scrubland clearing pilot, the original network consisted of 2 dataloggers, one in the treatment subplots and another in the control subplot (see Figure 4).

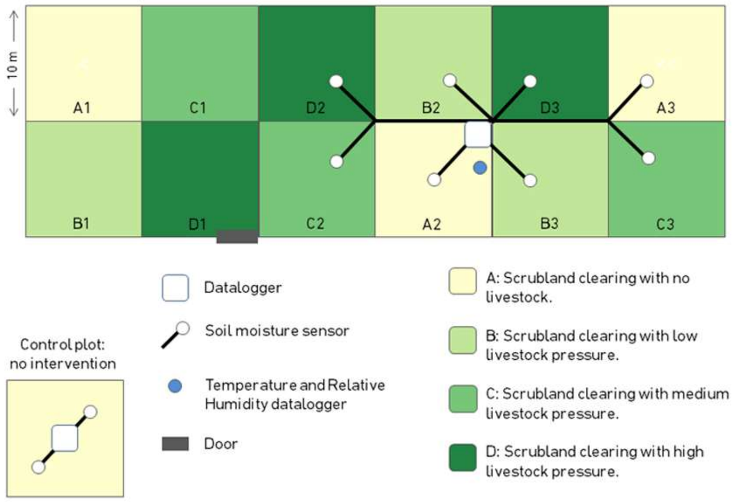


Figure 4. Original monitoring design of the livestock and monitoring subplots.

After finding several problems related to the connection between the probes and the extension cables (the fitted connectors were not as watertight as the manufacturer's instructions stated), it was decided that plots A3 and C3 would be connected directly to a HOBO micro station and the connectors of plots C2 and D2 would be covered with heat-shrink tubing to prevent the moisture. The current design (Figure 5) ensures that the datalogger does not run out of battery power, so that even if one probe stops logging data, the rest will continue measuring.

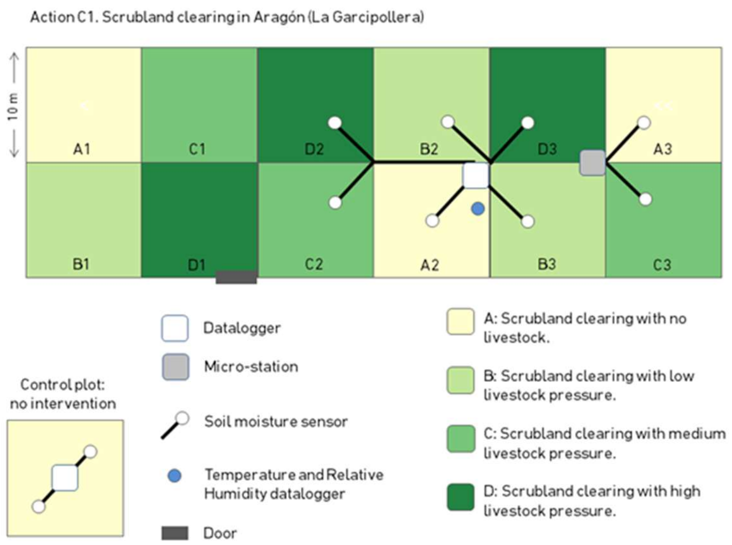


Figure 5. Diagram of the present livestock and monitoring subplots.

Figure 6 shows the soil moisture data recorded every hour by the probes installed in the control subplot and the mean of the replicates in the subplots with different treatments: A, No Livestock, and B-C-D with Low, Medium and High Livestock density, respectively. In addition, daily rainfall amount, recorded at the AEMET station located in Bescós de La Garcipollera is also included.

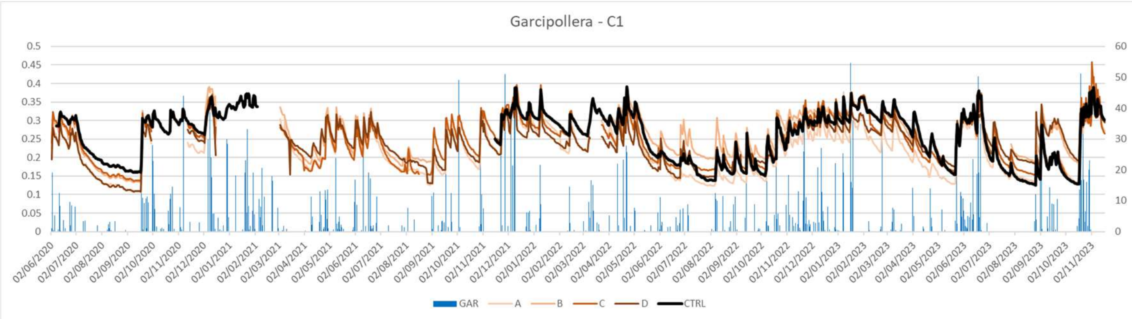
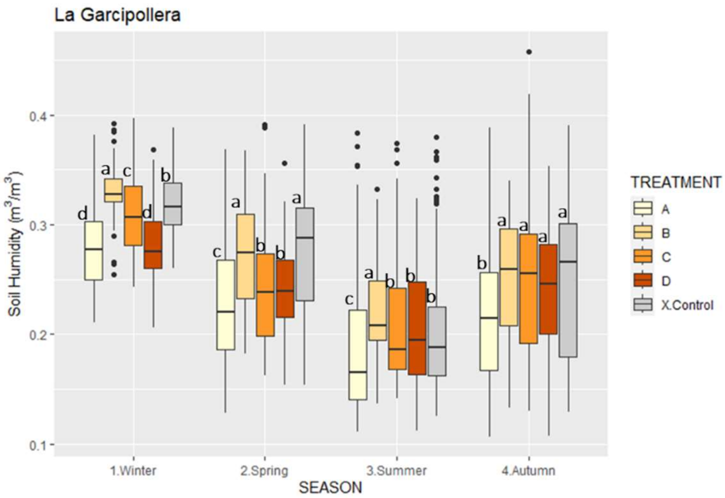


Figure 6. Soil humidity and precipitation in scrubland cleared experimental plot (La Garcipollera).

Figure 6 shows the good response of the probes to the recorded rainfall events: as expected higher values were observed after rainfall events. Differences can be observed between the different treatments.

Figure 7 shows seasonal soil moisture values of the different plots. Some preliminary results should be highlighted: (i) a high variability is observed in all the plots during the different seasons being higher in summer and autumn; (ii) in general, higher soil moisture values are recorded in the B (low livestock pressure) and control plots; (iii) in winter higher values are recorded in all the plots, and lower values are recorded in summer; and (iv) during the transition periods (autumn and spring) higher soil moisture values are recorded in the Control plot. Moreover, differences between plots are observed: (i) in winter between the B plot (Low livestock pressure) and control plot and the other management plots; (ii) in spring significant higher values were recorded in the control plot, and B plot; (iii) in summer the highest values were recorded in the B plot and the lowest values in the A plot; and (iv) in autumn differences were observed between the A plot (high livestock pressure) and the control plot (high soil moisture).



	Winter	Spring	Summer	Autumn
R^2	0.28	0.13	0.04	0.04
	$F_{4,935}$ = 92.7***	$F_{4,1171}$ = 46.6***	$F_{4,1666}$ = 21.2***	$F_{4,1384}$ = 13.8***
A	d	c	c	b
B	a	a	a	a
C	c	b	b	a
D	d	b	b	a
CTRL	b	a	b	a

Figure 7. Boxplot with seasonal soil humidity values in scrubland cleared experimental plot (La Garcipollera).

3.2. Monitoring results of the Pastures

The objective is to assess the effect of scrubland clearing and sheep grazing intensity on pasture service in terms of biodiversity, biomass production and nutritive quality. We hypothesize that scrubland clearing interacting with sheep grazing will help maintain biodiverse, productive, and highly nutritive herbaceous pastures. While species-rich pastures will contribute to their natural value and global biodiversity, the maintenance of their productivity and nutritive quality will enable to support extensive livestock activities in these areas, thus enhancing socio-economic development. Moreover, scrubland clearing and subsequent grazing by sheep will also restrain scrub encroachment, therefore diminishing the fire risk in these areas.

3.2.1. Biodiversity

Vegetation surveys were arranged within three subplots (1 m^2) at each of the three replicate plots per treatment: control area not cleared without livestock, cleared area without livestock grazing, cleared area with low level of grazing (once a year), cleared with medium level of grazing (twice a year) and cleared with high level of grazing (three times a year). Vegetation sampling was carried out once a year (between late spring and early summer) for 4 consecutive years to observe the evolution of the vegetation in the plots from the initial to the final stage (also evaluating the intermediate stage). The first sampling was done in June 2020 to record the initial stage of the pasture in the experimental plots prior to any livestock entry. Intermediate stage of the vegetation in the experimental plots was recorded in June 2021 (one year after the first sheep entrance) and in June 2022 (after having entered sheep two years in a row). Final stage of the pasture was recorded June 2023 (after having entered sheep three years in a row).

To assess the effects of scrubland clearing and sheep grazing on pasture biodiversity, the data evaluated were the cover and richness of herbaceous and woody species separately. We also assessed the effect of those factors on the bare soil cover. Regarding the scrubland clearing factor, we expected to find a positive effect of woody plant removal in the herbaceous pasture cover and richness in the first sampling because of the elimination of woody competitors for light, space, nutrients, and water. We expected this effect to be maintained over the years. On the other hand, regarding the sheep grazing levels (no grazing, low, medium, and high grazing), we expected not to find any effect of the livestock treatments in the first year since vegetation surveys were set prior to sheep entry in the plots. But we expected to find a positive effect of sheep grazing by promoting herbaceous species (both in cover and richness) and controlling the growth of woody species along the subsequent years (2021, 2022 and 2023). In particular, we expected the most positive effect on herbaceous species cover and richness in low and medium grazing levels and a more positive effect by controlling woody species growth in the high grazing level. Moreover, we expected the bare soil cover to be larger in plots with more frequent sheep entry than in those with no sheep entry and low and medium grazing.

As we expected, in the first year of monitoring, we found significant differences between the cleared and not cleared areas for the herbaceous and woody species cover, and this effect maintains along the years (Figure 8). Specifically, we found a larger woody species cover and lower herbaceous species cover in the control plots (not cleared) than in the cleared plots. Regarding livestock intensity, we found significant differences between treatments in some monitoring years. About herbaceous species cover, in 2020 we did not find significant differences between treatments, in 2021 the significantly largest cover was found in the medium grazing, in 2022 we found larger cover in ungrazed, low grazing and medium grazing than in high grazing, and in 2023 we did not find significant differences between treatments. For the woody species cover, in 2021 we did not find significant differences between treatments, in 2022 we found the lowest cover in medium and high grazing and in 2023 we found lower cover in all the grazing levels with no difference between them. The bare soil cover was the largest in the plots submitted to the highest grazing frequency (three times a year), especially after two and three years of sheep entry.

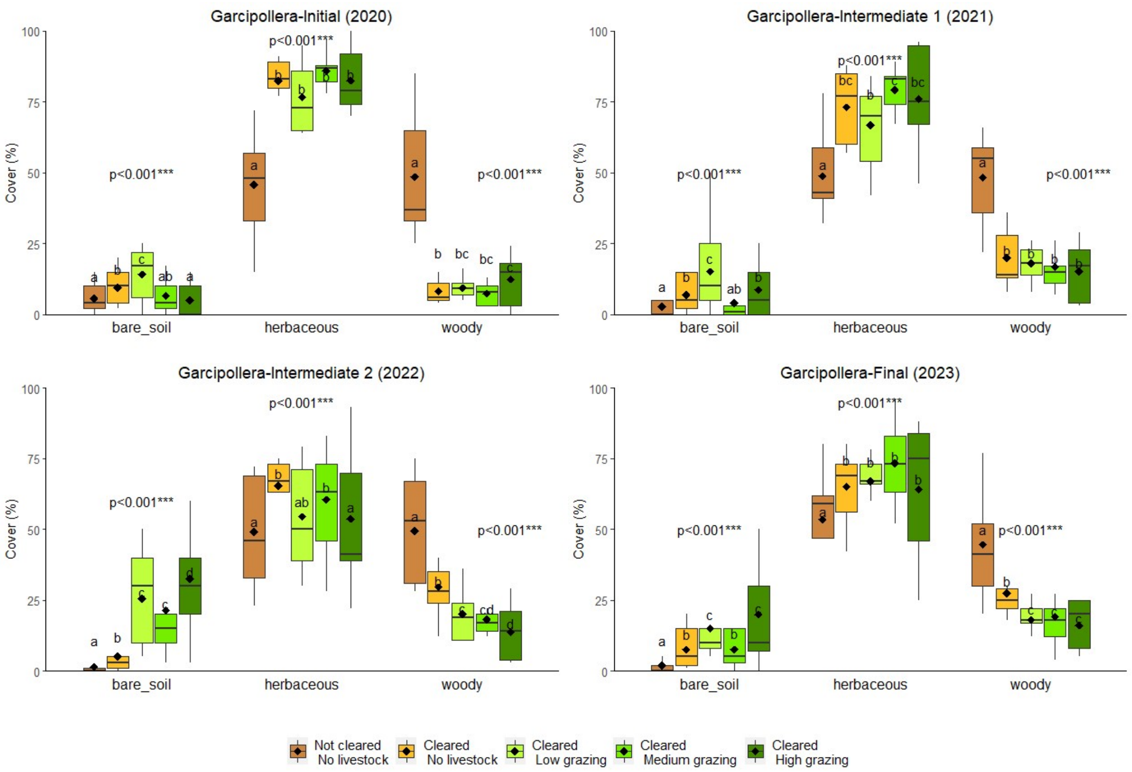


Figure 8. Boxplots showing mean cover and data variability of the bare soil, herbaceous species and woody species separately in each treatment (not cleared without livestock, cleared without livestock, cleared with low level of grazing, cleared with medium level of grazing and cleared with high level of grazing). Initial, intermediate, and final stages of the experimental plots are shown.

Regarding the scrubland clearing effect along the monitoring years, we found significant higher richness in herbaceous species between the control treatment and the cleared plots after 3 years of treatment, but no significant differences in woody species richness (Figure 9). Regarding livestock intensity, we did not find significant differences between treatments neither for herbaceous species nor for woody species.

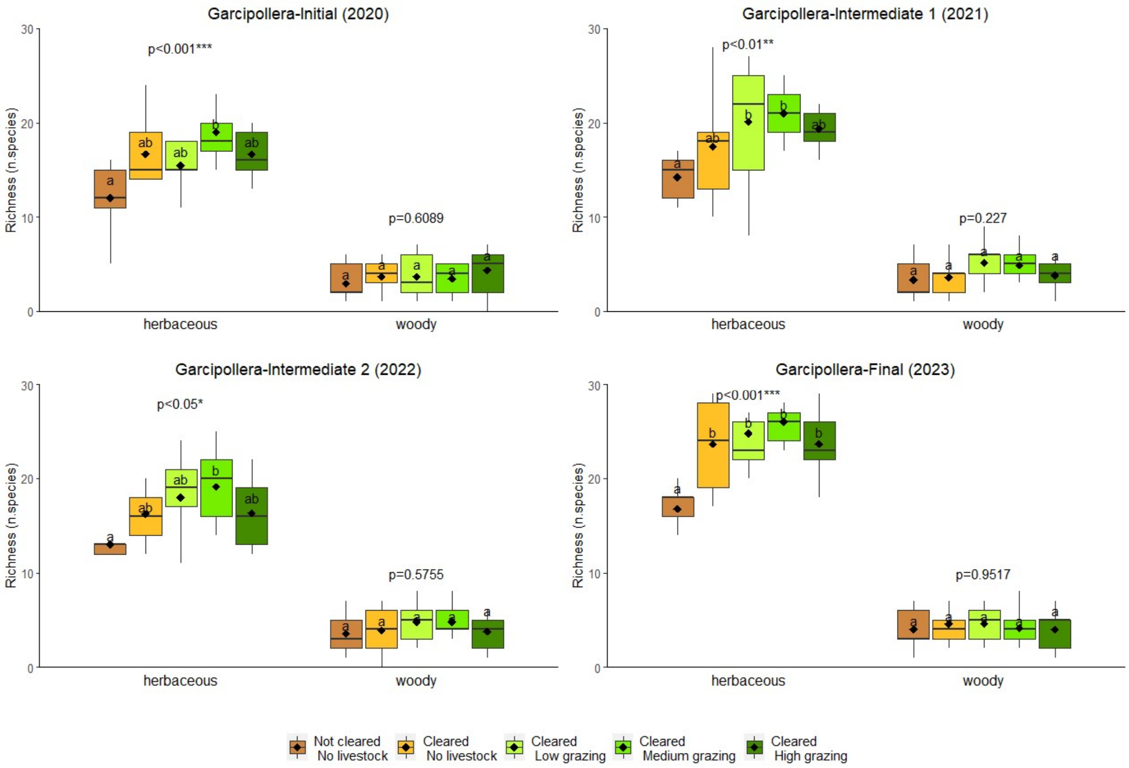


Figure 9. Boxplots showing mean species richness for herbaceous species and woody species separately in each treatment (not cleared without livestock, cleared without livestock, cleared with low level of grazing, cleared with medium level of grazing, and cleared with high level of grazing). Initial, intermediate, and final stages of the experimental plots are shown.

3.2.2. Pasture production and quality

To assess pasture production and nutritive quality we harvested the plants growing within three subplots (0.25 m^2) at each of the three replicate plots per treatment: control area not cleared without livestock, cleared area without livestock, cleared area with low level of grazing (once a year), cleared with medium level of grazing (twice a year) and cleared with high level of grazing (three times a year). Samples were collected between late spring and early summer (matching the vegetation growth peak) at the initial and final stage of the experiment. The first sampling was done in June 2020 to record the initial stage of the pasture in the experimental plots prior to any livestock entry and second sampling was done in June 2023 to record the final stage of the pasture after having entered sheep three years in a row. We considered that recording the intermediate stage of the pastures in terms of production and quality was not relevant because it is a short period of time to achieve significant results.

To assess the effects of scrubland clearing and sheep grazing on pasture production, we considered dry biomass (kg/ha) of the gathered herbaceous plants. The nutritive quality of pastures was evaluated in terms of the content of digestible fibers (Relative Feed Value) and crude protein (estimated in laboratory from the dry matter derived from the collected herbaceous samples).

Regarding the scrubland clearing factor, we expected to find a positive effect of woody plant removal in the herbaceous plants' biomass and quality because of the elimination of woody competitors for light, space, nutrients and water. We expected to find this effect both in the first and final samplings. On the other hand, regarding the sheep grazing levels (no grazing, low, medium and high grazing), we expected not to find any effect of the livestock treatments in the first year since samples were collected prior to sheep entry in the plots. But we expected to find a positive effect of sheep grazing by promoting the growth and nutritive quality of herbaceous species in the final stage. In particular, we expected the most positive effect on herbaceous biomass production and nutritive quality in medium grazing levels.

Regarding the scrubland clearing effect, we found a significantly larger herbaceous species biomass in the cleared plots than in the control plots in both the initial and final monitoring years (Figure 10). Regarding the grazing treatments, we found the largest herbaceous biomass in the plots with no sheep entry and the lowest herbaceous biomass in low and high grazing treatments.

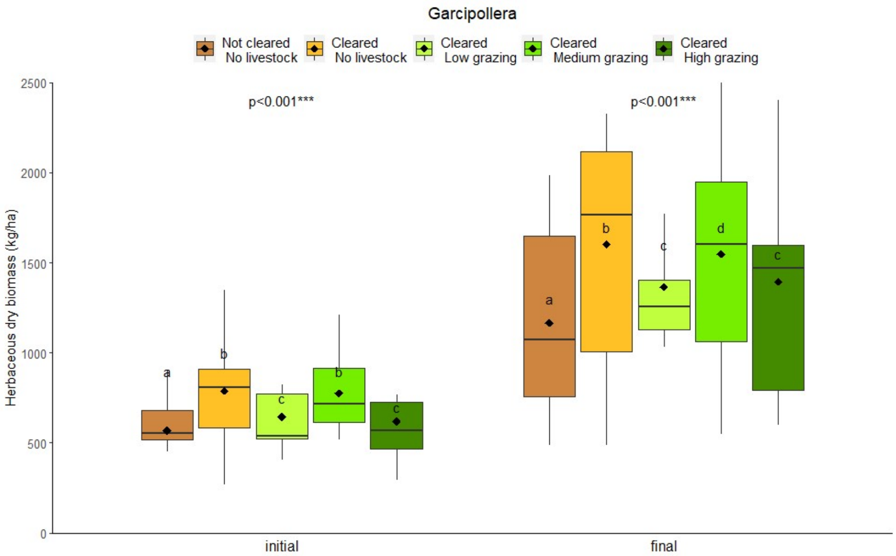


Figure 10. Boxplots showing mean herbaceous dry biomass in each treatment (not cleared without livestock, cleared without livestock, cleared with low level of grazing, cleared with medium level of grazing, and cleared with high level of grazing). Initial and final stages of the experimental plots are shown.

The nutritional quality of the grass harvested this June 2023 is in the process of laboratory analysis, having available only the data of the initial stage, so these data are not shown.

3.3. Monitoring results of 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 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 carried out rainfall simulation experiments in all monitoring subplots. Here we present the results of three years of monitoring (2020, 2021, 2022). The experiments were always carried out in winter, after the livestock grazed for the third time within the year. A detailed description of the rainfall simulations experiments is described in Nadal-Romero et al., 2020 (Deliverable 8). Although three experiments were performed per treatment (3 replicas) at each campaign, some results had to be removed because they seemed incorrect (e.g., Runoff Coefficient > 1). This can be due to problems in either the rainfall simulation experiment (e.g., the circular ring is not correctly fixed in the ground) or the post processing of the water samples.

In Garcipollera, the hydrological response (RC) was higher in the treated plots than in the control (shrubs) plot, except for treatment B, which had very low values of RC. This could be due to the lower slope of the B plots. The results suggest that medium and high grazing level tend to produce more runoff than low and no grazing. Shrubs recorded the lowest rate of infiltration. The lower values of RC and INF in shrubs could be explained by its higher interception capacity. No clear differences in INF were observed between the plots with different treatment.

The grazed plots showed higher sediment concentration, but no clear differences were observed between the different levels of grazing. However, the erosion rate was higher in the medium and high level of grazing.

Site	Land management	Slope (%)	RI (mm h^{-1})	INF (mm h^{-1})	RC (-)	SC (g L^{-1})	SP (g m^{-2})
Garcipollera	Cleared without livestock (A)	16	42.9	36.4	0.12	0.64	0.92
	Cleared with low pressure (B)	13	58.8	33.8	0.05	3.57	2.58
	Cleared with medium pressure (C)	16	62.1	33.2	0.26	3.87	8.26
	Cleared with high pressure (D)	17	48.5	36.8	0.18	3.09	6.98
	Control	17	51.1	30.0	0.07	0.59	1.44

Table 5. Mean hydrogeological and sedimentological variables extracted from rainfall simulations in Garcipollera (2020, 2021, 2022). RI: rainfall intensity (mm h-1), INF: infiltration rate (mm h-1), RC: Runoff coefficient (mm mm-1), SC: Sediment concentration (g l-1), SP: Sediment production or erosion rate (g m-2). Not cleared without livestock (control), cleared without livestock (A), cleared with low level of grazing (B), cleared with medium level of grazing (C), and cleared with high level of grazing (D).

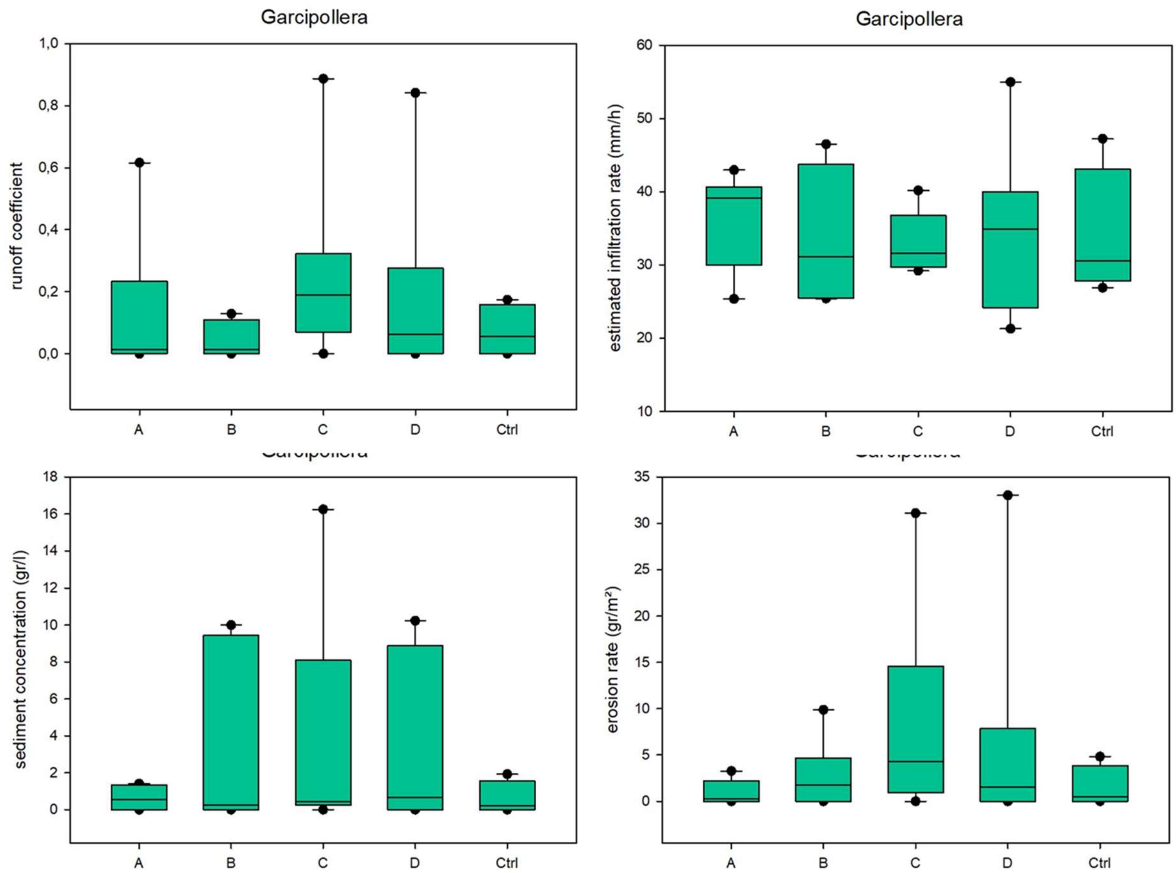


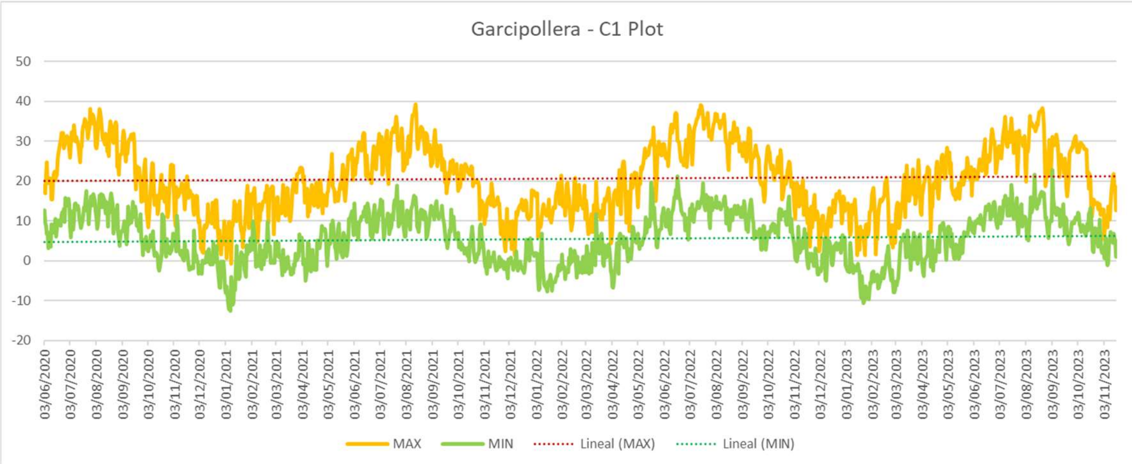
Figure 11. Runoff coefficient (mm mm^{-1}), Infiltration rate (mm h^{-1}), Sediment concentration (g l^{-1}) and erosion rate (g/m^2) in Garcipollera (2020, 2021, 2022): not cleared without livestock (control), cleared without livestock (A), cleared with low level of grazing (B), cleared with medium level of grazing (C), and cleared with high level of grazing (D).

3.4. 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 pluviometers or weather stations to record in continuum these meteorological variables.

Meteorological conditions are being recorded continuously since 03-06-2020. Two Temperature/Relative Humidity sensors were installed, one in the experimental plots (T1) and the other one, under a tree closed to the experimental plots (T2). In this case, it has not been necessary to install a rain gauge because we have the data recorded by the 9200 station of the State Meteorological Agency located in Bescós de la Garcipollera, which is located in the experimental farm of La Garcipollera, closed to the experimental plots.

In this period, until 15-11-2023, the maximum temperature has been 39.6 and 37.6 ºC for Tplot and Tplot (under tree) respectively (14-08-21 and 13-08-2021), and the minimum -11.3 and -12.6 ºC for Tplot and Tplot (under tree) respectively (08-01-2021) (see Figure 12 for more details). A trend line has been included in this deliverable and a detailed trend analysis will be made in the final deliverable about action C1 with data collected in the first months of 2024.



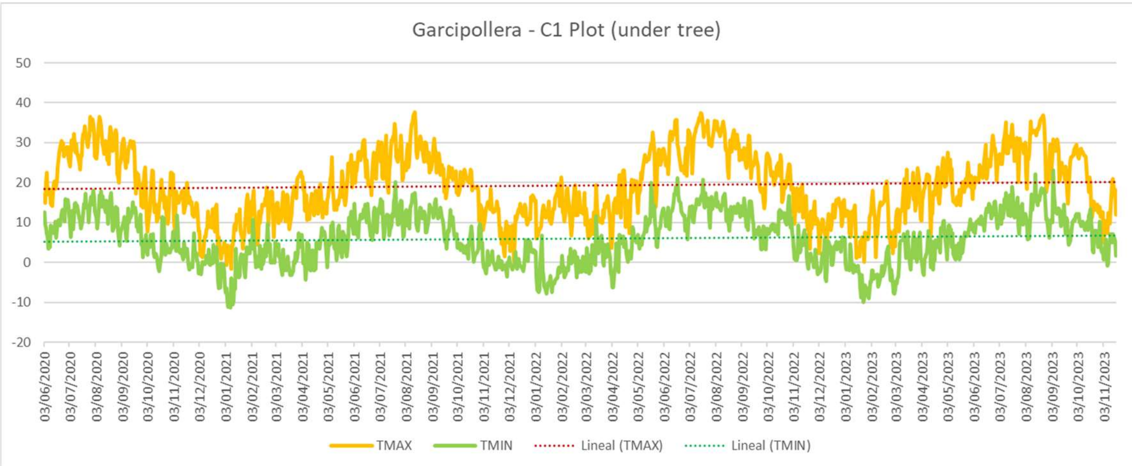


Figure 12. Daily average of minimum and maximum temperature and relative humidity in scrubland cleared experimental plots located in La Garcipollera.

Figure 13 shows monthly averages of maximum temperature, minimum temperature and mean monthly precipitation for the period 06-2020 to 11-2023 (41 months) recorded in the experimental plots located in La Garcipollera. It should be highlighted the low precipitation values recorded in March: in fact, on the Iberian Peninsula, the average value barely reached 30.5 mm, compared to the 47 mm of the average value for the reference period (1981-2010). High precipitation values were recorded in December and October, and a dry period was observed in summer months (July and August). Throughout the project, the data recorded in this, and the other stations will be compared with studies carried out on a regional scale, in order to contextualise our results, and will be used to establish relationships between other environmental variables (biodiversity, pasture production, soil moisture…) and meteorological conditions.

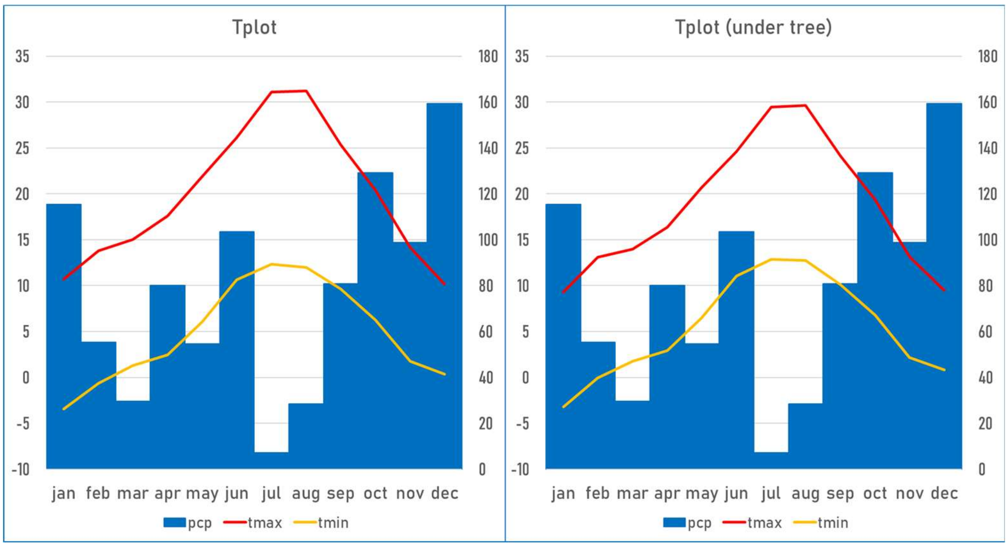


Figure 13. Climogram scrubland cleared experimental plot. Left: T in the subplot, right: T under a tree near the subplot.

4. Results of the 1st, 2nd and 3rd monitoring campaign in San Román, La Rioja

The pilot experience has been implemented in the Leza Valley (Iberian System, Spain) in a scrubland clearing area. This chapter includes the results of the 1st, 2nd and 3rd monitoring campaigns in San Román.

We include a summary of the implemented pilot experience and the experimental design of the monitoring network, to facilitate the understanding of the monitoring results. A more detailed description of the implemented actions can be consulted in Nadal-Romero *et al.* (2019, 2020a, 2020b).

The initial sampling of the monitoring variables was carried out in June 2020 and the monitoring campaigns were carried out in November 2021, 2022, and 2023, once the animals entered three times in the experimental plots (spring, summer and autumn). In winter 2021-2022 and 2022-2023, during the 1st- and 2nd-year campaigns, superficial soil samples (0-10 cm) have been taken to analyse the changes in carbon and nitrogen. In this deliverable, we present the results of 2021, 2022 and 2023.

Implemented pilot experience:

- Adaptive scrubland management of abandoned fields in 0.77 ha plot consisting in scrubland clearing.
- Control plot: An area with no actuation of 100 m^2.

Monitoring network:

- Four typologies of monitoring subplots (surface of 100 m^2):
  - control subplots, without neither scrubland clearing activities nor the entry of livestock.
  - managed subplots with different livestock density:
    - A no livestock,
    - B low pressure,
    - C medium pressure
    - D high pressure.
  - For each of monitoring subplots, three replicates were selected, except in the control area where there was only space for two replicates.

The monitoring network includes twelve monitoring managed subplots of 100 m^2, and two subplots in the control area.

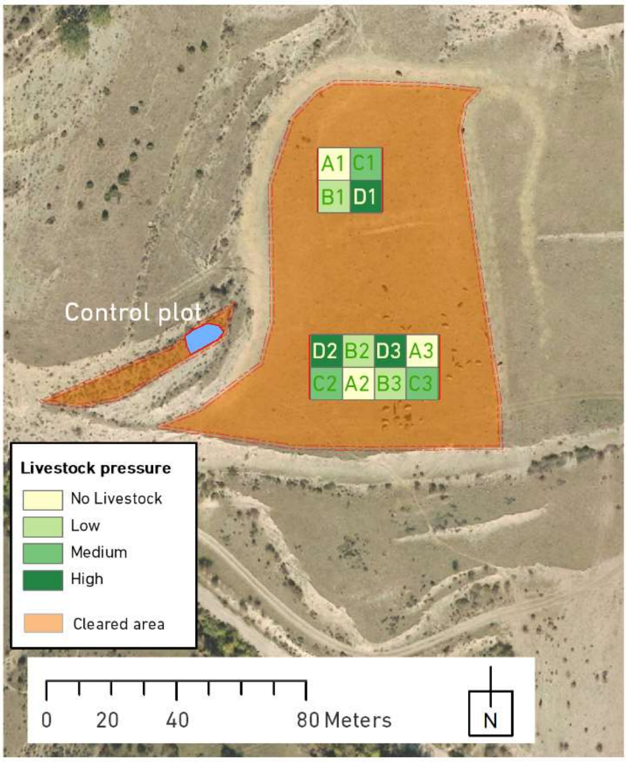


Figure 14. Location of the monitoring plots and replicates of the experimental design.

4.1. Monitoring results of the Soil

4.1.1. Soil characteristics

The initial sampling of the monitoring variables was carried out in June 2020 and the first- year and second year monitoring campaigns were carried out in November 2021 and November 2022 once the animals entered three times in the experimental plots (spring, summer, and autumn 2021 and 2022). In winter 2023-2024, during the third year monitoring campaign, soil samples (0-40 cm) are being again taken to analyse the changes in carbon and nitrogen content and stocks in the complete soil profile. In this deliverable, we present the results of the 2021 and 2022 campaigns (the last results about soil properties will be presented in the final deliverable).

At each monitoring subplot, three soil subsamples were sampled in a depth of 0-10 cm. In each site, 45 points were selected, and subsamples were recorded and later combined into one soil composite sample per plot and depth (0-10 cm). In total 15 composite samples were created in San Román.

The samples have been analysed by the Pyrenean Institute of Ecology (IPE-CSIC), evaluating the following soil variables: total carbon concentration (Ctotal), total nitrogen concentration (N), organic matter (OM), bulk density (BD), and soil organic carbon (SOC). It should be noted, that during this year the calculation to determine SOC and N stocks have been slightly modified, and consequently some data may differ from previous deliverables.

The following tables present the mean values at the initial conditions, after the first and second years of monitoring, and the change occurred in percentage for the main variables (0-10 cm) measured in the experimental plots during the 2021 and 2022 monitoring campaigns in San Román. Statistical results did not show significant differences between the management plots and the control plots at the second year of monitoring, neither between the initial conditions and the present values. Some changes could be highlighted. Related to SOC values (Table 6 and Figure 15) (i) lower SOCK stocks are observed after the first and second monitoring years in all the plots; (ii) the higher decreases in SOC stocks are observed in A and B plots (no and low livestock pressure); and (iii) higher SOC values are observed in the C and control plots (medium livestock pressure).

SOC Mg ha^{-1} (10 cm)	YEAR 0	YEAR 1	YEAR 2	Change 1 %	Change 2 %
A	69.9	65.5	48.4	*- 6.4*	*- 30.8*
B	70.1	53.5	47.3	*- 23.7*	*- 32.5*
C	74.0	58.1	54.2	*- 21.5*	*- 26.8*
D	52.8	52.4	47.1	*- 0.9*	*- 10.9*
CONTROL	66.5	48.9	53.6	*- 26.5*	*- 19.3*

Table 6. Soil organic carbon (SOC) stocks of soil samples for the initial conditions and first and second years of monitoring (at depth of 0-10 cm) and in the different plots (A, B, C and D and control plots).

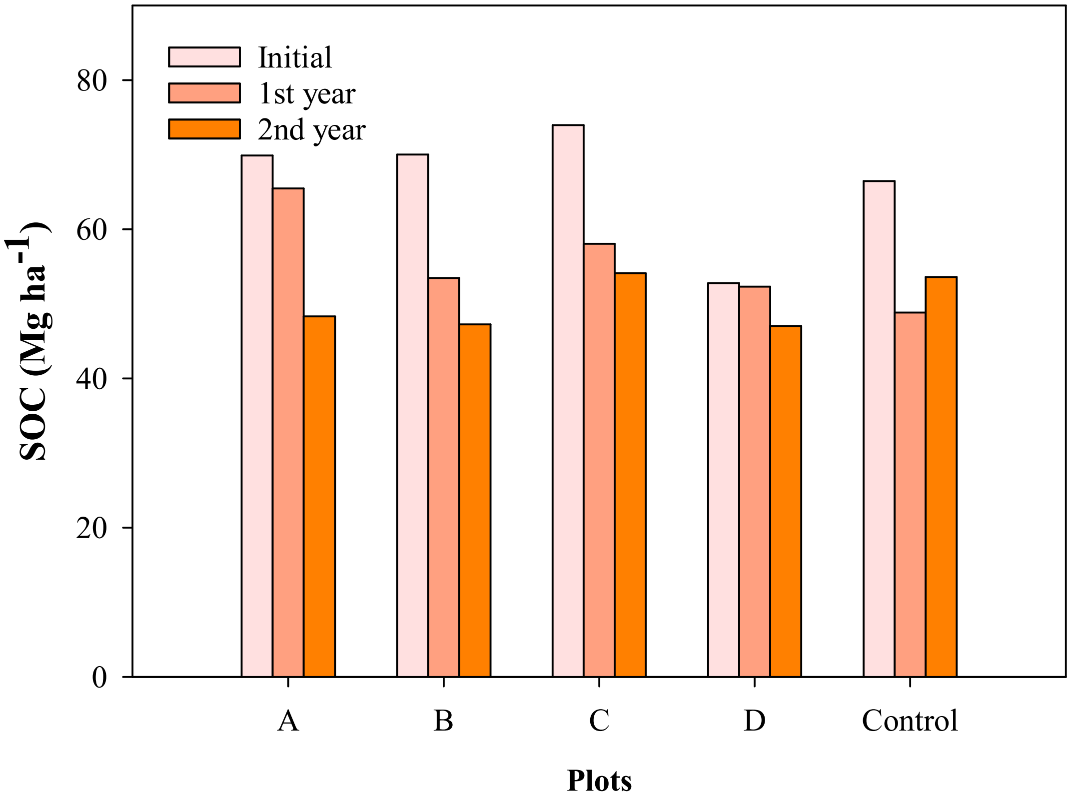


Figure 15. Soil organic carbon (SOC) stocks of soil samples for the initial conditions and first and second years of monitoring (at depth of 0-10 cm) and in the different plots (A, B, C and D and control plots).

Related to N stocks (Table 7 and Figure 16): (i) all the plots show a decrease in N stocks; and (ii) a higher decrease is observed in the B and control plots.

N Mg ha^{-1} (10 cm)	YEAR 0	YEAR 1	YEAR 2	Change 1 %	Change 2 %
A	5.6	4.2	3.1	- 25.6	- 59.4
B	5.6	3.0	3.1	- 47.6	- 85.1
C	5.5	3.3	3.4	- 40.0	- 63.3
D	4.5	3.3	3.2	- 28.2	- 41.0
CONTROL	4.3	2.1	2.6	- 53.1	- 88.1

Table 7. Nitrogen (N) stocks of soil samples for the initial conditions and first and second years of monitoring (at depth of 0-10 cm) and in the different plots (A, B, C and D and control plots).

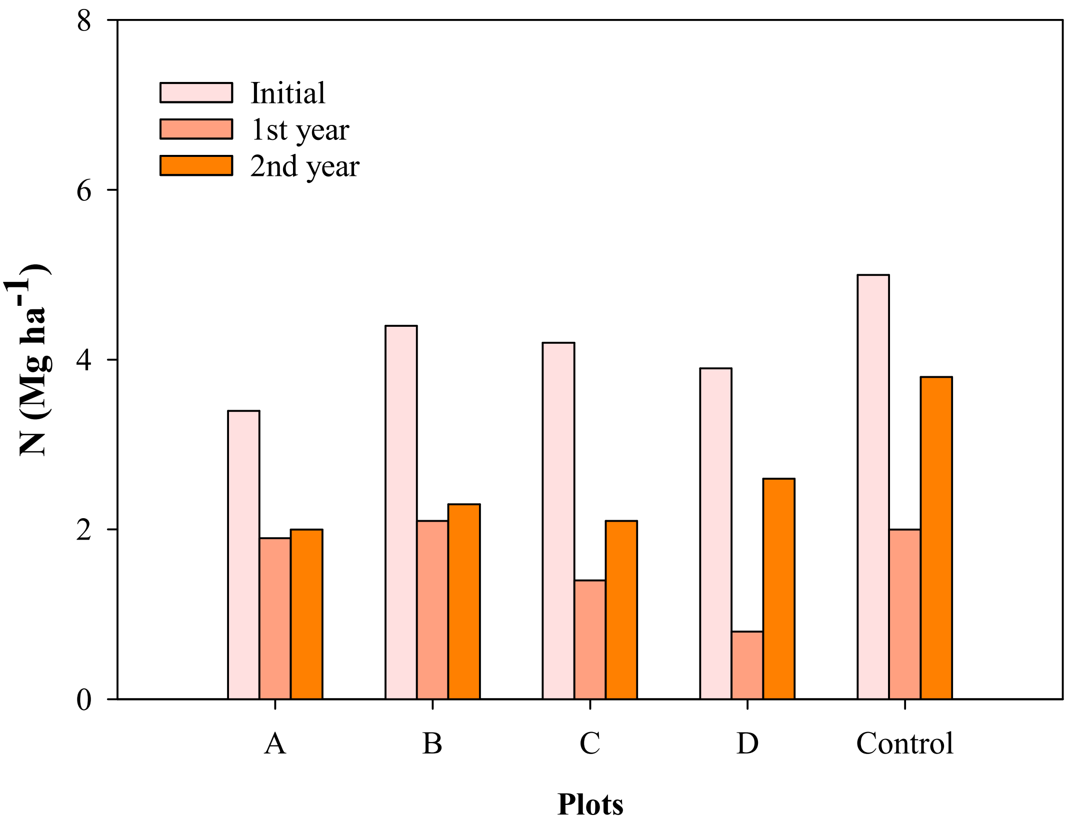


Figure 16. Nitrogen (N) stocks of soil samples for the initial conditions and first and second years of monitoring (at depth of 0-10 cm) and in the different plots (A, B, C and D and control plots).

Related to the Corg/N ratio (Table 8): (i) an increase is observed in all the plots; and (ii) the higher increase is observed in the D plots.

Corg/N ratio (10 cm)	YEAR 0	YEAR 1	YEAR 2	Change 1 %	Change 2 %
A	12.4	16.1	15.5	*+ 29.5*	*+ 25.0*
B	12.4	18.1	15.3	*+45.8*	*+ 23.0*
C	13.6	17.9	17.3	*+ 32.1*	*+ 27.3*
D	11.6	25.9	21.4	*+ 123.3*	*+ 83.9*
CONTROL	15.2	25.9	21.4	*+ 70.9*	*+ 40.8*

Table 8. Corg/N ratios of soil samples for the initial conditions and first and second years of monitoring (at depth of 0-10 cm) and in the different plots (A, B, C and D and control plots).

4.1.2. Soil moisture

The sensor network installed to monitor the evolution of the water in the first 20 cm of the soil has been continuously recording since the installation, excepting some gaps explained below. In the scrubland clearing pilot, the original network consisted of 2 dataloggers, one in the treatment subplots and another in the control subplot (see Figure 17). In this case and as was mentioned in Nadal-Romero *et al.* (2021), there were also problems with the connectivity between the probes and the extension cables (producing some gaps in the temporal database). The connectors were replaced and sealed with silicone and a proprietary coating system, but in April 2022 the connectors for plots D2, C2, A3 and C3 failed again. So, in September 2022 (15-09-2022) two microstations were installed for these plots as is shown in Figure 18.

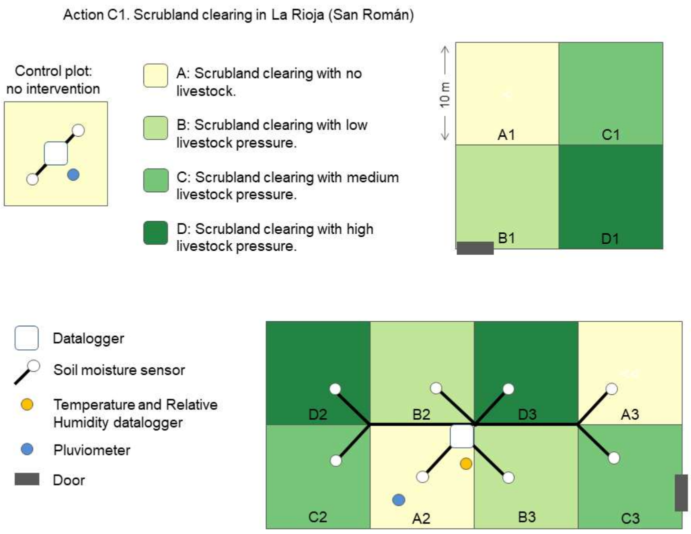


Figure 17. Original monitoring design of the livestock and monitoring subplots.

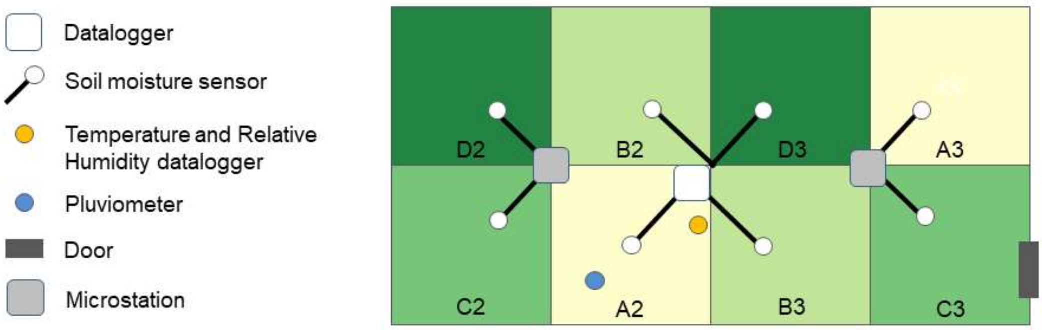


Figure 18. New monitoring design of the livestock and monitoring subplots.

Figure 19 shows the soil moisture data recorded every hour by the probes installed in the control subplot and the mean values recorded in the replicates in the subplots with different treatments: A, No Livestock and B-C-D with Low, Medium and High Livestock density, respectively, and the rainfall, recorded at a rain gauge station installed in the experimental plot. The figure shows the good response of the probes to the recorded rainfall events: as expected higher values were observed during and after rainfall periods and individual rainfall events. The installed rain gauge was knocked down, possibly by a windstorm. For this reason, there is no data for the events in autumn 2021 and the most part of 2022 in which several peaks in soil moisture were observed. At the end of the project, a data-filling protocol will be developed to improve this variable and complete the dataset. Differences can be observed between the different treatments, especially during dry periods (see Figure 20).

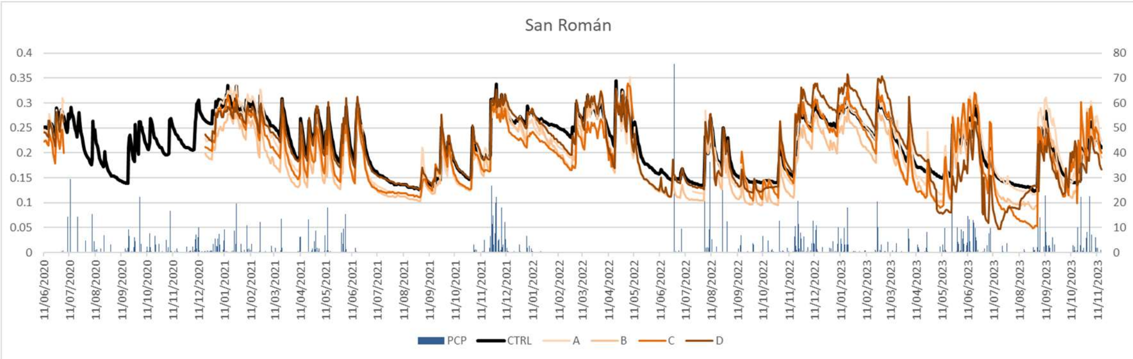
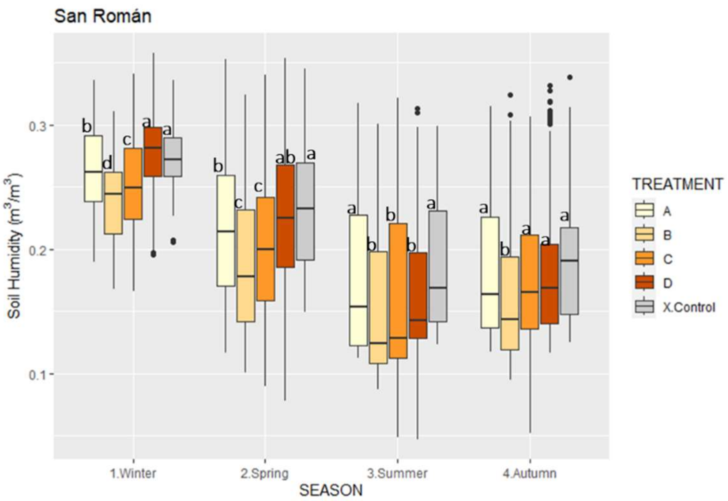


Figure 19. Soil humidity and precipitation in scrubland cleared experimental plot (San Román).



	Winter	Spring	Summer	Autumn
R^2	0.17	0.06	0.05	0.04
	$F_{4,1273}$ = 64.7***	$F_{4,1335}$ = 23.2***	$F_{4,1411}$ = 20.0***	$F_{4,1367}$ = 13.9***
A	b	b	a	a
B	d	c	b	b
C	c	c	b	a
D	a	ab	b	a
CTRL	a	a	a	a

Figure 20. Boxplot with seasonal soil humidity values in scrubland cleared experimental plot (San Román).

Figure 20 shows seasonal soil moisture values of the different plots. Some preliminary results should be highlighted: (i) a high variability is observed in all the plots during the different seasons being higher in spring, summer and autumn; (ii) in general, higher soil moisture values are recorded in the control plots; (iii) in winter higher mean values are recorded in all the plots, and lower values are recorded in summer; and (iv) during the transition periods (autumn and spring) higher soil moisture values are recorded in the Control plot. Besides, seasonal differences were observed between the plots: (i) in winter higher moisture values were recorded in the control plots, followed by A and D plots and lower values were recorded in B and C plots; (ii) in spring and summer higher values were recorded in the control plots and the lowest values in the B plots; finally, (iii) in autumn the highest values were recorded in the control plot, and the lowest values in the B and C plots.

4.2. Monitoring results of the Pastures

The objective is to assess the effect of scrubland clearing and sheep grazing intensity on pasture service in terms of biodiversity, biomass production and nutritive quality. We hypothesize that scrubland clearing interacting with sheep grazing will help maintain biodiverse, productive, and highly nutritive herbaceous pastures. While species rich pastures will contribute to their natural value and global biodiversity, the maintenance of their productivity and nutritive quality will enable to support extensive livestock activities in these areas, thus enhancing socio-economic development. Moreover, scrubland clearing and subsequent grazing by sheep will also restrain scrub encroachment, therefore diminishing the fire risk in these areas.

4.2.1. Biodiversity

Vegetation surveys were arranged within three subplots (1 m^2) at each of the three replicate plots per treatment: control area not cleared without livestock, cleared area without livestock, cleared area with low level of grazing (once a year), cleared with medium level of grazing (twice a year) and cleared with high level of grazing (three times a year). Vegetation sampling was carried out once a year (between late spring and early summer) for 4 consecutive years to observe the evolution of the vegetation in the plots from the initial to the final stage (also evaluating the intermediate stage). The first sampling was done in May 2020 to record the initial stage of the pasture in the experimental plots prior to any livestock entry. Intermediate stage of the vegetation in the experimental plots was recorded in May 2022 (after having entered sheep two years in a row). Final stage of the pasture was recorded May 2023 (after having entered sheep three years in a row).

To assess the effects of scrubland clearing and sheep grazing on pasture biodiversity, the data evaluated were the cover and richness of herbaceous and woody species separately. We also assessed the effect of those factors on the bare soil cover. Regarding the scrubland clearing factor, we expected to find a positive effect of woody plant removal in the herbaceous pasture cover and richness in the first sampling because of the elimination of woody competitors for light, space, nutrients, and water. We expected this effect to be maintained over the years. On the other hand, regarding the sheep grazing levels (no grazing, low, medium, and high grazing), we expected not to find any effect of the livestock treatments in the first year since vegetation surveys were set prior to sheep entry in the plots. But we expected to find a positive effect of sheep grazing by promoting the growth of herbaceous species (both in cover and richness) and controlling the growth of woody species along the subsequent years (2022 and 2023). In particular, we expected the most positive effect on herbaceous species cover and richness in low and medium grazing levels and a more positive effect by controlling woody species growth in the high grazing level. Moreover, we expected the bare soil cover to be larger in plots with more frequent sheep entry than in those with no sheep entry and low and medium grazing.

As expected, we found significantly lower herbaceous species and larger woody species in the control plots than in the cleared plots. This effect maintains over the years (Figure 21). Regarding livestock effects, we did not find significant differences in herbaceous species cover between the grazing levels neither in the first monitoring nor in the final monitoring, but we found significantly higher herbaceous species cover in low and high grazing than in plots ungrazed in the intermediate monitoring. We found a significant positive effect of sheep grazing by controlling woody species cover (lower woody species cover was found in all the grazed plots than in the ungrazed plots). The bare soil cover was very low, but we found the higher bare soil cover in all the plots submitted to sheep grazing in the final monitoring year.

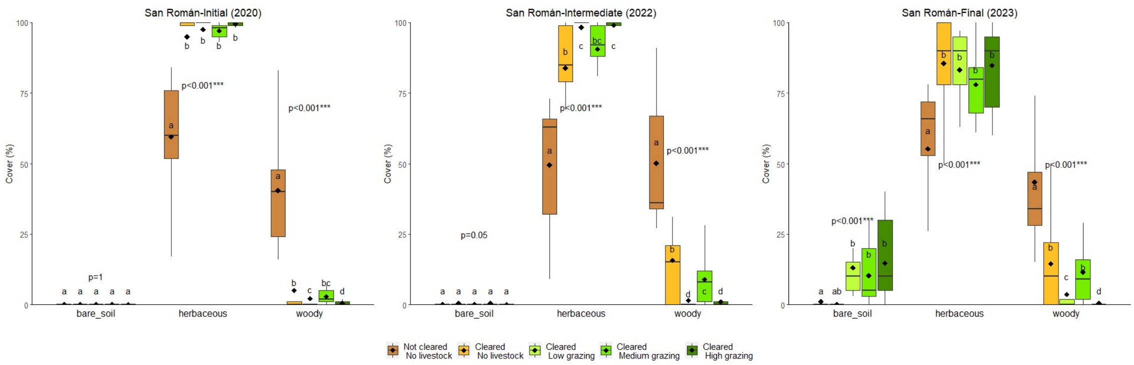


Figure 21. Boxplots showing mean cover and data variability of the bare soil, herbaceous species and woody species separately in each treatment (not cleared without livestock, cleared without livestock, cleared with low level of grazing, cleared with medium level of grazing and cleared with high level of grazing). Initial, intermediate, and final stages of the experimental plots are shown.

Considering species richness, we found significant differences between control and cleared plots, being in some cases cleared plots more rich in herbaceous species than the control plot, and in all the cases cleared plots less rich in woody species than the control plot (Figure 22). We did not find significant differences between livestock treatments for woody species richness but in the intermediate and final monitoring years we found larger herbaceous species richness in plots submitted to low, medium, and high grazing than in plots ungrazed.

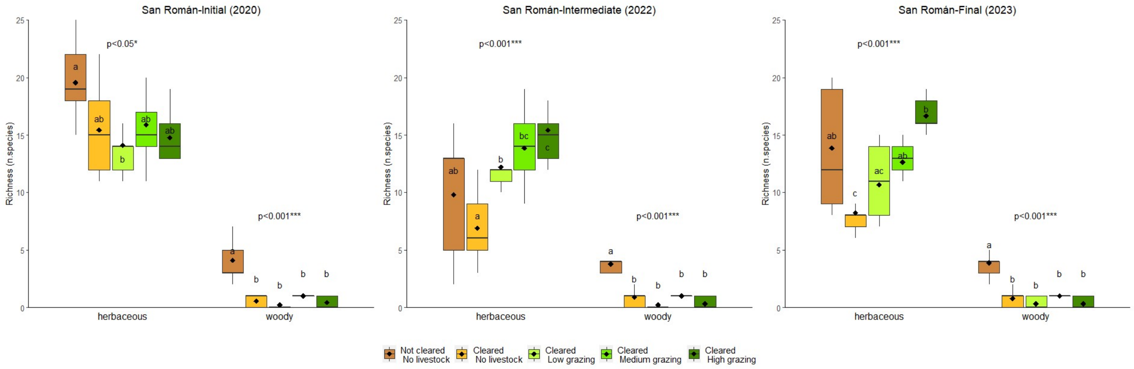


Figure 22. Boxplots showing mean species richness for herbaceous species and woody species separately in each treatment (not cleared without livestock, cleared without livestock, cleared with low level of grazing, cleared with medium level of grazing, and cleared with high level of grazing). Initial, intermediate, and final stages of the experimental plots are shown.

4.2.2. Pasture production and quality

To assess pasture production and nutritive quality we harvested the plants growing within three subplots (0.25 m^2) at each of the three replicate plots per treatment: control area not cleared without livestock, cleared area without livestock, cleared area with low level of grazing (once a year), cleared with medium level of grazing (twice a year) and cleared with high level of grazing (three times a year). Samples were collected between late spring and early summer (matching the vegetation growth peak) at the initial and final stage of the experiment. The first sampling was done in May 2020 to record the initial stage of the pasture in the experimental plots prior to any livestock entry and second sampling was done in May 2023 to record the final stage of the pasture after having entered sheep three years in a row. We considered that recording the intermediate stage of the pastures in terms of production and quality was not relevant because it is a short period of time to achieve significant results.

To assess the effects of scrubland clearing and sheep grazing on pasture production, we considered dry biomass (kg/ha) of the gathered herbaceous plants. The nutritive quality of pastures was evaluated in terms of the content of digestible fibers (Relative Feed Value) and crude protein (estimated in laboratory from the dry matter derived from the collected herbaceous samples).

Regarding the scrubland clearing factor, we expected to find a positive effect of woody plant removal in the herbaceous plants biomass and quality because of the elimination of woody competitors for light, space, nutrients and water. We expected to find this effect both in the first and final samplings. On the other hand, regarding the sheep grazing levels (no grazing, low, medium and high grazing), we expected not to find any effect of the livestock treatments in the first year since samples were collected prior to sheep entry in the plots. But we expected to find a positive effect of sheep grazing by promoting the growth and nutritive quality of herbaceous species in the final stage. In particular, we expected the most positive effect on herbaceous biomass production and nutritive quality in medium grazing levels.

We found a significantly higher herbaceous plant production in the scrubland clearing plots than in the control plots for both the initial and final monitoring year (Figure 23). We also found significant differences in herbaceous biomass between the livestock treatments in the final monitoring year. Specifically, we found the highest herbaceous biomass in plots ungrazed and the lowest herbaceous biomass in plots submitted to high grazing.

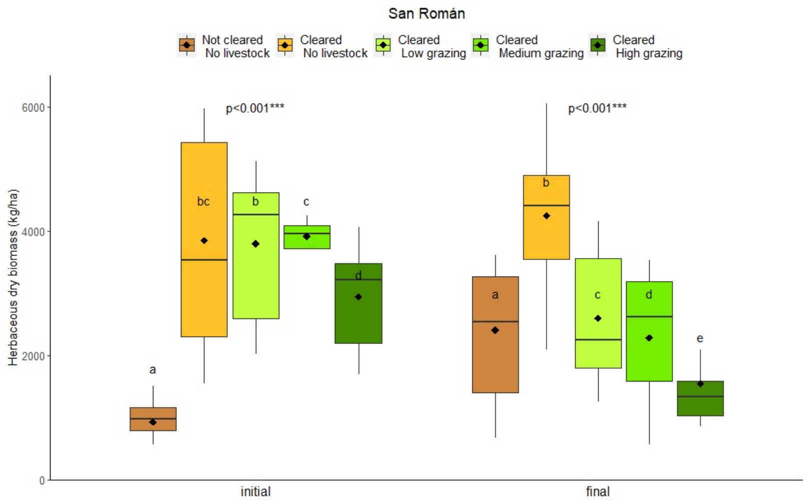


Figure 23. Boxplots showing mean herbaceous dry biomass in each treatment (not cleared without livestock, cleared without livestock, cleared with low level of grazing, cleared with medium level of grazing and cleared with high level of grazing). Initial and final stages of the experimental plots are shown.

The nutritional quality of the grass harvested this May 2023 is in the process of laboratory analysis, having available only the data of the initial stage, so these data are not shown.

4.3. Monitoring results of Rainfall simulations

In San Román, the monitoring scheme has been the same as in Garcipollera: with monitoring campaigns in winter, after the livestock grazed for the third time within the year. Here we present the results of the four years of monitoring from 2020 to 2023.

The results showed that there was no hydrological and sedimentological response under the rainfall simulation conditions (with rainfall intensities for a single experiment up to 67 mm/h during 20 min), except for the plots with the highest level of grazing (D) that showed very limited response with mean RC of 0.001, a SC of 0.02 g/l and a SP of 0.1 g/m^2. This may be partly due to the dense herbaceous vegetation cover in the treated plots and the low hillslope gradient of all the plots. The infiltrated water was lower under shrubs, due to its higher interception capacity but no clear differences were observed between the treated plots, except that in those with higher level of grazing the infiltration was slightly lower, suggesting that a higher level of grazing may reduce the infiltration capacity and produce more runoff.

Site	Land management	Slope (%)	RI (mm h-1)	INF (mm h-1)	RC (-)	SC (g L-1)	SP (g m-2)
San Román	Cleared without livestock (A)	11	54.5	29.4	0.00	0.00	0.00
	Cleared with low pressure (B)	13	40.5	29.4	0.00	0.00	0.00
	Cleared with medium pressure (C)	13	41.7	30.6	0.00	0.00	0.00
	Cleared with high pressure (D)	10	39.2	28.8	0.00	0.02	0.01
	Control	8	49.9	21.0	0.00	0.00	0.00

Table 9. Mean hydrogeological and sedimentological variables extracted from rainfall simulations in San Román (2020, 2021, 2022, 2023). RI: rainfall intensity (mm h-1), INF: infiltration rate (mm h-1), RC: Runoff coefficient (mm mm-1), SC: Sediment concentration (g l-1), SP: Sediment production or erosion rate (g m-2). Not cleared without livestock (control), cleared without livestock (A), cleared with low level of grazing (B), cleared with medium level of grazing (C), and cleared with high level of grazing (D).

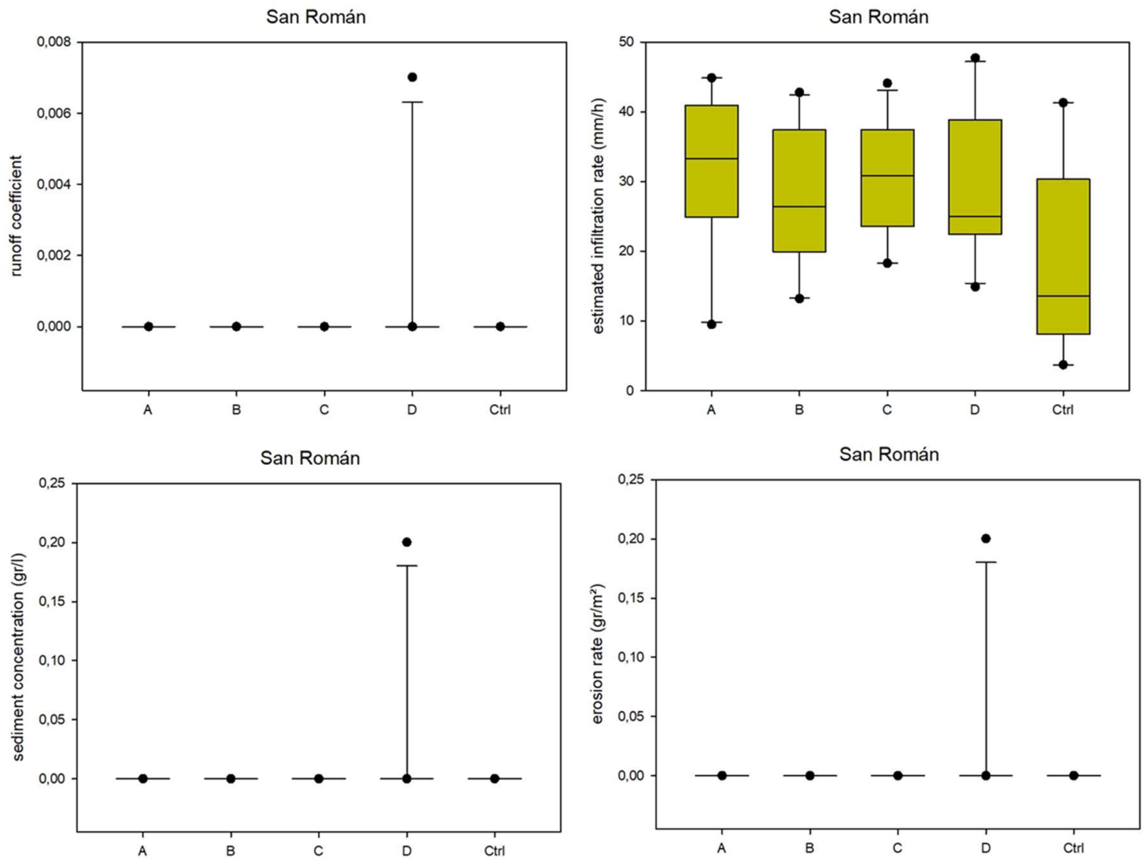


Figure 24. Runoff coefficient (mm mm-1), Infiltration rate (mm h-1), Sediment concentration (g l-1) and erosion rate (g/m2) in San Román (2020, 2021, 2022, 2023): not cleared without livestock (control), cleared without livestock (A), cleared with low level of grazing (B), cleared with medium level of grazing (C), and cleared with high level of grazing (D).

4.4. 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.

Meteorological conditions are being recorded continuously since 03-06-2020 (25 months). Two Temperature/Relative Humidity sensors were installed, one in the experimental plots (Tplot) and the other under a tree (Tplot under tree) closed to the experimental plots, and a rain gauge, to analyse differences between sites. In this period, until 28-06-2022, the maximum temperature has been 40.3 and 38.6 ºC for Tplot and Tplot under tree respectively (14-08-2021), and the minimum -10.3 and -9.1 ºC for Tplot and Tplot under tree respectively (07-01-2021; 08-01-2021) (see Figure 25).

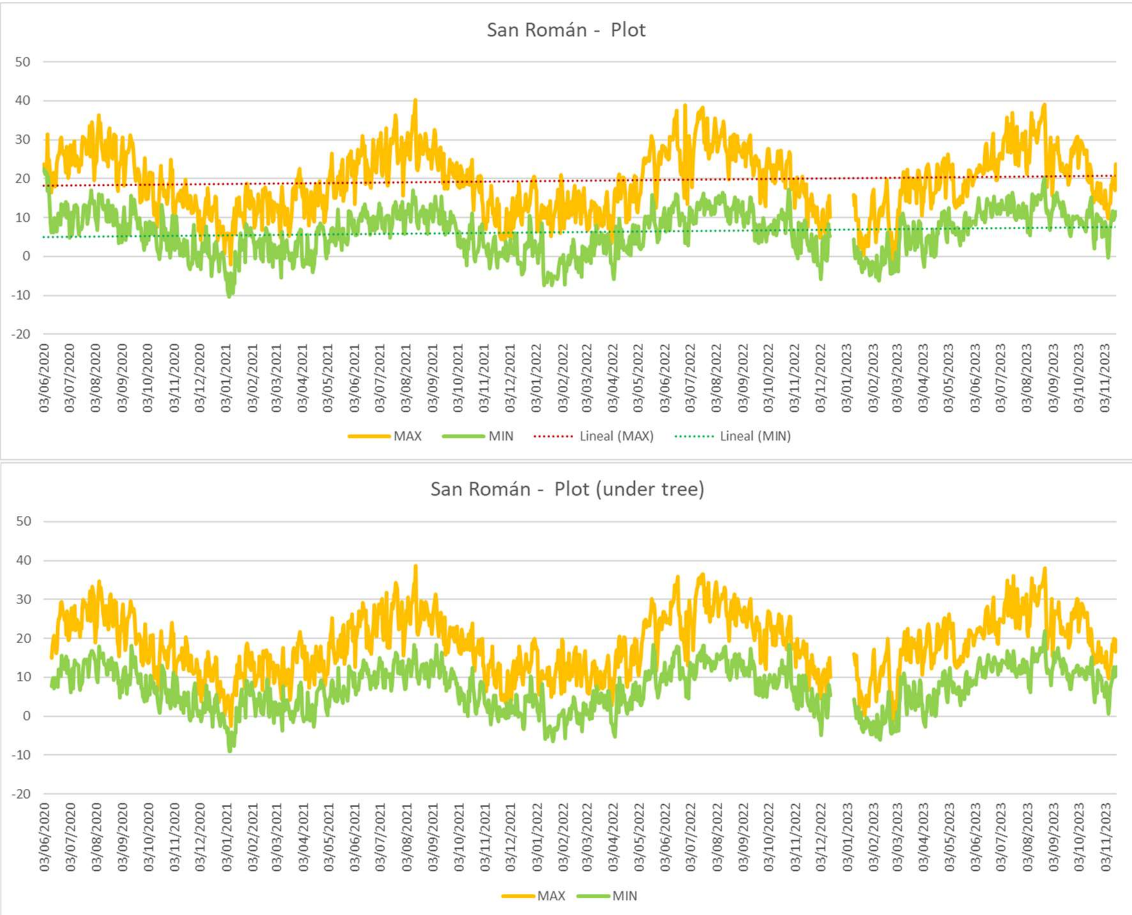


Figure 25. Daily average of minimum and maximum temperature and relative humidity in scrubland cleared experimental plots in San Román (La Rioja).

Figure 26 shows monthly averages of maximum and minimum temperature and mean monthly precipitation for the period 06-2020 to 06-2021 (25 months) recorded in the experimental plots located in San Román. In that case, contrary to the data recorded in Aragón, no clear dry periods were observed during the study period. High precipitation values were recorded in January and December, and during the spring period (April-

May). The lowest rainfall amounts were recorded in August and September. Throughout the project, the data recorded in this, and the other stations will be compared with studies carried out on a regional scale, to contextualise our results, and they will be also used to establish relationships between other environmental variables (biodiversity, pasture production, soil moisture…) and meteorological conditions.

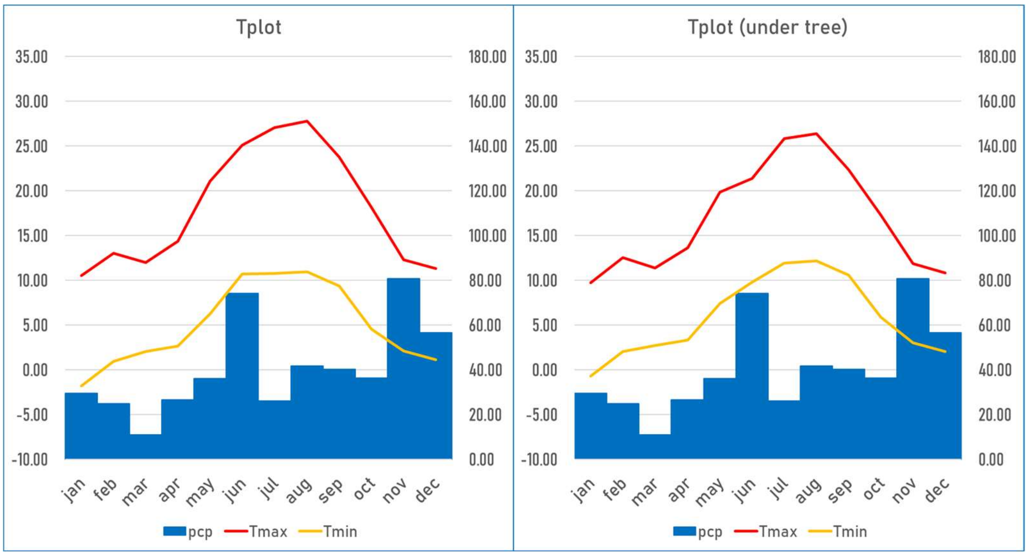


Figure 26. Climogram scrubland cleared experimental plot (San Roman). Left: Tplot in the subplot A2, right: Tplot under tree.

5. Results of the 1st, 2nd and 3rd monitoring campaign in Ajamil, La Rioja

The pilot experience has been implemented in the Leza Valley (Iberian System, Spain) in a scrubland clearing area. This chapter includes the results of the 1st, 2nd, and 3rd monitoring campaigns in Ajamil.

We include a summary of the implemented pilot experience and the experimental design of the monitoring network, to facilitate the understanding of the monitoring results. A more detailed description of the implemented actions can be consulted in Nadal-Romero *et al.* (2019, 2020a, 2020b).

The initial sampling of the monitoring variables was carried out in June 2020 and the monitoring campaigns were carried out in November 2021, 2022, and 2023, once the animals entered three times in the experimental plots (spring, summer, and autumn). In winter 2021-2022 and 2022-2023, during the 1st- and 2nd-year monitoring campaigns, superficial soil samples (0-10 cm) have been taken to analyse the changes in carbon and nitrogen. In this deliverable, we present the results of 2021, 2022 and 2023.

Implemented pilot experience:

- Adaptive scrubland management of abandoned fields in 0.36 ha plot consisting in scrubland clearing.
- Control plot: an area with no actuation of 100 m^2.

Monitoring network:

- Four classes of monitoring subplots (surface of 100 m^2):
  - control subplots, without neither scrubland management nor the entry of livestock;
  - managed subplots with different livestock density:
    - A no livestock,
    - B low pressure,
    - C medium pressure,
    - D high pressure.
  - For each of monitoring plots, three replicates were selected, except in the control area where there was only space for two replicates.

The monitoring network includes twelve monitoring managed subplots of 100 m^2, and two subplots in the control area.

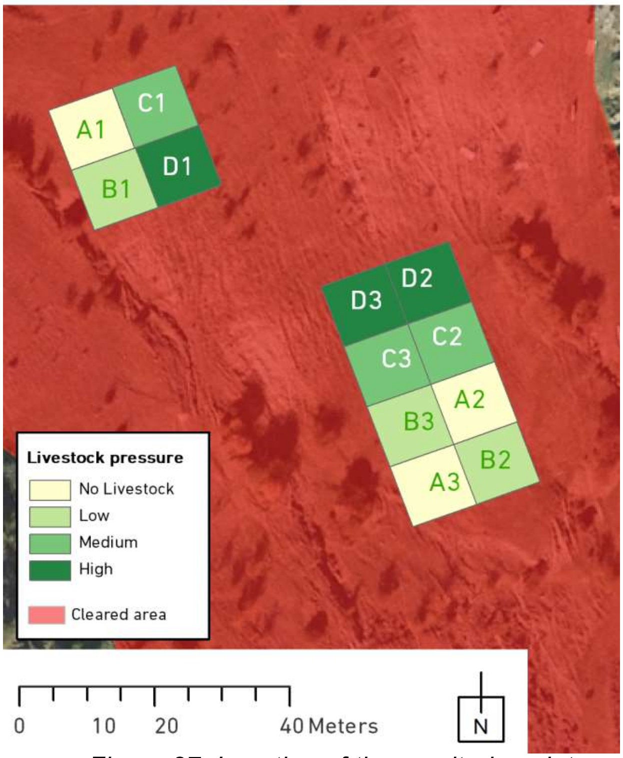


Figure 27. Location of the monitoring plots and replicates of the experimental design.

5.1. Monitoring results of the Soil

5.1.1. Soil characteristics

The initial sampling of the monitoring variables was carried out in June 2020 and the first- year and second year monitoring campaigns were carried out in November 2021 and November 2022 once the animals entered three times in the experimental plots (spring, summer, and autumn 2021 and 2022). In winter 2023-2024, during the third-year monitoring campaign, soil samples (0-40 cm) are being again taken to analyse the changes in carbon and nitrogen content and stocks in the complete soil profile. In this deliverable, we present the results of the 2021 and 2022 campaigns (the last results about soil properties will be presented in the final deliverable).

At each monitoring subplot, three soil subsamples were sampled in a depth of 0-10 cm. In each site, 45 points were selected, and subsamples were recorded and later combined into one soil composite sample per plot and depth (0-10 cm). In total 15 composite samples were created in Ajamil.

The samples have been analysed by the Pyrenean Institute of Ecology (IPE-CSIC), evaluating the following soil variables: total carbon concentration (Ctotal), total nitrogen concentration (N), organic matter (OM), bulk density (BD), and soil organic carbon (SOC). It should be noted, that during this year the calculation to determine SOC and N stocks have been slightly modified, and consequently some data may differ from previous deliverables.

The following tables present the mean values at the initial conditions, after the first and second years of monitoring and the change occurred in percentage for the main variables (0-10 cm) measured in the experimental plots during the 2021 and 2022 monitoring campaigns in Ajamil. Statistical results did not show significant differences between the management plots and the control plots at the second year of monitoring. However, significant differences were observed between the initial conditions and the present values for Corg/N values and N stocks for C (medium livestock pressure) and Control plots. Some changes should be highlighted. Related to SOC values (Table 10 and Figure 28) (i) lower SOCK stocks are observed after the first monitoring year, although these changes are not significant; However, in the second year positive changes are recorded in D (high livestock density) and control plot; and (ii) higher SOC values are observed in the control plots and D plots (high livestock pressure).

SOC Mg ha^{-1} (10 cm)	YEAR 0	YEAR 1	YEAR 2	Change 1 %	Change 2 %
A	35.7	34.3	28.5	*- 3.9*	*- 20.3*
B	47.5	37.8	30.9	*- 20.3*	*- 34.9*
C	45.3	27.6	31.2	*- 39.0*	*- 31.1*
D	32.1	22.2	36.4	*- 30.8*	*+ 13.4*
CONTROL	75.8	49.0	85.6	*- 35.3*	*+ 13.0*

Table 10. Soil organic carbon (SOC) stocks of soil samples for the initial conditions and first and second years of monitoring (at depth of 0-10 cm) and in the different plots (A, B, C and D and control plots).

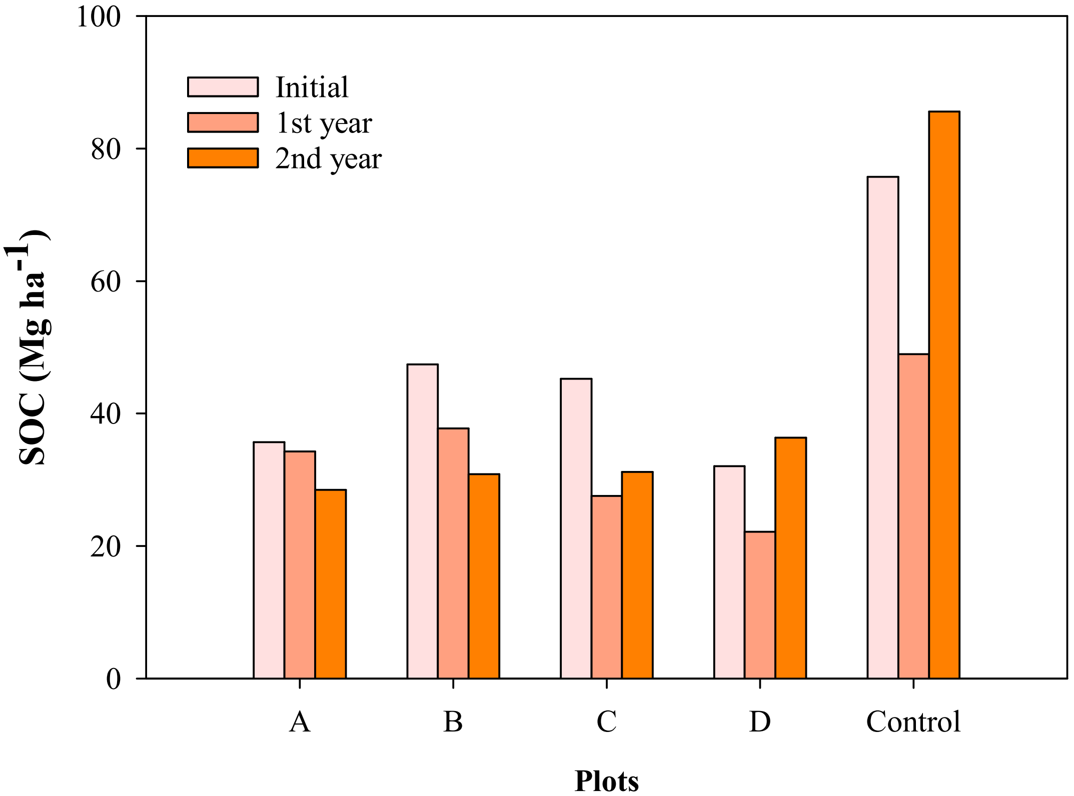


Figure 28. Soil organic carbon (SOC) stocks of soil samples for the initial conditions and first and second years of monitoring (at depth of 0-10 cm) and in the different plots (A, B, C and D and control plots).

Related to N stocks (Table 11 and Figure 29): (i) all the plots show a decrease in N stocks during the first and the second years; (ii) the lower N stocks are recorded in the A plots and the higher in the control plots.

N Mg ha^{-1} (10 cm)	YEAR 0	YEAR 1	YEAR 2	Change 1 %	Change 2 %
A	3.4	1.9	2.0	- 44.7	- 73.4
B	4.4	2.1	2.3	- 51.2	- 97.3
C	4.2	1.4	2.1	- 65.6	- 143.3
D	3.9	0.8	2.6	- 78.5	- 155.1
CONTROL	5.0	2.0	3.8	- 59.9	- 59.5

Table 11. Nitrogen (N) stocks of soil samples for the initial conditions and first and second years of monitoring (at depth of 0-10 cm) and in the different plots (A, B, C and D and control plots).

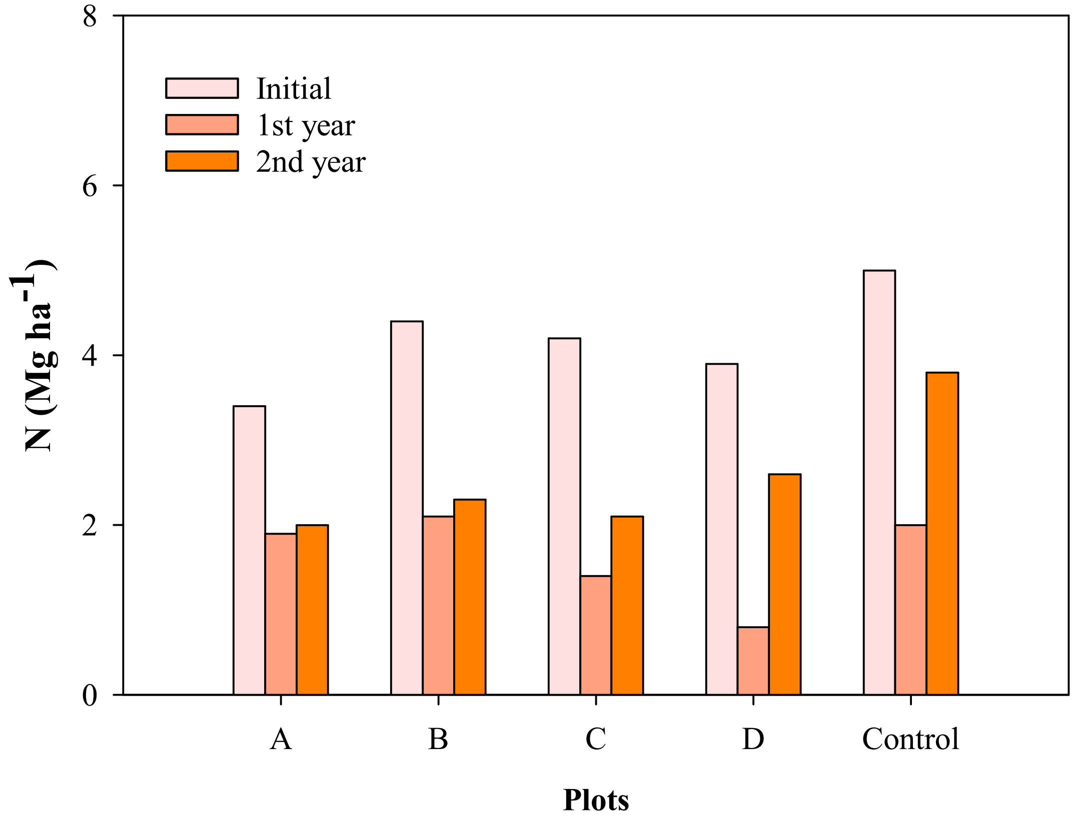


Figure 29. Nitrogen (N) stocks of soil samples for the initial conditions and first and second years of monitoring (at depth of 0-10 cm) and in the different plots (A, B, C and D and control plots).

Related to the Corg/N ratio (Table 12): (i) significant increases are observed in all the plots; and (ii) the highest ratios and higher increases are observed in the D plot (high livestock pressure) and control plots.

Corg/N ratio (10 cm)	YEAR 0	YEAR 1	YEAR 2	Change 1 %	Change 2 %
A	10.4	20.1	14.2	+ 93.8	+ 37.3
B	10.9	19.3	13.5	+ 78.2	+ 24.8
C	10.7	19.6	14.4	+ 83.3	+ 34.6
D	8.9	27.5	13.8	+ 207.2	+ 54.5
CONTROL	15.0	24.3	22.6	+ 61.9	+ 50.4

Table 12. Corg/N ratios of soil samples for the initial conditions and first and second years of monitoring (at depth of 0-10 cm) and in the different plots (A, B, C and D and control plots).

5.1.2. Soil moisture

The sensor network installed to monitor the evolution of the water in the first 20 cm of the soil has been continuously recording since the installation, except some gaps explained below. In the scrubland clearing pilot, the original network consisted of 2 dataloggers, one in the treatment subplots and another in the control subplot (Figure 30).

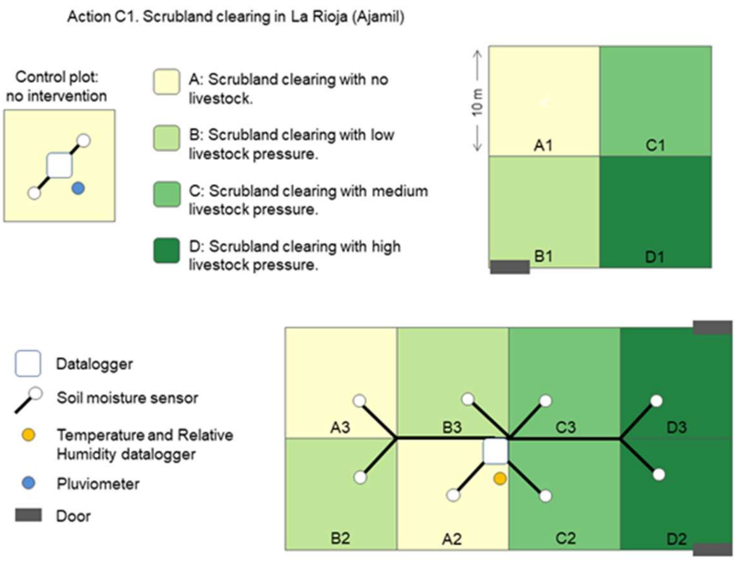


Figure 30. Diagram of the livestock and monitoring subplots.

As in the rest of the experimental plots, here the connections between the probes and the extension cables failed: first data gap between 05-07-2020 and 18-12-2020. It was fixed as in the Ajamil plots, sealed with silicone and with an own coating with plastic. Subsequently, an error was observed between 09-06-2021 and 23-08-2021, in the probes installed in the subplots D2 and D3 and the connectors were changed, and the coating was made with heat-shrink tubing. After that, on 11-09-2022 a gap is detected in D2 and a micro-station was installed. Unfortunately, since the last data download on 15th June 2023, the data collected from the probes of the different treatments have behaved extremely strangely and cannot be reflected in the graph. On 15th November, the datalogger was reset and new connections were made, checking that it was working correctly. In the last deliverable we will have data for the whole winter and hopefully they can be incorporated into the final analysis.

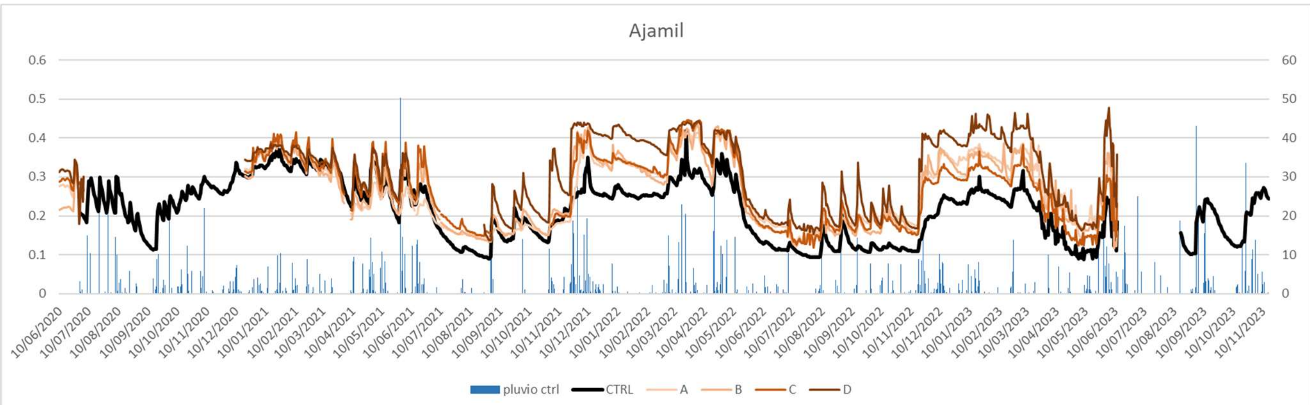
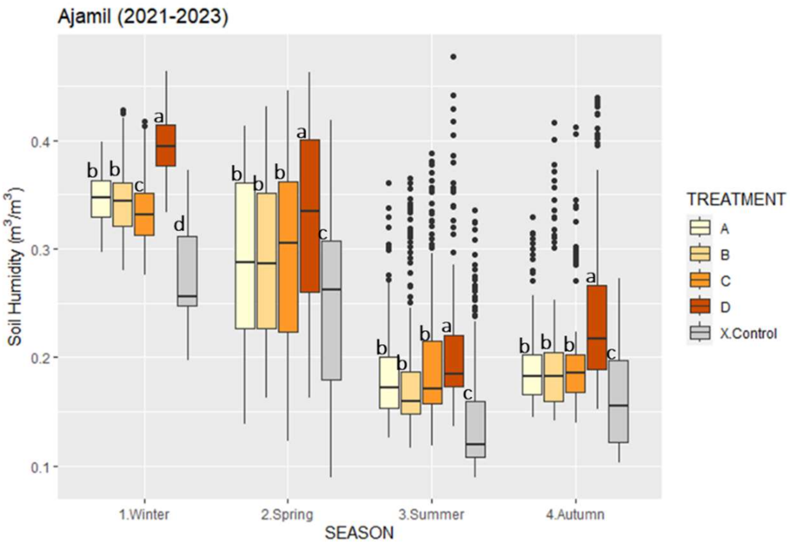


Figure 31. Soil humidity and precipitation in scrubland cleared experimental plot (Ajamil).

Figure 31 shows the good response of the probes to the recorded rainfall events and wet periods. As expected, higher values were observed after rainfall events and rainy periods. Differences can be observed between the different treatments, especially during dry periods.



	Winter	Spring	Summer	Autumn
R^2	0.62	0.09	0.12	0.19
	$F_{4,488}$ = 488.4***	$F_{4,1350}$ = 34.6***	$F_{4,908}$ = 31.9***	$F_{4,921}$ = 56.28***
A	b	b	b	b
B	b	b	b	b
C	c	b	b	b
D	a	a	a	a
CTRL	d	c	c	c

Figure 32. Boxplot with seasonal soil humidity values in scrubland cleared experimental plot (Ajamil).

Figure 32 shows seasonal soil moisture values of the different plots. Some preliminary results should be highlighted: (i) a high variability is observed in all the plots during the different seasons being higher in spring, and autumn; (ii) in general, lower soil moisture values are recorded in the control plots; and (iii) in spring higher mean values are recorded in all the plots, and lower values are recorded in summer. Besides, significant differences between plots are observed: (i) all the seasons significant higher values were recorded in the D plots and lower values in the control plot; (ii) in spring differences were also observed between A and D plots; and (iii) in summer between A, C and D plots.

5.2. Monitoring results of the Pastures

The objective is to assess the effect of scrubland clearing and sheep grazing intensity on pasture service in terms of biodiversity, biomass production and nutritive quality. We hypothesize that scrubland clearing interacting with sheep grazing will help maintain biodiverse, productive, and highly nutritive herbaceous pastures. While species rich pastures will contribute to their natural value and global biodiversity, the maintenance of their productivity and nutritive quality will enable to support extensive livestock activities in these areas, thus enhancing socio-economic development. Moreover, scrubland clearing and subsequent grazing by sheep will also restrain scrub encroachment, therefore diminishing the fire risk in these areas.

5.2.1. Biodiversity

Vegetation surveys were arranged within three subplots (1 m^2) at each of the three replicate plots per treatment: control area not cleared without livestock, cleared area without livestock, cleared area with low level of grazing (once a year), cleared with medium level of grazing (twice a year) and cleared with high level of grazing (three times a year). Vegetation sampling was carried out once a year (between late spring and early summer) for 4 consecutive years to observe the evolution of the vegetation in the plots from the initial to the final stage (also evaluating the intermediate stage). The first sampling was done in May 2020 to record the initial stage of the pasture in the experimental plots prior to any livestock entry. Intermediate stage of the vegetation in the experimental plots was recorded in May 2022 (after having entered sheep two years in a row). Final stage of the pasture was recorded May 2023 (after having entered sheep three years in a row).

To assess the effects of scrubland clearing and sheep grazing on pasture biodiversity, the data evaluated were the cover and richness of herbaceous and woody species separately. We also assessed the effect of those factors on the bare soil cover. Regarding the scrubland clearing factor, we expected to find a positive effect of woody plant removal in the herbaceous pasture cover and richness in the first sampling because of the elimination of woody competitors for light, space, nutrients, and water. We expected this effect to be maintained over the years. On the other hand, regarding the sheep grazing levels (no grazing, low, medium, and high grazing), we expected not to find any effect of the livestock treatments in the first year since vegetation surveys were set prior to sheep entry in the plots. But we expected to find a positive effect of sheep grazing by promoting the growth of herbaceous species (both in cover and richness) and controlling the growth of woody species along the subsequent years (2022 and 2023). In particular, we expected the most positive effect on herbaceous species cover and richness in low and medium grazing levels and a more positive effect by controlling woody species growth in the high grazing level. Moreover, we expected the bare soil cover to be larger in plots with more frequent sheep entry than in those with no sheep entry and low and medium grazing.

As expected, we found significantly lower herbaceous species and larger woody species in the control plots than in the cleared plots (Figure 33). This effect maintains over the years. Regarding livestock effects, we did not find significant differences in herbaceous species cover between the grazing levels, but we found a significant positive effect of medium and high grazing by controlling woody species cover (the lowest woody species cover was found in those treatments). We barely recorded bare soil covering the sampled surface, but we found the highest bare soil cover in the high grazing treatment in the final monitoring year.

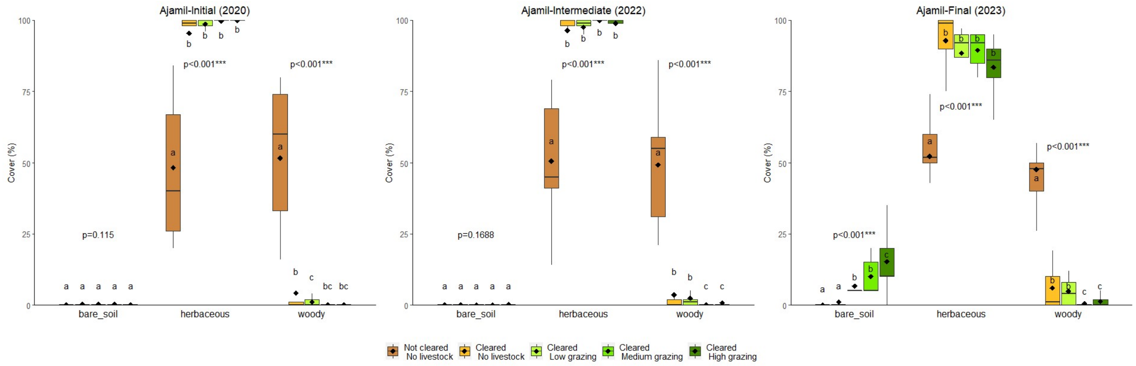


Figure 33. Boxplots showing mean cover and data variability of the bare soil, herbaceous species, and woody species separately in each treatment (not cleared without livestock, cleared without livestock, cleared with low level of grazing, cleared with medium level of grazing and cleared with high level of grazing). Initial, intermediate, and final stages of the experimental plots are shown.

Considering species richness, we found significant differences between control and cleared plots, being in some cases cleared plots more rich in herbaceous species than the control plot, and in all the cases cleared plots less rich in woody species than the control plot (Figure 34). We did not find significant differences between livestock treatments for woody species richness, but we found the largest herbaceous species richness in plots submitted to high grazing in 2022 and medium and high grazing in 2023.

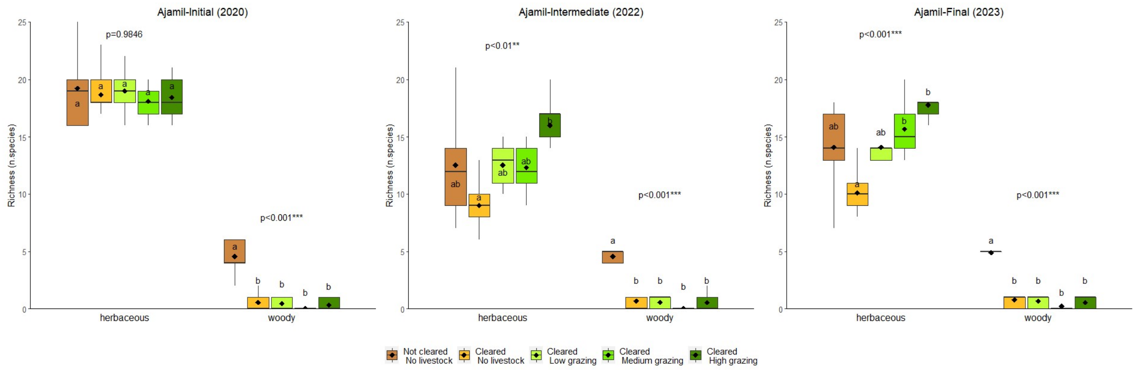


Figure 34. Boxplots showing mean species richness for herbaceous species and woody species separately in each treatment (not cleared without livestock, cleared without livestock, cleared with low level of grazing, cleared with medium level of grazing, and cleared with high level of grazing). Initial, intermediate, and final stages of the experimental plots are shown.

5.2.2. Pasture production and quality

To assess pasture production and nutritive quality we harvested the plants growing within three subplots (0.25 m^2) at each of the three replicate plots per treatment: control area not cleared without livestock, cleared area without livestock, cleared area with low level of grazing (once a year), cleared with medium level of grazing (twice a year) and cleared with high level of grazing (three times a year). Samples were collected between late spring and early summer (matching the vegetation growth peak) at the initial and final stage of the experiment. The first sampling was done in May 2020 to record the initial stage of the pasture in the experimental plots prior to any livestock entry and second sampling was done in May 2023 to record the final stage of the pasture after having entered sheep three years in a row. We considered that recording the intermediate stage of the pastures in terms of production and quality was not relevant because it is a short period of time to achieve significant results.

To assess the effects of scrubland clearing and sheep grazing on pasture production, we considered dry biomass (kg/ha) of the gathered herbaceous plants. The nutritive quality of pastures was evaluated in terms of the content of digestible fibers (Relative Feed Value) and crude protein (estimated in laboratory from the dry matter derived from the collected herbaceous samples).

Regarding the scrubland clearing factor, we expected to find a positive effect of woody plant removal in the herbaceous plants' biomass and quality because of the elimination of woody competitors for light, space, nutrients, and water. We expected to find this effect both in the first and final samplings. On the other hand, regarding the sheep grazing levels (no grazing, low, medium, and high grazing), we expected not to find any effect of the livestock treatments in the first year since samples were collected prior to sheep entry in the plots. But we expected to find a positive effect of sheep grazing by promoting the growth and nutritive quality of herbaceous species in the final stage. In particular, we expected the most positive effect on herbaceous biomass production and nutritive quality in medium grazing levels.

We found a significantly higher herbaceous plant production in the scrubland clearing plots than in the control plots for both the initial and final monitoring year (Figure 35). We also found significant differences in herbaceous biomass between the livestock treatments. Specifically, we found the highest herbaceous biomass in plots ungrazed than in plots submitted to any grazing intensity. Among them, in the first monitoring we found the significantly highest biomass in plots submitted to low grazing but in the final monitoring we found the significantly highest biomass in plots submitted to medium grazing.

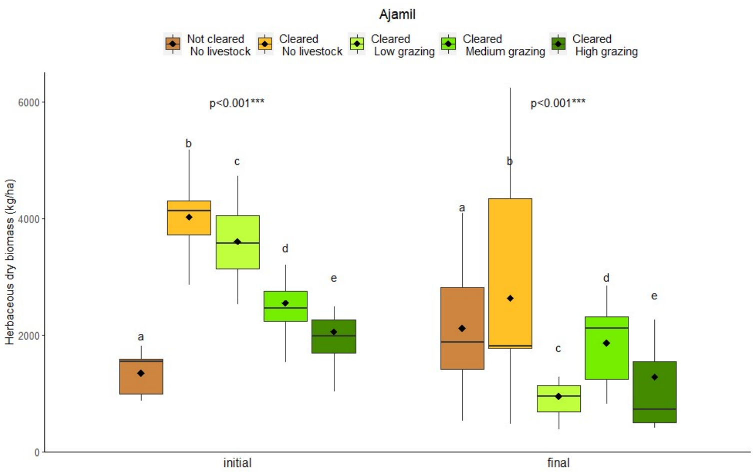


Figure 35. Boxplots showing mean herbaceous dry biomass in each treatment (not cleared without livestock, cleared without livestock, cleared with low level of grazing, cleared with medium level of grazing, and cleared with high level of grazing). Initial (in 2021) and final (2023) stages of the experimental plots are shown.

The nutritional quality of the grass harvested this May 2023 is in the process of laboratory analysis, having available only the data of the initial stage, so these data are not shown.

5.3. Monitoring results of Rainfall simulations

In Ajamil, the monitoring scheme has been the same as in San Román and Garcipollera, with monitoring campaigns in winter after the livestock grazed for the third time within the year. Here, we present the results of three years of monitoring (2020, 2021, 2022). The hydrological and sedimentological response was clearly higher in the plots under treatment than in the control (shrub) plot, which showed no runoff and no soil erosion. The hydrological response (RC) increased with increasing level of grazing; however, this did not affect the sediment production as there were no clear differences between treatments in terms of sediment concentration and erosion rate. As expected from the values of RC, the infiltrated water decreased with increasing level of grazing (B, C, D). Under shrubs, the lack of runoff and the low value of INF indicate the effect of interception processes by the vegetation. The relation between lower runoff – higher infiltration was not observed in treatment A (cleared with no livestock) neither, also suggesting an effect of vegetation interception.

Site	Land management	Slope (%)	RI (mm h^{-1})	INF (mm h^{-1})	RC (-)	SC (g L^{-1})	SP (g m^{-2})
Ajamil	Cleared without livestock (A)	23	46.4	21.7	0.16	0.04	0.46
	Cleared with low pressure (B)	13	44.4	26.3	0.20	0.05	0.38
	Cleared with medium pressure (C)	19	41.0	15.4	0.30	0.07	0.69
	Cleared with high pressure (D)	19	41.7	9.9	0.31	0.04	0.37
	Control	15	39.8	15.5	0.00	0.00	0.00

Table 13. Mean hydrogeological and sedimentological variables extracted from rainfall simulations in San Román (2020, 2021, 2022, 2023). RI: rainfall intensity (mm h-1), INF: infiltration rate (mm h^{-1}), RC: Runoff coefficient (mm mm^{-1}), SC: Sediment concentration (g l^{-1}), SP: Sediment production or erosion rate (g m^{-2}). Not cleared without livestock (control), cleared without livestock (A), cleared with low level of grazing (B), cleared with medium level of grazing (C), and cleared with high level of grazing (D).

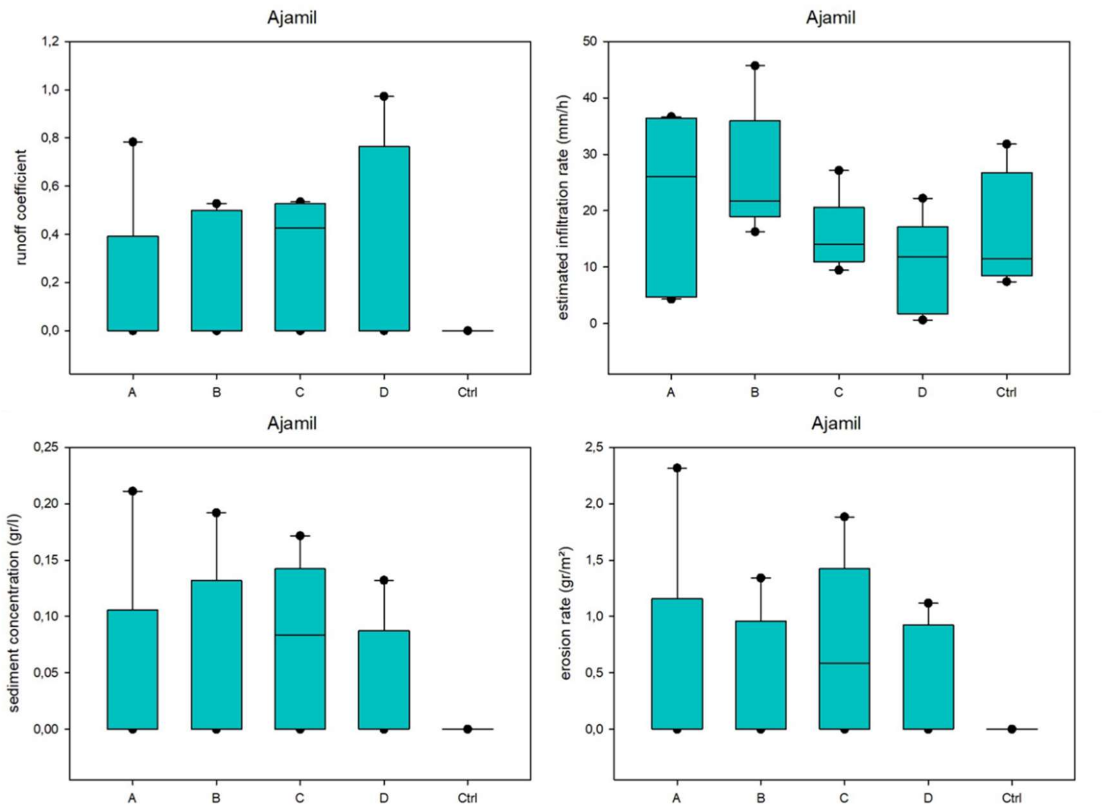


Figure 36. Runoff coefficient (mm mm^{-1}), Infiltration rate (mm h^{-1}), Sediment concentration (g l^{-1}) and erosion rate (g/m^2) in Ajamil (2020, 2021, 2022): not cleared without livestock (control), cleared without livestock (A), cleared with low level of grazing (B), cleared with medium level of grazing (C), and cleared with high level of grazing (D).

5.4. 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.

Meteorological conditions are recorded continuously since 10-06-2020 in Ajamil (Figure 37). Two Temperature/Relative Humidity sensors were installed, one in the experimental plots (T1) and the other under a tree (T2). Rainfall amounts were recorded at the SAIH-Ebro (Sistema Automático de Información Hidrológica) P007 in Ajamil and at a rainfall gauge datalogger installed at the control plot.

In this period, until 06-10-2022, the maximum temperature has been 35.6 and 36.3 ºC for T1 and T2 respectively (7-08-2021 and14-08-2021), and the minimum -9.1 and -8.9 ºC for T1 and T2 respectively (08-01-2021).

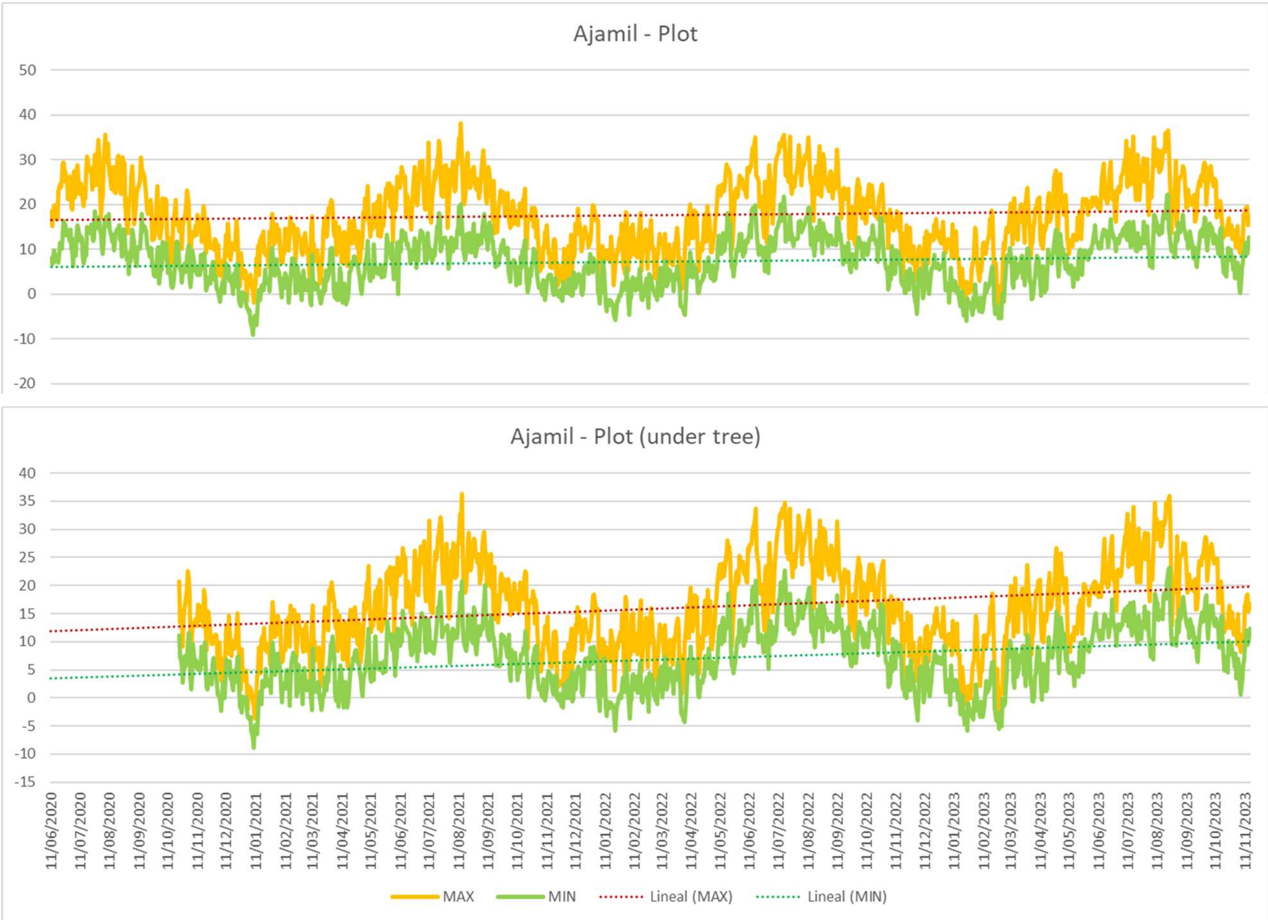


Figure 37. Daily average of minimum and maximum temperature and relative humidity in scrubland cleared experimental plot in Ajamil. T1: in the A2 experimental subplot; T2: under a tree. *It starts in October because the data logger was stolen.*

The Temperature/Relative Humidity sensors in the control plot was installed on 01-07-2021. A data gap was detected between 01-04-2021 and 07-04-2021 due to a download error. In this period, until 15-11-2023, the maximum temperature has been 36.3 ºC (14-08-2021) and the minimum -9.3 ºC (08-01-2021) (Figure 38).

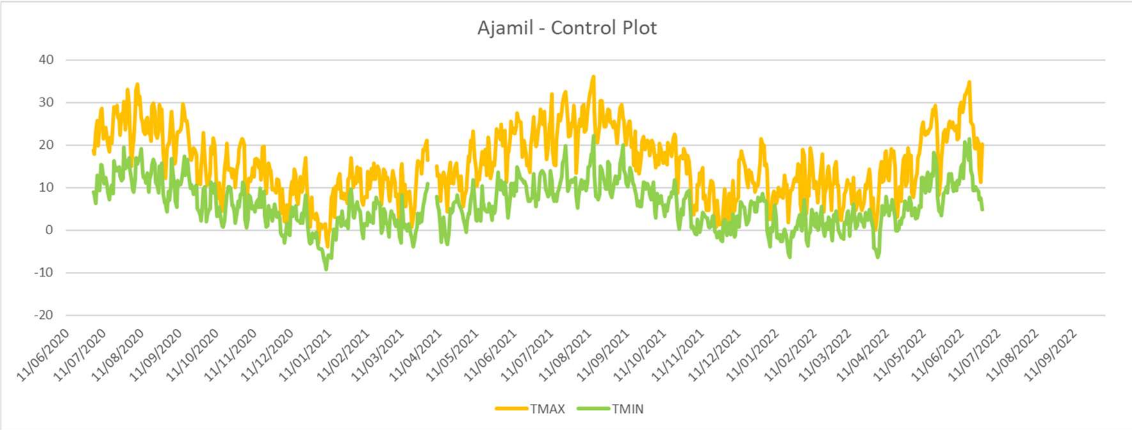


Figure 38. Daily average of minimum and maximum temperature and relative humidity in scrubland cleared experimental Control plot in Ajamil.

Figure 39 shows monthly averages of maximum temperature, minimum temperature and mean monthly precipitation for the period 06-2020 to 11-2023 (42 months) recorded in the experimental plots located in Ajamil (management and control plots). In the management plots, high rainfall values were recorded in spring and autumn, being the highest precipitation in November at experimental plot (76.1 mm) and in April in the control plot (71.54 mm). Throughout the project, the data recorded in this, and the other stations will be compared with studies carried out on a regional scale, to contextualise our results, and they will be also used to establish relationships between other environmental variables (biodiversity, pasture production, soil moisture…) and meteorological conditions.

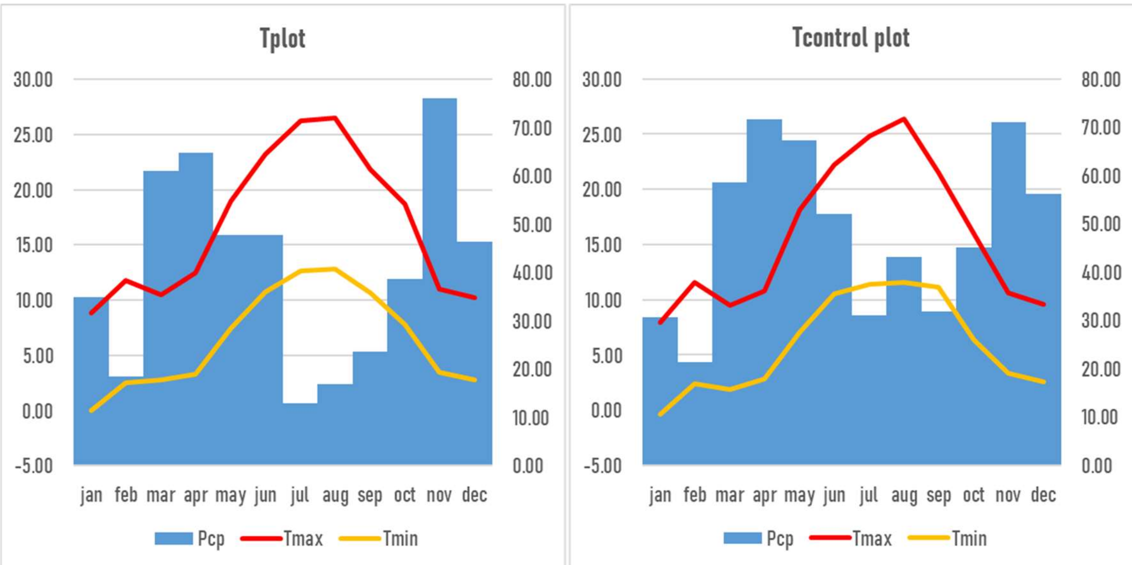


Figure 39. Climogram registered in the scrubland cleared experimental plot (Ajamil). Left: in the subplot A2, right: in the control plot.

6. Conclusions

The main objective of this deliverable is to present the initial monitoring variables and the results of the first-year monitoring related to scrubland clearing with livestock grazing, carried out in Aragon and La Rioja: *Action C.1: Climate change adaptation measure: scrubland clearing*.

La Garcipollera (Aragon)		
Soil	Soil characteristics	Results of soil samples in a depth of 0-10 cm are shown, comparing initial conditions (2020) and after the 1st and second years of monitoring (2021 and 2022). Statistical results did not show significant differences between the management plots and the control plots. Changes to be highlighted: (i) higher SOC (soil organic carbon) stocks are observed after the first and the second monitoring years; (ii) the higher increase in SOC stocks are observed in the B plots and higher SOC values are observed in the B and C plots (low and medium livestock pressure); (iii) all the plots show a decrease in N stocks, in the first year, and an increase in the second year limited to the B, C and control plots; (iv) and related Corg/N ratios, a sharply increase is observed in all the plots. Results show an increase of SOC, N stocks and a sharply increase in Corg/N ratios, after two years of livestock grazing.
	Soil moisture	A sensor network is installed since 2020. Soil moisture data shows a good response of the sensors to the recorded rainfall events. Results show: (i) a high variability in all the plots during the different seasons being higher in summer and autumn; (ii) a higher soil moisture values are recorded in the B (low livestock pressure) and control plots; (iii) seasonal differences between plots are observed.
Pastures	Biodiversity	Scrubland clearing had a positive significant effect in pastures because it significantly increased the cover of herbaceous species, and this effect maintains along the years. Regarding livestock activity we did not find significant differences between treatment in herbaceous species cover, but the bare soil cover was the largest in the plots submitted to the highest grazing frequency (three times a year), especially after two and three years of sheep entry. Regarding the scrubland clearing effect along the monitoring years, we found significant higher richness in herbaceous species between the control treatment and the cleared plots after 3 years of treatment, but no significant differences in woody species richness. Regarding livestock intensity, we did not find significant differences between treatments neither for herbaceous species nor for woody species.
	Pasture prod. and quality	Scrubland clearing had a positive significant effect in the production of herbaceous species biomass. Regarding the grazing treatments, we found the largest herbaceous biomass in the plots with no sheep entry and the lowest herbaceous biomass in low and high grazing treatments.
Rainfall simulations		The hydrological response (RC) was higher in the treated plots than in the control plot. Medium and high grazing produce more runoff than low and no grazing. The grazed plots showed higher sediment concentration. Sediment production was higher in the medium and high level of grazing. Shrubs recorded the lowest rate of infiltration, and no clear differences were observed between the treated plots.
Site meteorological conditions		Maximum, minimum temperature and relative humidity are recorded continuously from June 2020 to November 2023

San Román de Cameros (La Rioja)		
Soil	Soil characteristics	Results of soil samples in a depth of 0-10 cm are shown, comparing initial conditions (2020) and after the 1st and second years of monitoring (2021 and 2022). Statistical results did not show significant differences between the management plots and the control plots. Changes to be highlighted: (i) lower SOC stocks are observed after the first and second monitoring years in all the plots, and the highest decreases are observed in the A and B plots (no and low livestock pressure) although these changes are not significant; (ii) higher SOC values are observed in the C plots (medium livestock pressure) and control plots; (iii) all the plots show a decrease in N stocks, especially in the B plots; (iv) Corg/N ratios, show an increase in all the plots. Results show a decrease of SOC and N stocks and an increase in Corg/N ratios, after two years of livestock grazing.
	Soil moisture	A sensor network is installed since 2020. Soil moisture data shows a good response of the sensors to the recorded rainfall events. Results show: (i) a high variability in all the plots during the different seasons being higher in summer and autumn; (ii) in general, lower soil moisture values are recorded in the B plots; (iii) seasonal differences between plots are observed.
Pastures	Biodiversity	We found significantly lower herbaceous species and larger woody species in the control plots than in the cleared plots. This effect maintains over the years. Regarding livestock effects, we did not find significant differences in herbaceous species cover between the grazing levels neither in the first monitoring nor in the final monitoring, but we found significantly higher herbaceous species cover in low and high grazing than in plots ungrazed in the intermediate monitoring. Sheep grazing controlling woody species cover (lower woody species cover was found in all the grazed plots than in the ungrazed plots). The bare soil cover was very low, but we found the higher bare soil cover in all the plots submitted to sheep grazing in the final monitoring year. We found significant differences between control and cleared plots, being in some cases cleared plots richer in herbaceous species than the control plot, and in all the cases cleared plots less rich in woody species than the control plot. We did not find significant differences between livestock treatments for woody species richness but in the intermediate and final monitoring years we found larger herbaceous species richness in plots submitted to low, medium, and high grazing than in plots ungrazed.
	Pasture prod. and quality	Scrubland clearing had a positive significant effect in herbaceous plant production. We also found significant differences in herbaceous biomass between the livestock treatments in the final monitoring year. Specifically, we found the highest herbaceous biomass in plots ungrazed and the lowest herbaceous biomass in plots submitted to high grazing. .
Rainfall simulations		No hydrological and sedimentological response under the rainfall simulation conditions. Only plots with the highest level of grazing showed limited hydro-sedimentological response. The infiltrated water was lower under shrubs and no clear differences were observed between the treated plots
Site meteorological conditions		Maximum, minimum temperature and relative humidity are recorded continuously from June 2020 to November 2023.

Ajamil (La Rioja)		
Soil	Soil characteristics	Results of soil samples in a depth of 0-10 cm are shown, comparing initial conditions (2020) and after the 1st and second years of monitoring (2021 and 2022). Statistical results show significant differences between the management plots in the second year (between C and D plots). Also, significant differences were observed between the initial conditions and the present values for Corg/N values and N stocks for C (medium livestock pressure) and Control plots. Changes to be highlighted: (i) higher SOC stocks are observed after the second monitoring year, only in D and control plots, although these changes are not significant; (ii) the higher SOC stocks are observed in D and control in the second year; (iii) all the plots show a decrease in N stocks; (iv) and related Corg/N ratios, significant increases are observed in all the plots, being higher in the D plots. Results show an increase of SOC limited to the D and control plots) and Corg/N ratios in all the plots, and a decrease in N stocks after 2 years of livestock grazing.
	Soil moisture	A sensor network is installed since 2020. Soil moisture data shows a good response of the sensors to the recorded rainfall events. Results show: (i) a high variability in all the plots during the different seasons being higher in summer and autumn; (ii) in general, lower soil moisture values are recorded in the control plots; (iii) seasonal differences between plots are observed.
Pastures	Biodiversity	We found significantly lower herbaceous species and larger woody species in the control plots than in the cleared plots. This effect maintains over the years. Regarding livestock effects, we did not find significant differences in herbaceous species cover between the grazing levels, but we found a significant positive effect of medium and high grazing by controlling woody species cover (the lowest woody species cover was found in those treatments). We barely recorded bare soil covering the sampled surface, but we found the highest bare soil cover in the high grazing treatment in the final monitoring year. Considering species richness, we found significant differences between control and cleared plots, being in some cases cleared plots richer in herbaceous species than the control plot, and in all the cases cleared plots less rich in woody species than the control plot. We did not find significant differences between livestock treatments for woody species richness, but we found the largest herbaceous species richness in plots submitted to medium and high grazing in 2023.
	Pasture prod. and quality	We found a significantly higher herbaceous plant production in the scrubland clearing plots than in the control plots for both the initial and final monitoring year. We also found significant differences in herbaceous biomass between the livestock treatments. Specifically, we found the highest herbaceous biomass in plots ungrazed than in plots submitted to any grazing intensity. Among them, in the first monitoring we found the significantly highest biomass in plots submitted to low grazing but in the final monitoring we found the significantly highest biomass in plots submitted to medium grazing.
Rainfall simulations		The hidro-sedimentological response was higher in the plots under treatment than in the control plot. The hydrological response increased with increasing level of grazing; there were no clear differences between treatments in terms of sediment concentration and erosion rate. The infiltrated water decreased with increasing level of grazing.
Site meteorological conditions		Maximum, minimum temperature and relative humidity are recorded continuously from June 2020 to November 2023.

7. References

Nadal-Romero E, Lasanta T, Zabalza J, Pueyo Y, Pascual D, Pla E, Aranda X, de Herralde F, Reiné R, Barrantes O (2019) Technical planning of the climate change adaptation measures. Deliverable 1. LIFE MIDMACC.

Nadal-Romero E, Foronda A, Lasanta T, Pueyo Y, Zabalza J, Reiné R, Barrantes O, Vicente Serrano S (2020a) Implementation of the scrubland clearing pilot experiences. Deliverable 6. LIFE MIDMACC.

Nadal-Romero E, Lasanta T, Zabalza J, Pueyo Y, Foronda A, Reiné R, Barrantes O, Pacual D, Pla E, Lana-Renault N, Ruiz Flaño P (2020b) Monitoring protocol of C1 action. Deliverable 8. LIFE MIDMACC.

Nadal-Romero, E., Zabalza, J., Foronda, A., Lasanta, T., Pueyo, Y., Reiné, R., Barrantes, O., Lana-Renault, N., Ruiz, P. (2021) Report with the 1st year monitoring results of the implementation action C1. Deliverable 13. LIFE MIDMACC.

Nadal-Romero, E., Zabalza, J., Foronda, A., Lasanta, T., Pueyo, Y., Reiné, R., Barrantes, O., Lana-Renault, N., Ruiz, P. (2022) Report with the second year monitoring results of the implementation action C1. Deliverable 18. LIFE MIDMACC.