LIFE MIDMACC

Mid-mountain adaptation to climate change

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Report with the 2nd year monitoring results of the implementation action C1

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Executive summary

This deliverable presents the results obtained from the monitoring of the pilot experiences in scrub clearing during the second year of the monitoring in 2022. 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 and this second monitoring campaign has been performed since the beginning at the end of 2022.

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 summaries 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 second monitoring campaign** related to scrubland clearing with livestock grazing, carried out in Aragon and La Rioja. Scrubland clearing has consisted on 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, 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 and 2nd 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 first and second monitoring campaign in the plots.

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).

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 with a 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.

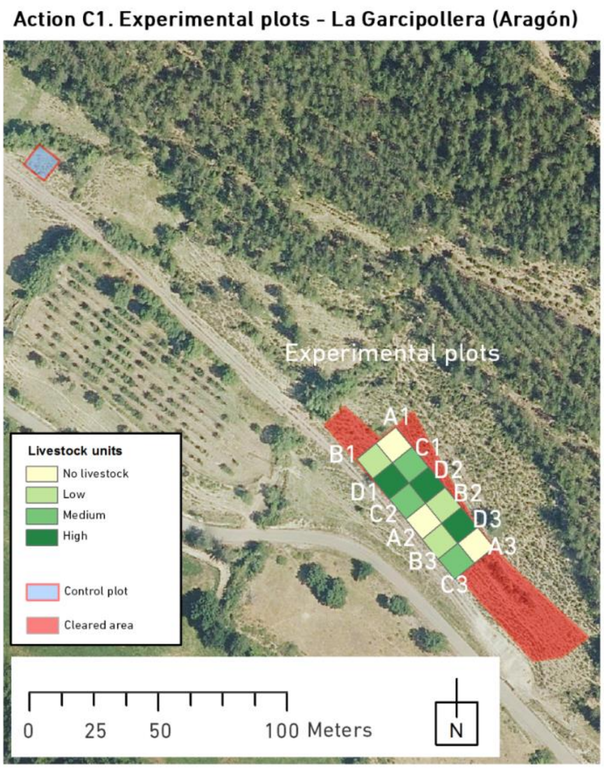


Figure 1. Location of the monitoring plots and replicates of the experimental design.

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 monitoring campaign was carried out in November 2021 once the animals entered three times in the experimental plots during the second year of livestock grazing (spring, summer and autumn 2021). In winter 2022-2023, during the second-year monitoring campaign, superficial soil samples (0-10 cm) will be again taken to analyse the changes in carbon and nitrogen content and stocks. In this deliverable, we present the results of the 2021 campaign.

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).

The following tables present the mean values at the initial conditions, after the first year of monitoring, and the change occurred in percentage for the main variables (0-10 cm) measured in the experimental plots during the 2021 monitoring campaign in La Garcipollera Research Station. 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. However, some changes could be highlighted. Related to SOC values (Table 2) (i) higher SOCK stocks are observed after the first monitoring year, although these changes are not significant; (ii) the higher increase in SOC stocks and higher SOC values are observed in the C plots (medium livestock pressure); and (iii) the A plots (no livestock) show a slightly decrease. Related to N stocks (Table 3): (i) all the plots show a decrease in N stocks; and (ii) a higher decrease is observed in the A plots, and a lower decrease in the B, C and D plots. Related to the Corg/N ratio (Table 4), a sharply increase is observed in all the plots.

SOC Mg ha^{-1} (10 cm)	YEAR 0	YEAR 1	Change %
A	44.0	41.7	*-5*
B	40.6	46.6	*15*
C	43.7	53.2	*22*
D	36.5	41.9	*15*
CONTROL	41.2	47.4	*15*

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

N Mg ha^{-1} (10 cm)	YEAR 0	YEAR 1	Change %
A	0.32	0.23	*-29*
B	0.29	0.28	*-3*
C	0.31	0.30	*-4*
D	0.25	0.24	*-7*
CONTROL	0.27	0.23	*-15*

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

Corg/N ratio (10 cm)	YEAR 0	YEAR 1	Change %
A	12.08	21.39	*77*
B	11.30	16.22	*44*
C	11.70	17.00	*45*
D	11.27	17.51	*55*
CONTROL	12.36	20.31	*64*

Table 4. Corg/N ratios of soil samples for the initial conditions and first year 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 on 2 dataloggers, one in the treatment subplots and another in the control subplot (see Figure 2).

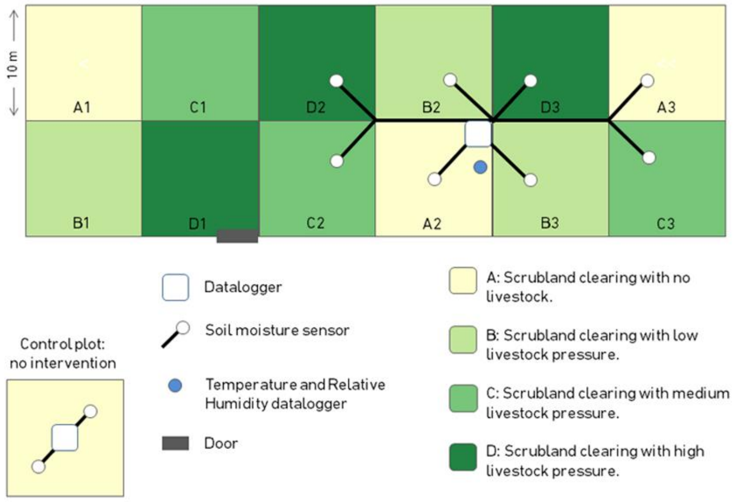


Figure 2. Original monitoring design of the livestock and monitoring subplots.

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 3) 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.

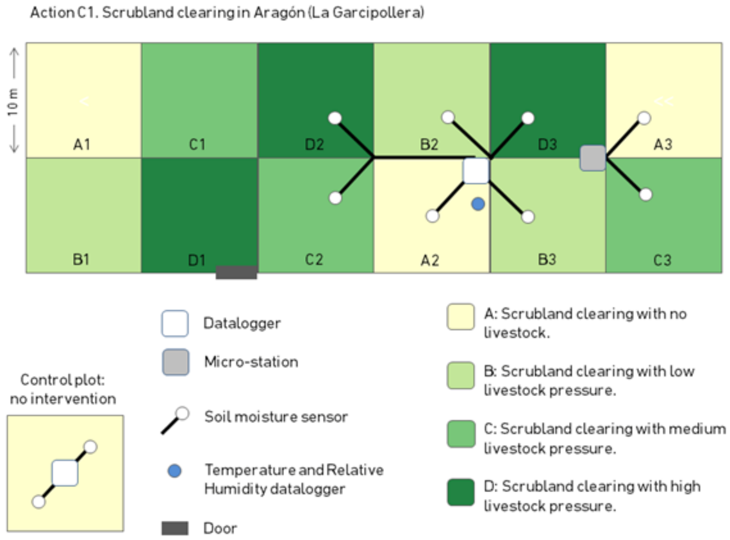


Figure 3. Diagram of the present livestock and monitoring subplots.

Figure 4 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.

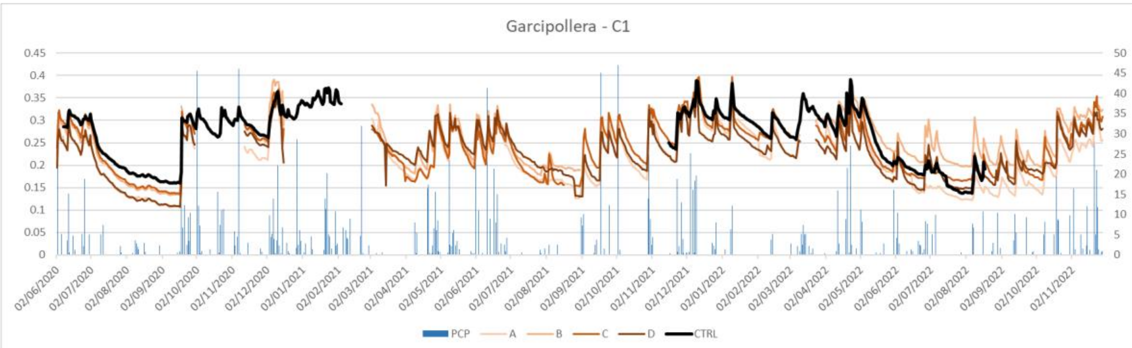
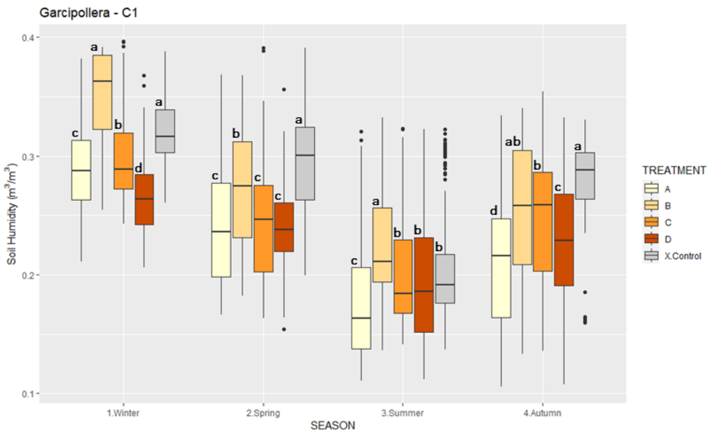


Figure 4. Soil humidity and precipitation in scrubland cleared experimental plot (La Garcipollera).

Figure 4 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 5 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	0.24	0.15	0.088	0.11
	$F_{4,485} = 38.06$ ***	$F_{4,753} = 33.46$ ***	$F_{4,1250} = 30.43$ ***	$F_{4,926} = 28.78$ ***
A	c	c	c	d
B	a	b	a	ab
C	b	c	b	b
D	d	c	b	c
CTRL	a	a	b	a

Figure 5. 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 on pasture production and quality in terms of biodiversity, biomass productivity and nutritive quality. We hypothesize that scrubland clearing interacting with sheep grazing will help maintain biodiverse, productive and highly nutritive herbaceous pastures. Pasture's productivity and nutritive quality maintenance will enable to support extensive livestock activities in these areas, thus enhancing socio-economic development. Moreover, these measures will also restrain scrub encroachment, therefore diminishing the fire risk in these areas.

3.2.1. Biodiversity

Vegetation surveys are arranged inside three subplots (1 m^2) at each replicate plot per typology/treatment: control area not cleared without livestock (SD), cleared without livestock (A), cleared with low grazing level (B), cleared with medium grazing level (C), and cleared with high grazing level (D). Vegetation surveys are carried out in late spring or early summer (May-June), matching with the vegetation growth peak, in order to record the maximum number of species. The first sampling was done in June 2020 to record the initial status of the pasture in the experimental plots. The intermediate status of the pastures were recorded in June 2021 (one year after the livestock entrance) and in June 2022 (two years after the livestock entrance). A final vegetation survey will be done in June 2023 to study the potential effects of livestock activity over a longer period (after three years of grazing).

In the first sampling, we expected to find a positive effect of scrubland clearing in the herbaceous pasture biodiversity, because of the elimination of woody competitors for light, space and nutrients. We expect that this effect will maintain over time in the experimental plots, which we would observe in both the intermediate and final samplings too. On the other hand, we expected not to find any effect of the livestock treatments in the first year (2020) since vegetation surveys were set previous to sheep's entry in the plots, but to find a positive effect of the livestock in the pasture biodiversity along the subsequent years (2021, 2022 and 2023), especially of low and medium grazing levels.

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 in both intermediate statuses (Figure 6). Specifically, we found a larger woody species cover and a lower herbaceous species cover in the control plots (not cleared) than in the cleared plots. On the one hand, contrarily to what expected, in the first monitoring we found significant differences between livestock treatments for all the bare soil cover and the herbaceous and woody species cover. On the other hand, as we expected, we found significant differences between livestock treatments in the subsequent years for the bare soil cover, for herbaceous species in 2021 only and woody species in 2022 only. In particular, the significantly largest herbaceous species cover was found in the medium grazing in 2021 and the largest woody species cover was found in the plots without livestock in 2022.

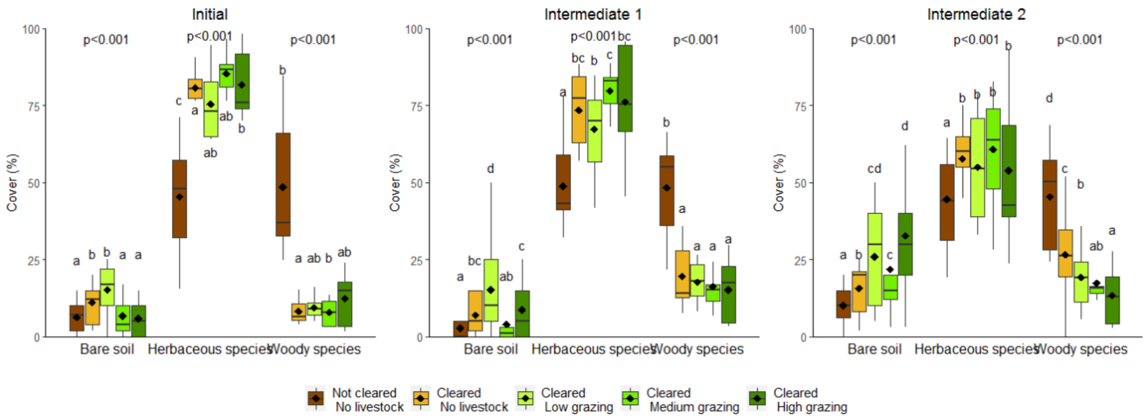


Figure 6. Boxplots showing mean cover (and data variability) of the bare soil, herbaceous species and woody species for each treatment: not cleared without livestock (SD), cleared without livestock (A), cleared with low level of grazing (B), cleared with medium level of grazing (C), and cleared with high level of grazing (D). Initial status (first monitoring, 2020) and Intermediate statuses (2021 and 2022) of the experimental plots are shown.

In terms of total species richness, we found significant differences between the control plot and the cleared plots in all the monitoring years (Figure 7). In the initial sampling we found significantly less species in the control than in the cleared plots submitted to medium and high grazing. In the intermediate statuses (2021 and 2022) we found significantly less species in the control than in the cleared plots submitted to low and medium grazing. Regarding the livestock intensity effects, we did not find significant differences in total species richness neither in the initial status nor in the intermediate statuses.

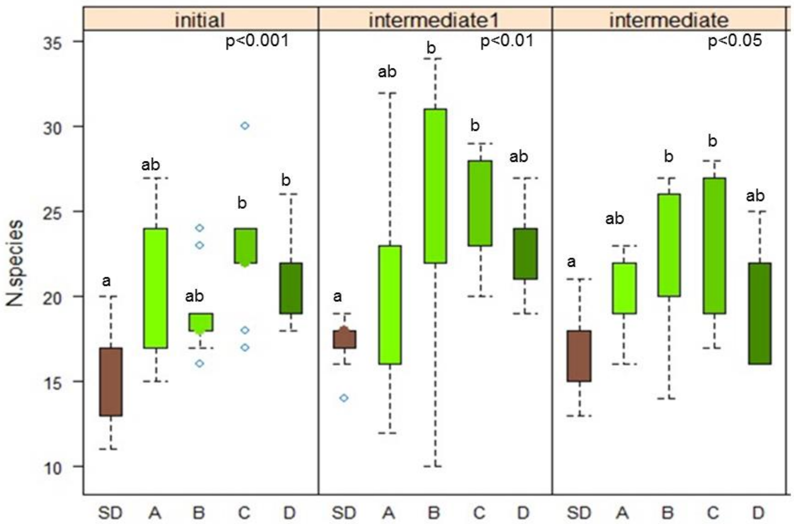


Figure 7. Boxplots showing mean species richness (and data variability) for each treatment: not cleared without livestock (SD), cleared without livestock (A), cleared with low level of grazing (B), cleared with medium level of grazing (C), and cleared with high level of grazing (D). Initial status (first monitoring, 2020) and intermediate statuses (2021 and 2022) of the experimental plots are shown.

Taking the species composition in terms of functional groups cover (grasses, legumes and other families), significant differences were found between the control plots and the cleared plots, and between the livestock treatments (Figure 8). Regarding grasses, the significantly largest cover was found in the cleared plots without livestock in the initial and intermediate statuses. With regard to legumes, the largest cover was found in the control plots, probably mainly due to the abundance of woody legumes (i.e. *Genista scorpius*) which were not removed in the control area and were removed in the cleared area. About other families, we found the largest cover in the control plots and medium grazing plots in the initial status, in the not grazed and high grazing plots in 2021, and in the medium grazed plots in 2022. These differences may be most probably due to inter-annual differences in the growing peak, since the majority of these species are annuals.

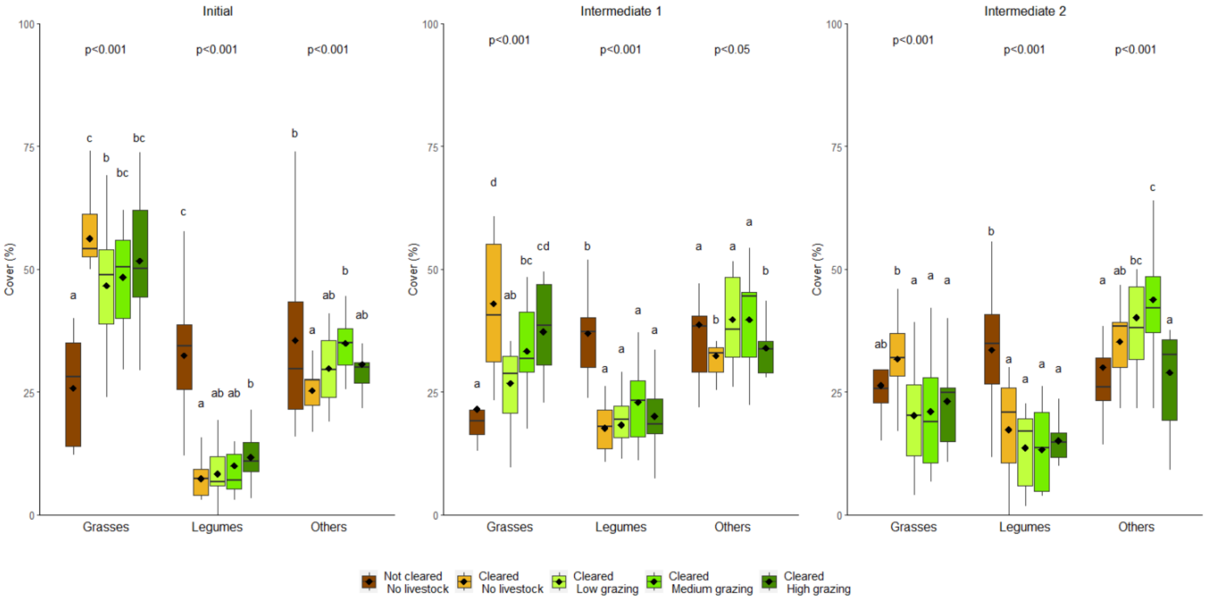


Figure 8. Boxplots showing mean cover (and data variability) of grasses, legumes and other families for each treatment: not cleared without livestock (SD), cleared without livestock (A), cleared with low level of grazing (B), cleared with medium level of grazing (C), and cleared with high level of grazing (D). Initial status (first monitoring, 2020) and Intermediate statuses (2021 and 2022) of the experimental plots are shown.

3.2.2. Pasture production and quality

Pasture production and quality samplings are carried out in late spring or early summer (May-June), as well as the biodiversity surveys. The first sampling was done in June 2020 in order to record the initial status of the pasture in the experimental plots. The second sampling will be made in June 2023 in order to record the final status of the pastures. We considered that recording the intermediate status of the pastures in terms of production and quality was not relevant because it is a short period of time to achieve significant results. Therefore, vegetation samples were not gathered in the 2nd monitoring campaign and consequently, no results are shown in this report. Results of the initial status of the pasture production and quality are available in the first monitoring report.

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 also the soil properties, with significant consequences for runoff and soil erosion. The objective of this environmental monitoring is to assess the effect of scrub clearing and different livestock intensities on the hydrological response and soil erosion.

For this purpose, we carried out rainfall simulation experiments in all monitoring subplots. Here we present the results of the first (2020) and second (2021) year of monitoring. 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 general, the hydrological (RC) and sedimentological (SC, SP) responses were higher in the plots under treatments than in the control plot (RC=0.04, SC=0.2 g/l and SP=0.3 g/m^2). The highest hydrological response was in the cleared plots with higher level of grazing (C and D), with RC>0.3. However, in terms of soil erosion, the differences between treated plots were not clear, with similar SC values (except for B plots, with a lower slope gradient). Additional experiments (monitoring campaigns 2022 and 2023) are needed to confirm these tendencies.

Site	Land management	Slope (%)	RI (mm h^{-1})	RC (-)	TR (min)	WF (cm)	SC (g L^{-1})	SP (g m^{-2})
Garcipollera	Control	18	61.8	0.04	8.2		0.15	0.3
	Cleared without livestock (A)	22	52.9	0.21	6.7	7.0	0.37	1.9
	Cleared with low pressure (B)	16	78.4	0.03	6.1	8.7	0.06	0.4
	Cleared with medium pressure (C)	20	78.6	0.34	10.8	12.7	0.29	3.2
	Cleared with high pressure (D)	23	55.5	0.38	6.3	8.0	0.30	2.6

Table 5. Mean hydrogeological and sedimentological variables extracted from rainfall simulations in Garcipollera in the first (2020) and second (2021) year of monitoring. RI: rainfall intensity (mm h^{-1}), RC: Runoff coefficient (mm mm^{-1}), IR: Infiltration rate (mm h^{-1}), TR: Time to runoff (min), WF: Wetting front (cm), SC: Sediment concentration (g l^{-1}), SP: Sediment production or erosion rate (g m^{-2}).

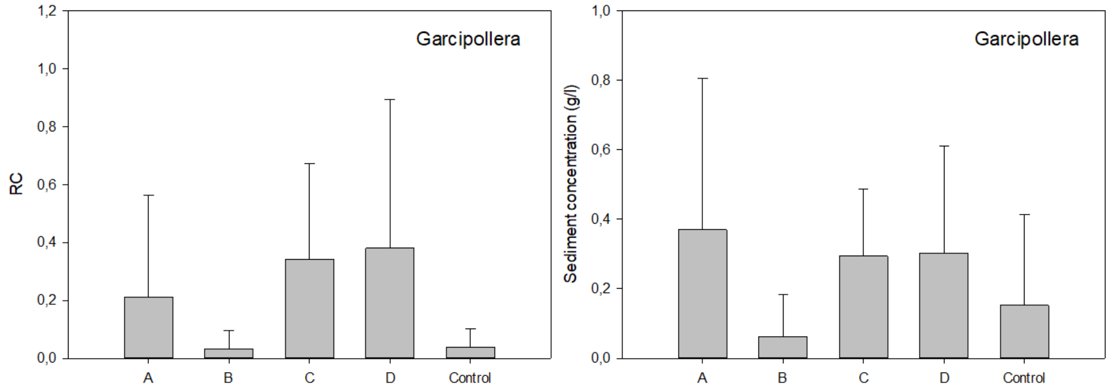


Figure 9. Mean runoff coefficient (RC) and sediment concentration for each treatment: not cleared without livestock (control), cleared without livestock (A), cleared with low level of grazing (B), cleared with medium level of grazing (C), and cleared with high level of grazing (D), in Garcipollera.

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 10-11-2022, 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 10 for more details).

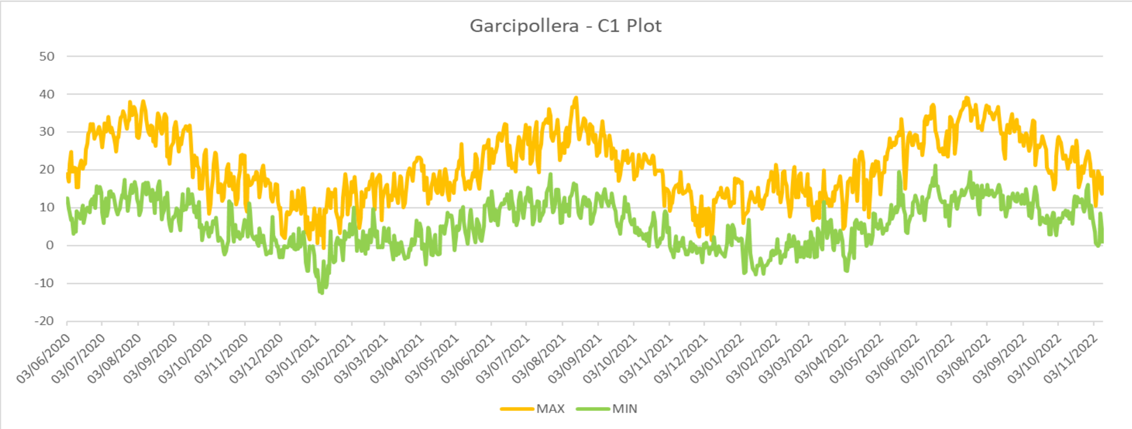


Figure 10. Daily average of minimum and maximum temperature and relative humidity in scrubland cleared experimental plots located in La Garcipollera.

Figure 11 shows monthly averages of maximum temperature, minimum temperature and mean monthly precipitation for the period 06-2020 to 11-2022 (29 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 20.25 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.

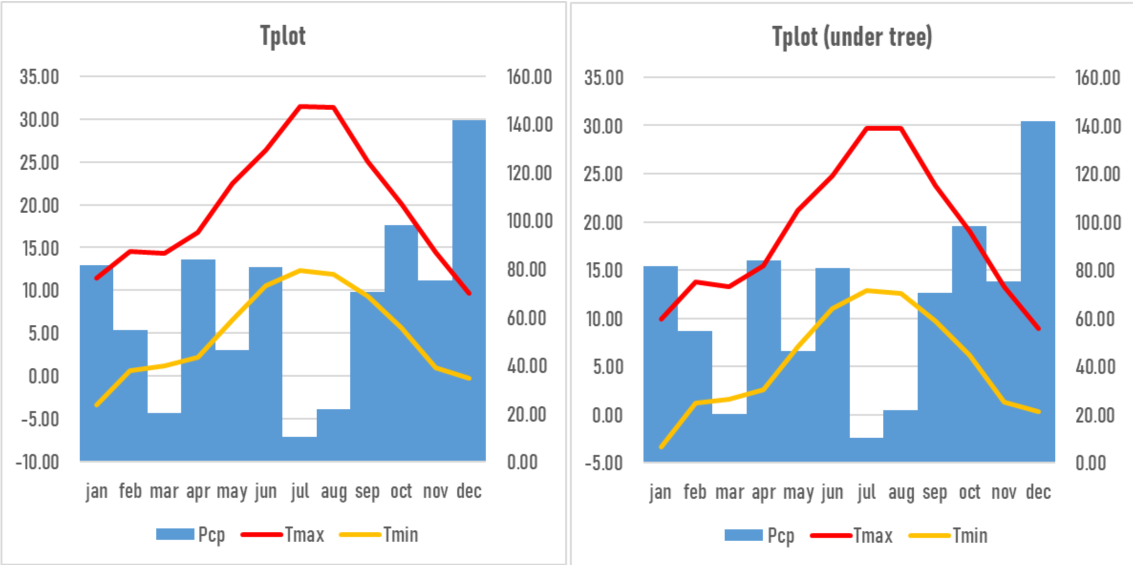


Figure 11. Climogram scrubland cleared experimental plot. Left: T in the subplot, right: T under a tree near the subplot.

4. Results of the 1st and 2nd 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 initial monitoring variables and the results of the 1st year monitoring campaign 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 first-year monitoring campaign was carried out in November 2021 once the animals entered three times in the experimental plots during the second year of livestock grazing (spring, summer and autumn 2021). In winter 2022-2023, during the second-year monitoring campaign, superficial soil samples (0-10 cm) will be again taken to analyze the changes in carbon and nitrogen. In this deliverable, we present the results of 2021 campaign.

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 with a 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.

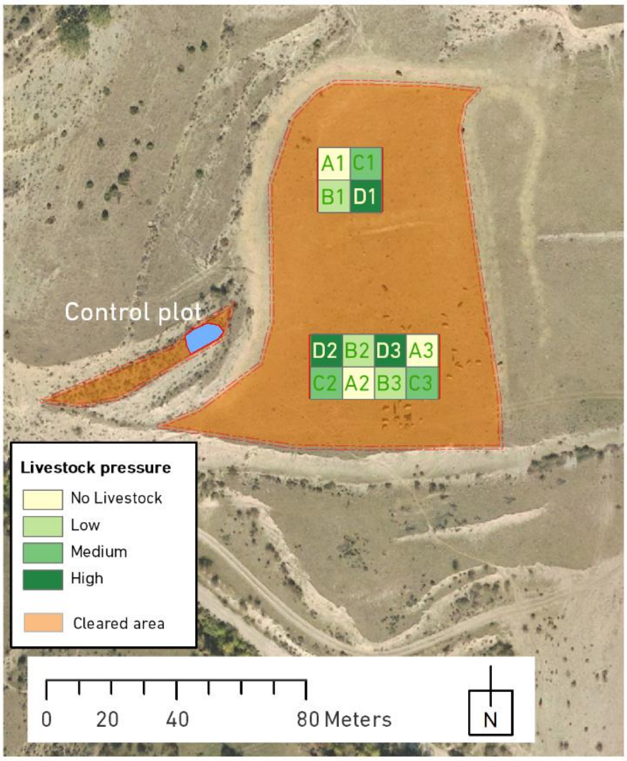


Figure 12. Location of the monitoring plots and replicates of the experimental design.

4.1. Monitoring results of the Soil

4.1.1. Soil characteristics

The initial soil sampling of the monitoring variables was carried out in June 2020 and the first-year monitoring campaign was carried out in November 2021 once the animals entered three times in the experimental plots during the second year of livestock grazing (spring, summer and autumn 2021). In winter 2022-2023, during the second-year monitoring campaign, superficial soil samples (0-10 cm) will be again taken to analysis the changes in carbon and nitrogen. In this deliverable, we present the results of the 2021 campaign.

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).

The following tables present the mean values at the initial conditions, after the first year of monitoring, and the change occurred in percentage for the main variables (0-10 cm) measured in the experimental plots during the 2021 monitoring campaign 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. However, some changes could be highlighted. Related to SOC values (Table 6) (i) lower SOCK stocks are observed after the first monitoring year, except in the D plots (high livestock pressure) although these changes are not significant; (ii) the higher decrease in SOC stocks is observed in B plots (low livestock pressure) and control plots; and (iii) higher SOC values are observed in the C plots (medium livestock pressure). Related to N stocks (Table 7): (i) all the plots show an increase in N stocks; and (ii) a higher increase is observed in the B and Control plots, and a lower increase in the D plots. Related to the Corg/N ratio (Table 8): (i) an increase is observed in all the plots; and (ii) the higher increases are observed in the D and Control plots.

SOC Mg ha^{-1} (10 cm)	YEAR 0	YEAR 1	Change %
A	56.78	52.55	-7.5
B	65.03	45.66	-29.8
C	61.07	56.60	-7.3
D	51.41	55.92	8.8
CONTROL	53.57	41.85	-21.9

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

N Mg ha^{-1} (10 cm)	YEAR 0	YEAR 1	Change %
A	0.42	0.48	12.5
B	0.35	0.61	73.5
C	0.38	0.53	38.2
D	0.39	0.40	4.7
CONTROL	0.24	0.39	66.3

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

Corg/N ratio (10 cm)	YEAR 0	YEAR 1	Change %
A	11.32	12.83	13.3
B	11.46	13.53	18.0
C	11.25	13.66	21.4
D	11.35	16.61	46.4
CONTROL	12.23	16.61	35.8

Table 8. Corg/N ratios of soil samples for the initial conditions and first year 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 on 2 dataloggers, one in the treatment subplots and another in the control subplot (see Figure 13). 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 on 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 14.

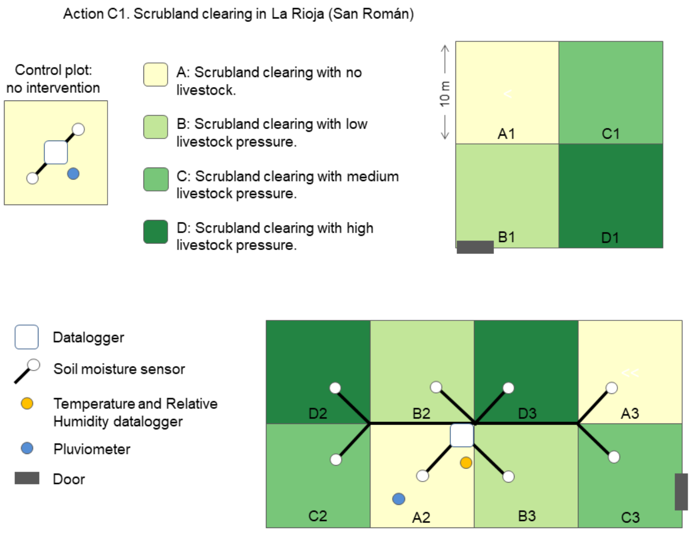


Figure 13. Original monitoring design of the livestock and monitoring subplots.

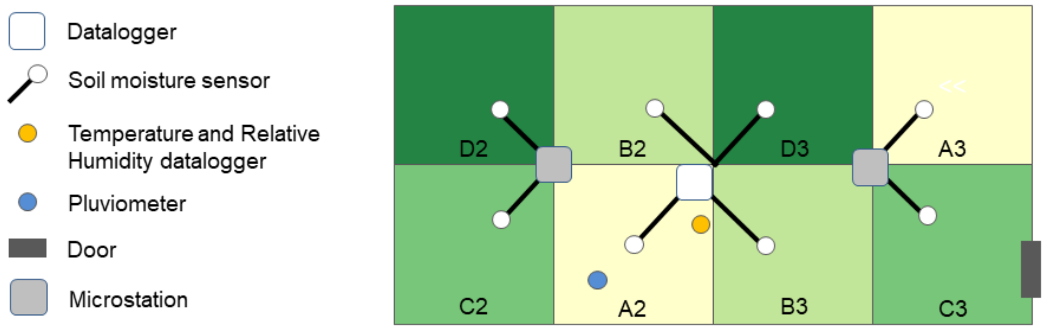


Figure 14. New monitoring design of the livestock and monitoring subplots.

Figure 15 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 16).

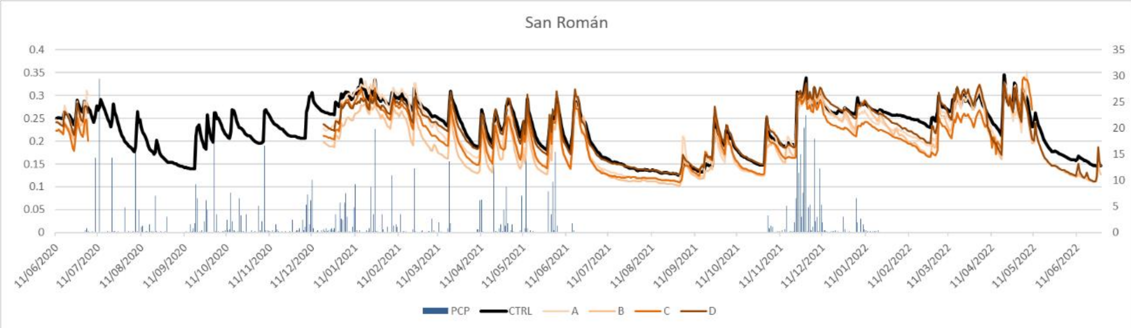
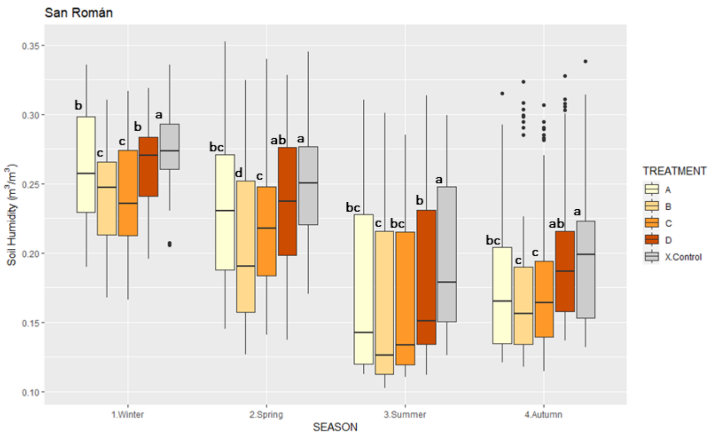


Figure 15. Soil humidity and precipitation in scrubland cleared experimental plot (San Román).



	Winter	Spring	Summer	Autumn
R^2	0.14	0.086	0.059	0.078
	$F_{4,823}$ =34.78 ***	$F_{4,869}$ =20.69 ***	$F_{4,717}$ =11.33 ***	$F_{4,541}$ =9.32 ***
A	b	bc	bc	bc
B	c	d	c	c
C	c	c	bc	c
D	b	ab	b	ab
CTRL	a	a	a	a

Figure 16. Boxplot with seasonal soil humidity values in scrubland cleared experimental plot (San Román).

Figure 16 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 on pasture production and quality in terms of biodiversity, biomass productivity and nutritive quality. We hypothesize that scrubland clearing interacting with sheep grazing will help maintain biodiverse, productive and highly nutritive herbaceous pastures. Pasture's productivity and nutritive quality maintenance will enable to support extensive livestock activities in these areas, thus enhancing socio-economic development. Moreover, these measures will also restrain scrub encroachment, therefore diminishing the fire risk in these areas.

4.2.1. Biodiversity

Vegetation surveys are arranged inside three subplots (1 m^2) at each replicate plot per typology/treatment: control area not cleared without livestock (SD), cleared without livestock (A), cleared with low grazing level (B), cleared with medium grazing level (C), and cleared with high grazing level (D). Vegetation surveys are carried out in late spring or early summer, matching with the vegetation growth peak, in favour of recording the maximum number of species. The first sampling was done June 2020 in order to record the initial status of the pasture in the experimental plots. The second monitoring campaign was made in May 2022 in order to record the intermediate status of the pastures two years after the livestock entrance. A final vegetation survey will be done in May 2023 to study potential effects of the livestock activity over a longer period of time (after three years of grazing).

In the first sampling, we expected to find a positive effect of the scrubland clearing in the herbaceous pasture biodiversity, because of the elimination of woody competitors for light, space and nutrients. We expect that this effect will maintain over time in the experimental plots, which we would observe in both the intermediate and final samplings too. On the other hand, we expected not to find any effect of the livestock treatments in the first year (2020) since vegetation surveys were set previous to sheep's entry in the plots, but to find a positive effect of the livestock in the pasture biodiversity along the subsequent years (2022 and 2023), especially of low and medium grazing levels.

We found significant differences between the cleared and not cleared area, being herbaceous species cover significantly lower and woody species cover significantly larger in the control area than in the cleared area in the initial and intermediate statuses (Figure 17). Regarding the effects of livestock, in the first monitoring we found a significantly larger bare soil cover in medium grazing than in the other treatments, a significantly larger cover of woody species in the plots not submitted to grazing and we did not find any differences between livestock treatments for herbaceous species cover. On the other hand, in the second monitoring we found a significantly larger bare soil cover and a lower herbaceous species cover in the plots without livestock than in those submitted to low and high grazing, and we found the largest woody species cover in plots without livestock.

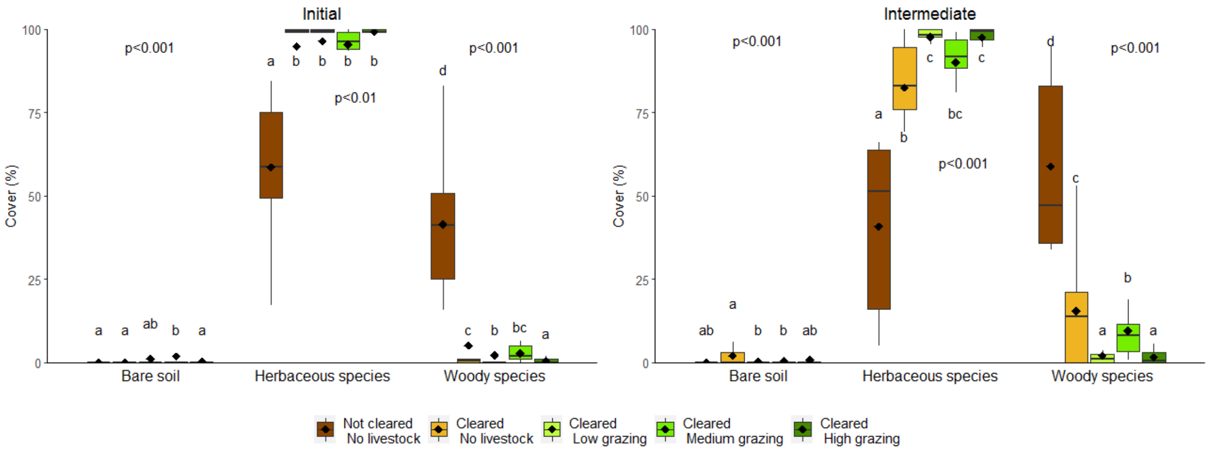


Figure 17. Boxplots showing mean cover (and data variability) of the bare soil, herbaceous species and woody species for each treatment: not cleared without livestock (SD), cleared without livestock (A), cleared with low level of grazing (B), cleared with medium level of grazing (C), and cleared with high level of grazing (D). Initial status (first monitoring, 2020) and Intermediate status (second monitoring, 2022) of the experimental plots are shown.

In terms of total species richness, in the initial monitoring we found significant differences between the control plots and the cleared plots. However, in the second monitoring (intermediate status) we found significant differences in total species richness between the control plots and the cleared plots not submitted to grazing, only (Figure 18). Comparing the cleared plots with different grazing levels, as we expected, we did not find any significant differences in total species richness in the initial status and we found significant differences between livestock treatments in the second sampling, being the lowest species richness found in cleared plots without livestock.

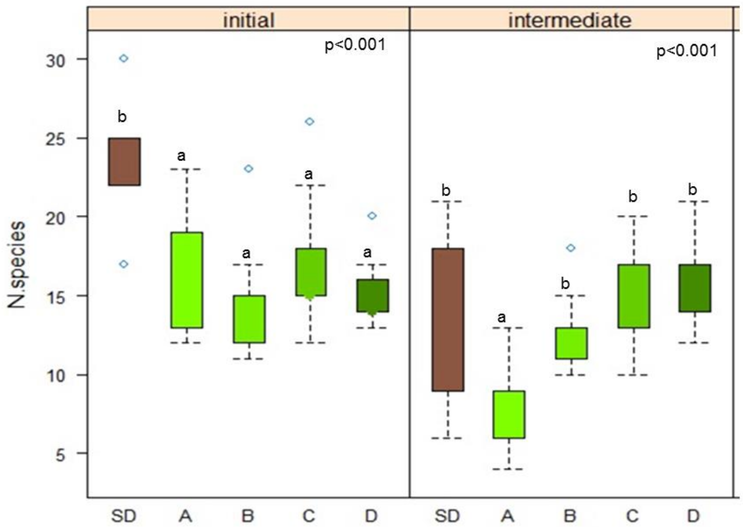


Figure 18. Boxplots showing mean species richness (and data variability) for each treatment: not cleared without livestock (SD), cleared without livestock (A), cleared with low level of grazing (B), cleared with medium level of grazing (C), and cleared with high level of grazing (D). Initial status (first monitoring, 2020) and Intermediate status (second monitoring, 2022) of the experimental plots are shown.

4.2.2. Pasture production and quality

Pasture production and quality samplings are carried out in late spring or early summer (May-June), as well as the biodiversity surveys. The first sampling was done in June 2020 in order to record the initial status of the pasture in the experimental plots. The second sampling will be made in the 3rd monitoring campaign in June 2023 in order to record the final status of the pastures. We considered that recording the intermediate status of the pastures in terms of production and quality was not relevant because it is a short period of time to achieve significant results. Therefore, vegetation samples were not gathered in the 2nd monitoring campaign and consequently, no results are shown in this report. Results of the initial status of the pasture production and quality are available in the first monitoring report.

4.3. Monitoring results of Rainfall simulations

In La Rioja, the monitoring scheme has been the same as in Garcipollera: two monitoring campaigns (2020 and 2021) in winter, after the livestock grazed for the third time within the year, have been carried out.

In San Román, the hydrological and sedimentological responses were very limited in the control and all treated plots, with no runoff and no sediment except for the plot with the highest level of grazing (D) that showed a RC of 0.15, a SC of 0.02 g/l and a SP of 0.3 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.

Site	Land management	Slope (%)	RI (mm h^{-1})	RC (-)	TR (min)	WF (cm)	SC (g L^{-1})	SP (g m^{-2})
San Roman	Control	8	48.8	0.00		4.0	0.00	0.0
	Cleared without livestock (A)	13	37.6	0.00		5.5	0.00	0.0
	Cleared with low pressure (B)	12	40.9	0.00		5.7	0.00	0.0
	Cleared with medium pressure (C)	12	40.0	0.00		6.3	0.00	0.0
	Cleared with high pressure (D)	13	41.3	0.15	11	5.6	0.02	0.3

Table 9. Mean hydrogeological and sedimentological variables extracted from rainfall simulations in San Román in the first (2020) and second (2021) year of monitoring. RI: rainfall intensity (mm h^{-1}), RC: Runoff coefficient (mm mm^{-1}), IR: Infiltration rate (mm h^{-1}), TR: Time to runoff (min), WF: Wetting front (cm), SC: Sediment concentration (g l^{-1}), SP: Sediment production (g m^{-2}).

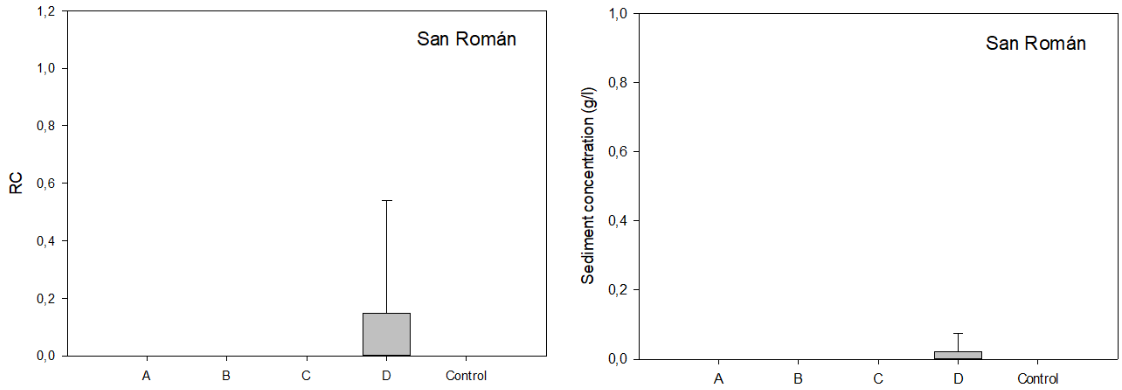
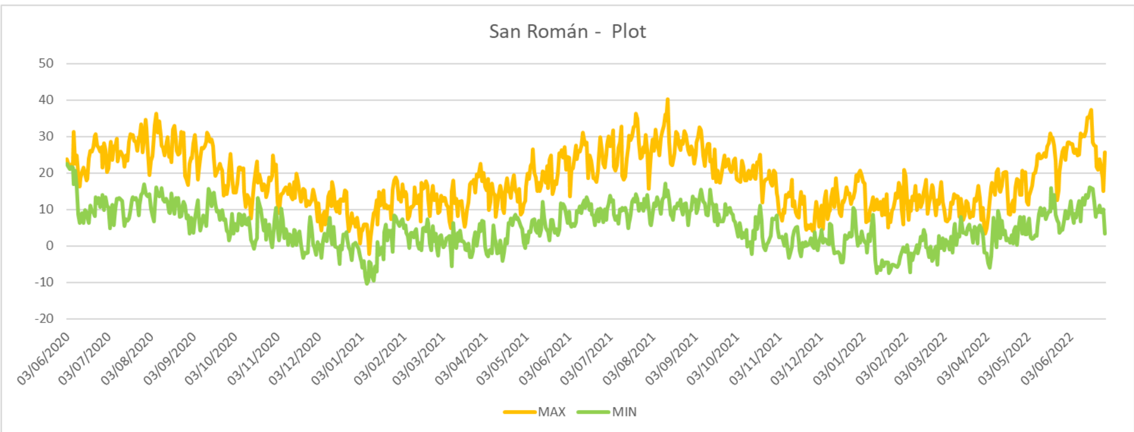


Figure 19. Mean runoff coefficient (RC) and sediment concentration for each treatment: not cleared without livestock (control), cleared without livestock (A), cleared with low level of grazing (B), cleared with medium level of grazing (C), and cleared with high level of grazing (D), in San Román.

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 20).



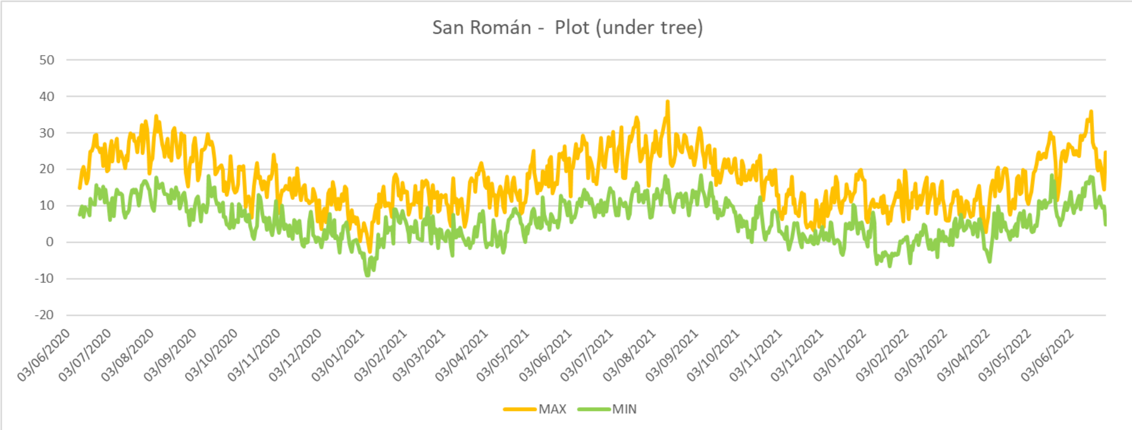


Figure 20. Daily average of minimum and maximum temperature and relative humidity in scrubland cleared experimental plots in San Román (La Rioja).

Figure 21 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 also 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, in order 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.

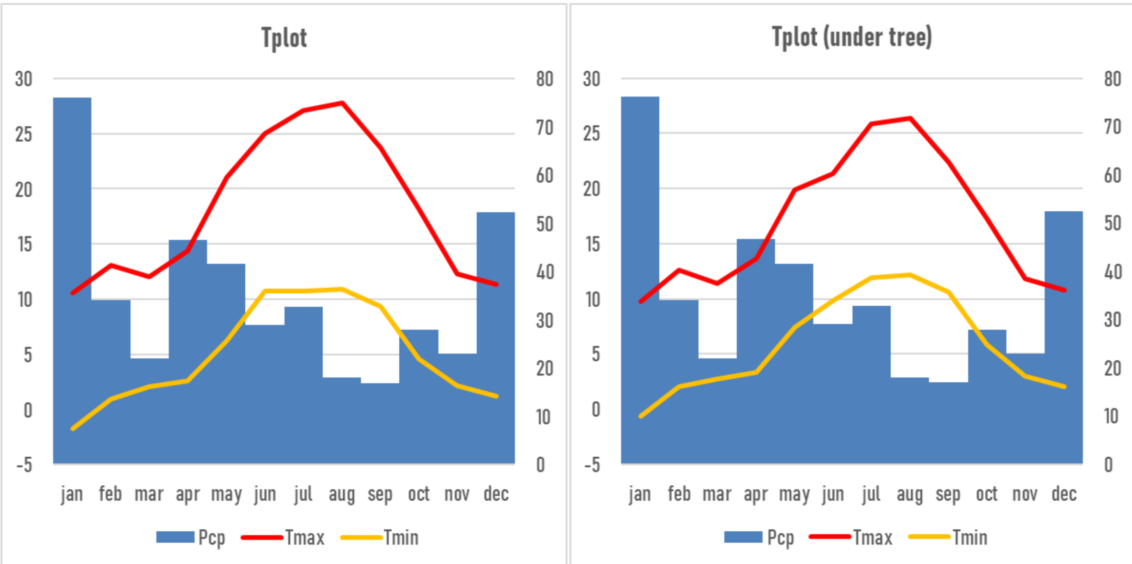


Figure 21. Climogram scrubland cleared experimental plot (San Roman). Left: Tplot in the subplot A2, right: Tplot under tree.

5. Results of the 1st and 2nd 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 initial monitoring variables and the results of the 1st year monitoring campaign 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 first-year monitoring campaign was carried out in November 2021 once the animals entered three times in the experimental plots during the second year of livestock grazing (spring, summer and autumn 2021). In winter 2022-2023, during the second-year monitoring campaign, superficial soil samples (0-10 cm) will be again taken to analyse the changes in carbon and nitrogen. In this deliverable, we present the results of 2021 campaign.

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 with a 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 (the control is not shown in this picture but can be checked in Nadal-Romero *et al*. (2019, 2020a, 2020b).

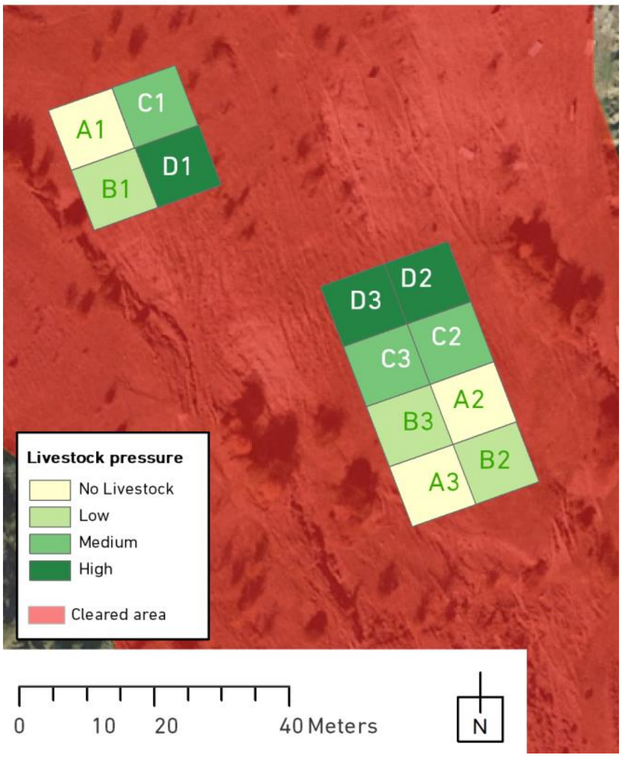


Figure 22. Location of the monitoring plots and replicates of the experimental design.

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 monitoring campaign was carried out in November 2021 once the animals entered three times in the experimental plots during the second year of livestock grazing (spring, summer and autumn 2021). In winter 2022-2023, during the second-year monitoring campaign, superficial soil samples (0-10 cm) will be again taken to analyse the changes in carbon and nitrogen. In this deliverable, we present the results of the 2021 campaign.

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).

The following tables present the mean values at the initial conditions, after the first year of monitoring and the change occurred in percentage for the main variables (0-10 cm) measured in the experimental plots during the 2021 monitoring campaign 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 could be highlighted. Related to SOC values (Table 10) (i) higher SOCK stocks are observed after the first monitoring year, except in the control plots, although these changes are not significant; (ii) the higher increase in SOC stocks is observed in A and B plots (low and medium livestock pressure); and (iii) higher SOC values are observed in the B plots (low livestock pressure). Related to N stocks (Table 11): (i) all the plots show an increase in N stocks; and (ii) a higher and significant increase is observed in the C, 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).

SOC Mg ha^{-1} (10 cm)	YEAR 0	YEAR 1	Change %
A	20.73	36.23	*74.8*
B	27.65	40.92	*48.0*
C	26.30	28.00	*6.5*
D	18.56	22.91	*23.4*
CONTROL	44.05	39.81	*-9.6*

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

N Mg ha^{-1} (10 cm)	YEAR 0	YEAR 1	Change %
A	0.17	0.24	*40.4*
B	0.21	0.32	*51.3*
C	0.17	0.31	*76.9*
D	0.10	0.27	*176.0*
CONTROL	0.24	0.42	*74.5*

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

Corg/N ratio (10 cm)	YEAR 0	YEAR 1	Change %
A	6.02	21.55	*258.1*
B	6.30	21.32	*238.3*
C	6.20	19.91	*221.4*
D	5.18	28.11	*442.6*
CONTROL	8.72	20.71	*137.6*

Table 12. Corg/N ratios of soil samples for the initial conditions and first year 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 on 2 dataloggers, one in the treatment subplots and another in the control subplot (Figure 23).

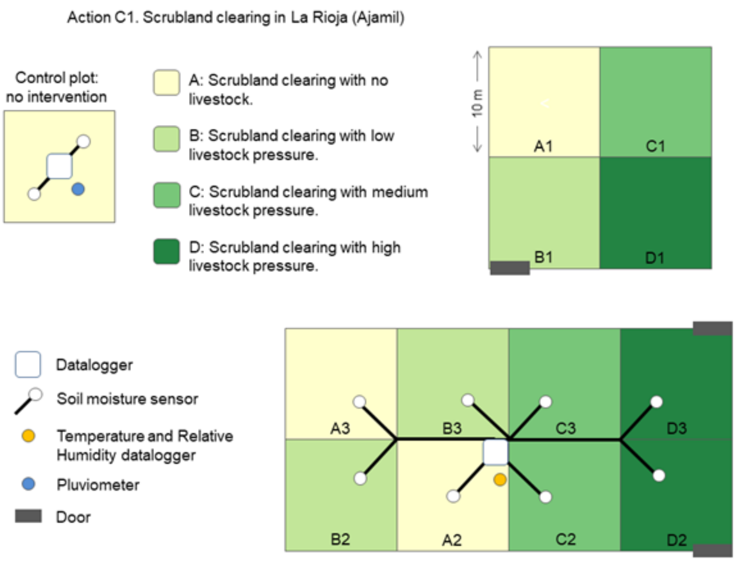


Figure 23. Diagram of the livestock and monitoring subplots.

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.

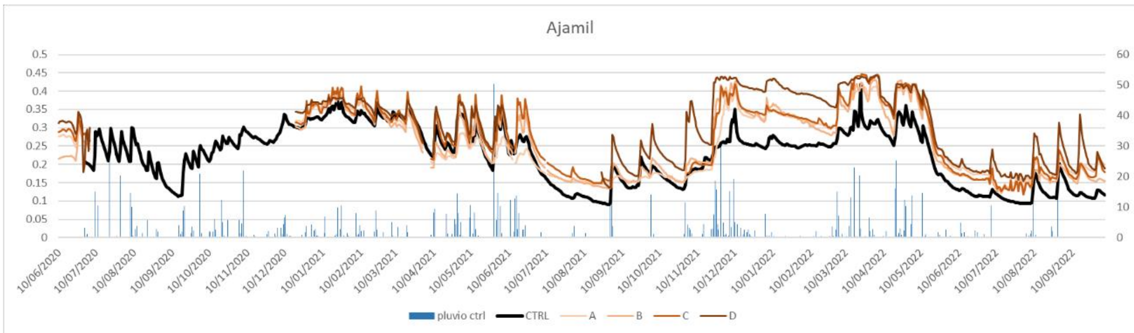
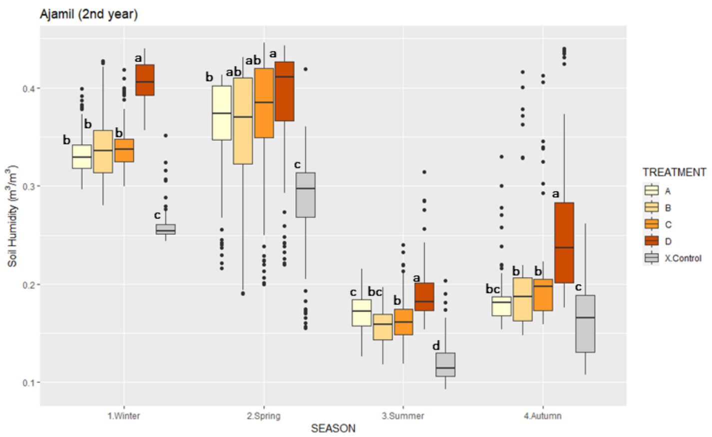


Figure 24. Soil humidity and precipitation in scrubland cleared experimental plot (Ajamil).

Figure 24 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	0.77	0.24	0.505	0.26
	$F_{4,445} = 370.5$ ***	$F_{4,445} = 36.79$ ***	$F_{4,445} = 116.3$ ***	$F_{4,418} = 37.06$ ***
A	b	b	c	bc
B	b	ab	bc	b
C	b	ab	b	b
D	a	a	a	a
CTRL	c	c	d	c

Figure 25. Boxplot with seasonal soil humidity values in scrubland cleared experimental plot (Ajamil).

Figure 25 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 on pasture production and quality in terms of biodiversity, biomass productivity and nutritive quality. We hypothesize that scrubland clearing interacting with sheep grazing will help maintain biodiverse, productive and highly nutritive herbaceous pastures. Pasture's productivity and nutritive quality maintenance will enable to support extensive livestock activities in these areas, thus enhancing socio-economic development. Moreover, these measures will also restrain scrub encroachment, therefore diminishing the fire risk in these areas.

5.2.1. Biodiversity

Vegetation surveys are arranged inside three subplots (1 m^2) at each replicate plot per typology/treatment: control area not cleared without livestock (SD), cleared without livestock (A), cleared with low grazing level (B), cleared with medium grazing level (C), and cleared with high grazing level (C). Vegetation surveys are carried out in late spring or early summer (May-June), matching with the vegetation growth peak, in order to record the maximum number of species. The first sampling was done in June 2020 to record the initial status of the pasture in the experimental plots. The second monitoring campaign was made in May 2022 to record the intermediate status of the pastures one year after the livestock entrance. A final vegetation survey will be done in May 2023 to study the potential effects of livestock activity over a longer period (after three years of grazing).

In the first sampling, we expected to find a positive effect of scrubland clearing in the herbaceous pasture biodiversity, because of the elimination of woody competitors for light, space and nutrients. We expect that this effect will maintain over time in the experimental plots, which we would observe in both the intermediate and final samplings too. On the other hand, we expected not to find any effect of the livestock treatments in the first year (2020) since vegetation surveys were set previous to sheep's entry in the plots, but to find a positive effect of the livestock in the pasture biodiversity along the subsequent years (2022 and 2023), especially of low and medium grazing levels.

As we expected, in the first year monitoring, we found significant differences between the cleared and not cleared area, being herbaceous species cover significantly lower and woody species cover significantly larger in the control area than in the cleared area (*Figure 26*). This tendency maintains in the intermediate survey. Regarding the effects of livestock, in the first monitoring we found a significantly lower bare soil cover in medium grazing than in the other treatments, a significantly larger cover of woody species in the plots not submitted to grazing and we did not find any differences between livestock treatments for herbaceous species cover. On the other hand, in the second monitoring we found a significantly larger bare soil cover and a lower herbaceous species cover in the plots not submitted to grazing than in those submitted to grazing, independently of the grazing level.

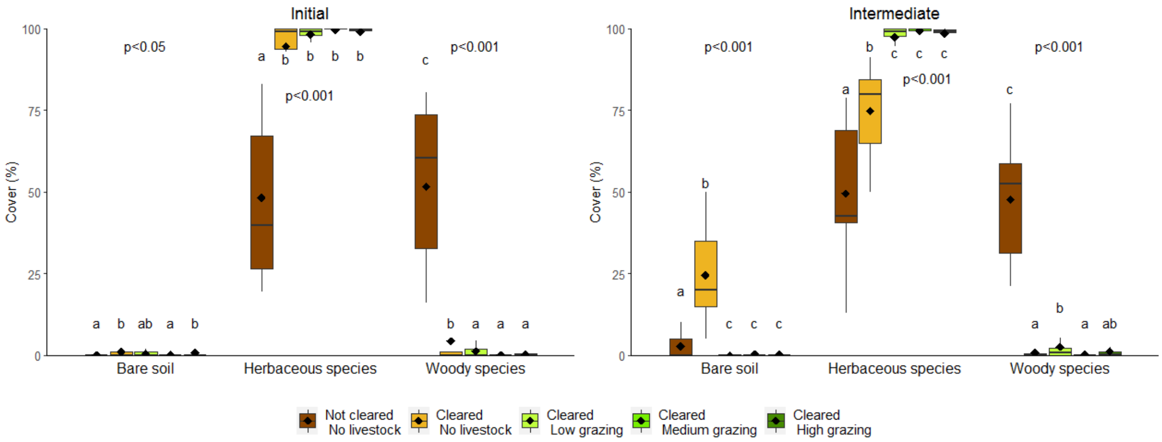


Figure 26. Boxplots showing mean cover (and data variability) of the bare soil, herbaceous species and woody species for each treatment: not cleared without livestock (SD), cleared without livestock (A), cleared with low level of grazing (B), cleared with medium level of grazing (C), and cleared with high level of grazing (D). Initial status (first monitoring, 2021) and Intermediate status (second monitoring, 2022) of the experimental plots are shown.

In terms of total species richness, in the initial monitoring we found significant differences between the control plots and the cleared plots. However, in the second monitoring (intermediate status) we found significant differences in total species richness between the control plots and the cleared plots not submitted to grazing, only (Figure 27). Comparing the cleared plots with different grazing levels, as we expected, we did not find any significant differences in total species richness in the initial status and we found significant differences between livestock treatments in the second sampling. In the intermediate status, the largest species richness was found in the plots submitted to high grazing.

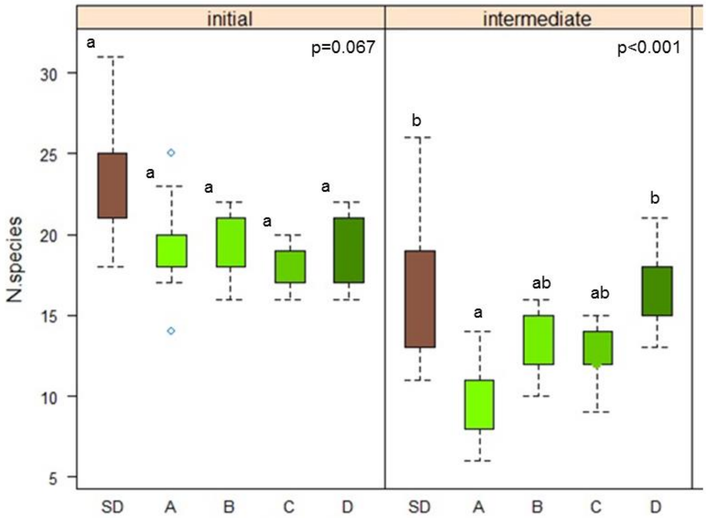


Figure 27. Boxplots showing mean species richness (and data variability) for each treatment: not cleared without livestock (SD), cleared without livestock (A), cleared with low level of grazing (B), cleared with medium level of grazing (C), and cleared with high level of grazing (D). Initial status (first monitoring, 2021) and Intermediate status (second monitoring, 2022) of the experimental plots are shown.

Regarding species composition by differentiating the species into functional groups (grasses, legumes and other families), in the initial status, we found a significantly lower cover of grasses and legumes and a larger cover of other families in the control plots than in the cleared plots (Figure 28). In the intermediate status, we found the same tendency, but in legumes cover, which was significantly lower in the cleared plots not submitted to livestock than in the control plots. Considering the livestock effect, we did not find significant differences between treatments in the initial conditions, except for the legumes cover, which was significantly higher in plots submitted to high grazing than in plots not submitted to livestock. In the intermediate status, we found significant differences between livestock treatments for all grasses, legumes and other families cover. Specifically, the lowest grasses cover was found in plots submitted to high grazing, the lowest legumes cover and other species cover was found in plots without livestock.

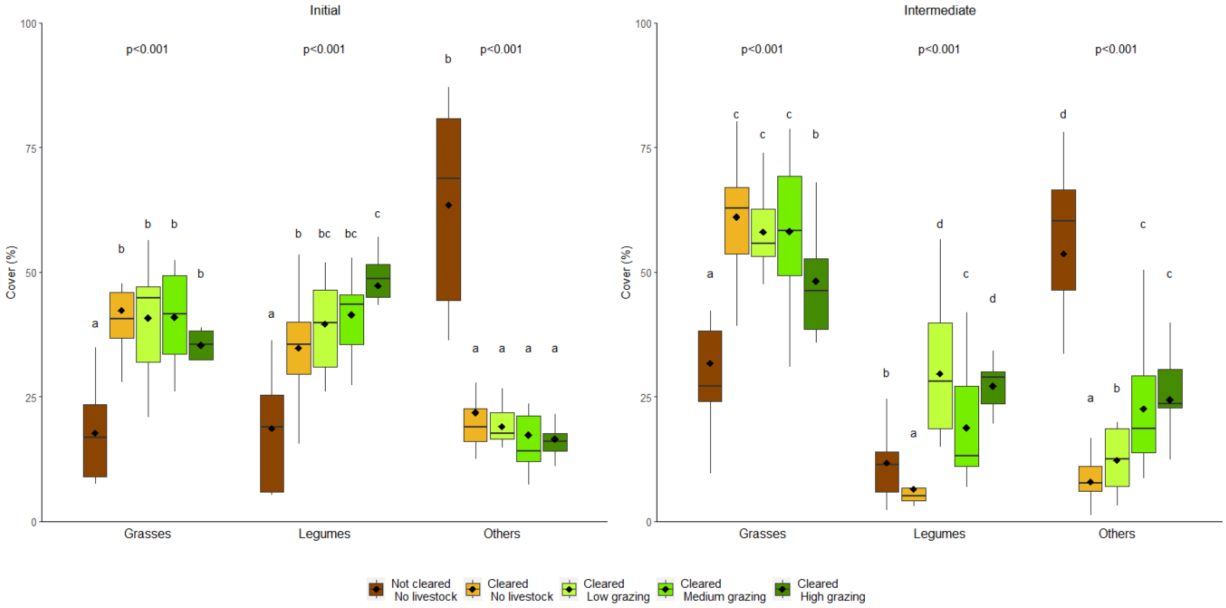


Figure 28. Boxplots showing mean cover (and data variability) of grasses, legumes and other families for each treatment: not cleared without livestock (SD), cleared without livestock (A), cleared with low level of grazing (B), cleared with medium level of grazing (C), and cleared with high level of grazing (D). Initial status (first monitoring, 2021) and Intermediate status (second monitoring, 2022) of the experimental plots are shown.

5.2.2. Pasture production and quality

Pasture production and quality samplings are carried out in late spring or early summer (May-June), as well as the biodiversity surveys. The first sampling was done in May 2021 because in 2020 vegetation was withered away (delays in samplings due to mobility restrictions of Covid-19), therefore, the initial status of the pasture biomass and quality will be assumed not to be recorded. The second sampling will be made in the 3rd monitoring campaign in May 2023 in order to record the final status of the pastures. Previous results on the pasture production and quality are available in the first monitoring report.

5.3. Monitoring results of Rainfall simulations

In Ajamil, the monitoring scheme has been the same as in San Román, with two monitoring campaigns (2020 and 2021) in winter, after the livestock grazed for the third time within the year. Here, the hydrological and sedimentological responses were higher in the plots under treatment than in the control plot, which showed no runoff nor soil erosion. Clearly, the hydrological response increased with increasing level of grazing (RC from 0.16 without grazing A, to 0.31 with high level of grazing, D). Interestingly, the response was similar in terms of soil erosion, with SC values between 0.04 and 0.06 g/l, and SP values between 0.4 and 0.6 g/m^2.

Site	Land management	Slope (%)	RI (mm h^{-1})	RC (-)	TR (min)	WF (cm)	SC (g L^{-1})	SP (g m^{-2})
Ajamil	Control	17	31,1	0.00		4.5	0.00	0.0
	Cleared without livestock (A)	29	46.4	0.16	4.9	4.1	0.04	0.5
	Cleared with low pressure (B)	20	44.4	0.20	6.3	7.6	0.05	0.4
	Cleared with medium pressure (C)	25	39.9	0.25	5.0	5.0	0.06	0.6
	Cleared with high pressure (D)	22	41.7	0.31	3.1	3.3	0.04	0.4

Table 13. Mean hydrogeological and sedimentological variables extracted from rainfall simulations in Ajamil in the first (2020) and second (2021) year of monitoring. RI: rainfall intensity (mm h^{-1}), RC: Runoff coefficient (mm mm^{-1}), IR: Infiltration rate (mm h^{-1}), TR: Time to runoff (min), WF: Wetting front (cm), SC: Sediment concentration (g l^{-1}), SP: Sediment production (g m^{-2}).

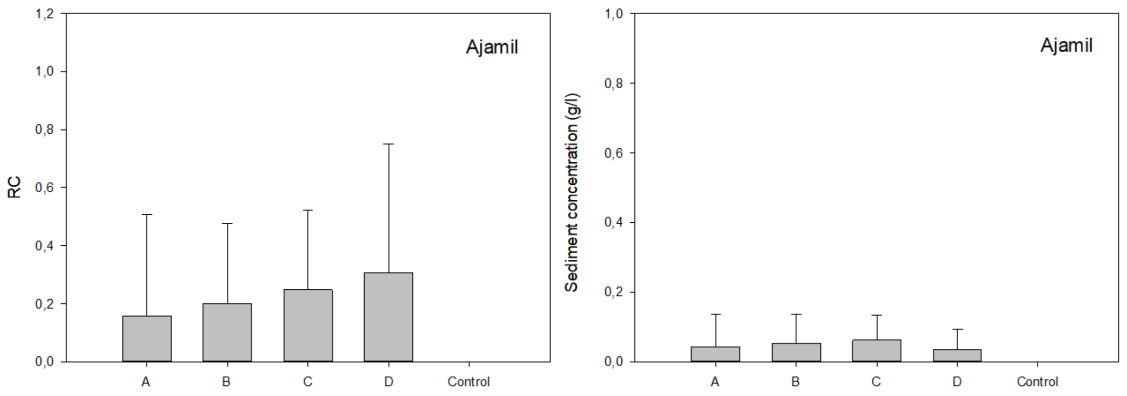


Figure 29. Figure. Mean runoff coefficient (RC) and sediment concentration for each treatment: not cleared without livestock (control), cleared without livestock (A), cleared with low level of grazing (B), cleared with medium level of grazing (C), and cleared with high level of grazing (D), in Ajamil.

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 30). 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).

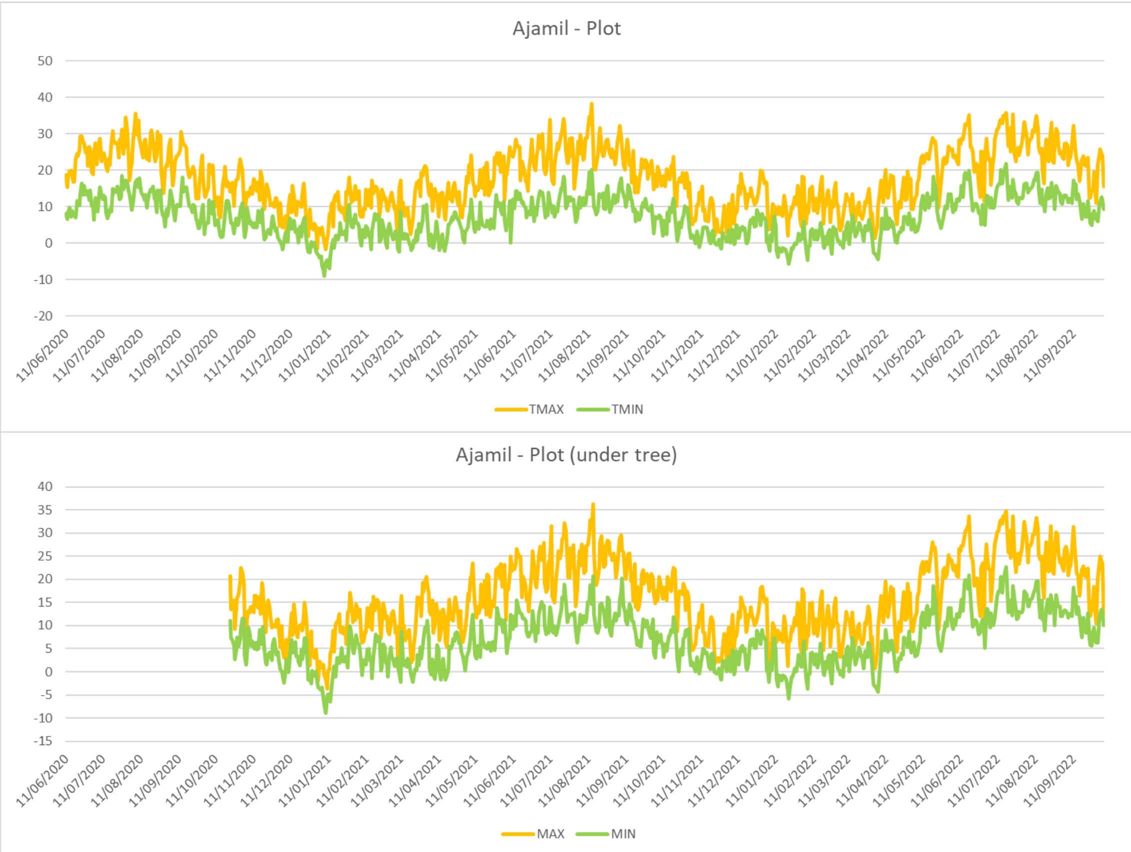


Figure 30. Daily average of minimum and maximum temperature and relative humidity in scrubland cleared experimental plot in Ajamil. T1: in the A2 experimental subplot; T2: under a tree. *It starts in October because the data logger was stolen.*

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 28-06-2022, the maximum temperature has been 36.3 ºC (14-08-2021) and the minimum -9.3 ºC (08-01-2021) (Figure 31).

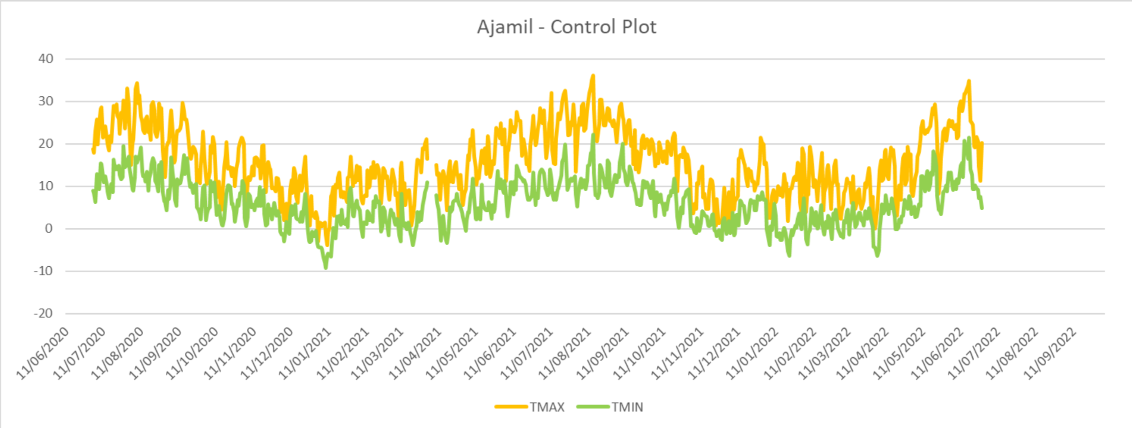


Figure 31. Daily average of minimum and maximum temperature and relative humidity in scrubland cleared experimental Control plot in Ajamil.

Figure 32 shows monthly averages of maximum temperature, minimum temperature and mean monthly precipitation for the period 06-2020 to 10-2022 (29 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, in order 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.

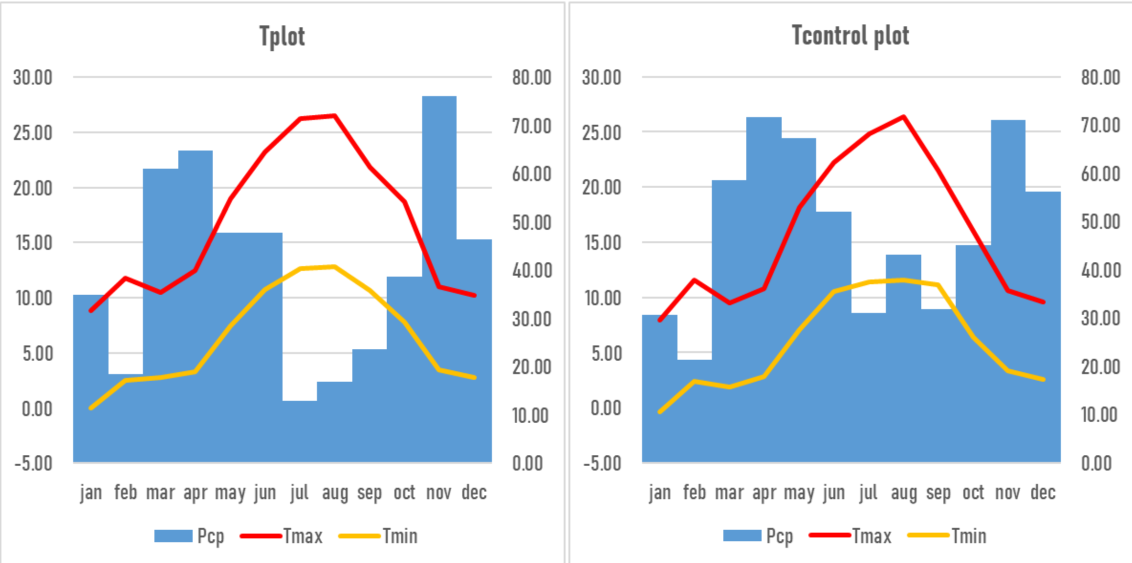


Figure 32. Climogram registered in the scrubland cleared experimental plot (Ajamil). Left: in the subplot A2, right: in the control plot.

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*.

<table>
<tr><th colspan="3">La Garcipollera (Aragon)</th></tr>
<tr><td rowspan="2">Soil</td><td>Soil characteristics</td><td>Results of soil samples in a depth of 0-10 cm are shown, comparing initial conditions (2020) and after the 1st year of monitoring (2021). 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 in 2021, except in the A plots; (ii) the higher increase in SOC stocks and higher SOC values are observed in the C plots (medium livestock pressure); (iii) all the plots show a decrease in N stocks; (iv) and related Corg/N ratios, a sharply increase is observed in all the plots. Results show an increase of SOC and a sharply increase in Corg/N ratios, and a decrease in N stocks after one year of livestock grazing.</td></tr>
<tr><td>Soil moisture</td><td>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, higher soil moisture values are recorded in the B (low livestock pressure) and control plots; (iii) seasonal differences between plots are observed.</td></tr>
<tr><td rowspan="2">Pastures</td><td>Biodiversity</td><td>Scrubland clearing had a positive significant effect in pastures because it increased significantly the cover of herbaceous species, being grasses the most positively affected (very important species for grazing). However, it also increases the bare soil cover, which may have a negative effect on soil conservation. Regarding livestock activity, medium grazing intensity showed the most positive effects in terms of diminishing the bare soil cover, increasing the herbaceous species cover and also increasing species richness. On the other hand, high grazing intensity showed the most negative effects on pastures by increasing the bare soil cover, hosting the lowest grasses cover and the lowest species richness too. Plots not submitted to livestock showed an increase in woody species over time and show the lowest species richness together with the high grazing intensity plots.</td></tr>
<tr><td>Pasture prod. and quality</td><td>There is not annual monitoring of this variable.</td></tr>
<tr><td colspan="2">Rainfall simulations</td><td>The control plots and managed without livestock plots showed limited hydrological and sedimentological response. However, the response was clearly higher in the managed plot with livestock, for both runoff and soil erosion. The highest hydrological response was in the cleared plots with higher level of grazing (C and D)</td></tr>
<tr><td colspan="2">Site meteorological conditions</td><td>Maximum, minimum temperature and relative humidity are recorded continuously from June 2020.</td></tr>
</table>

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 year of monitoring (2021). Statistical results did not show significant differences between the management plots and the control plots. Changes to be highlighted: (i) lower SOCK stocks are observed after the first monitoring year, except in the D plots (high livestock pressure) although these changes are not significant; (ii) the higher decrease in SOC stocks is observed in B plots (low livestock pressure) and control plots; (iii) all the plots show an increase in N stocks, especially in the B and Control plots; (iv) and related Corg/N ratios, an increase is observed in all the plots. Results show a decrease of SOC (except in D plots) and an increase in both N stocks and Corg/N ratios, after one year 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, higher soil moisture values are recorded in the control plots; (iii) seasonal differences between plots are observed.
Pastures	Biodiversity	Scrubland clearing had a positive effect by increasing herbaceous species cover, being grasses the most positively affected (very important species for grazing). However, due to woody species removal, species richness was diminished (especially legumes and other families as *Rosaceae*). Regarding livestock activity, plots submitted to grazing generally showed a positive effect compared to plots not submitted to grazing, which showed the highest bare soil cover and the lowest herbaceous species cover, legumes cover and species richness. Low and high grazing intensities showed the most positive effects on pastures in terms of herbaceous species cover, being grasses the most positively affected in low intensity and legumes and other families in high intensity. Nevertheless, grasses cover was the lowest in plots submitted to high grazing intensity (grasses are very important species for livestock). Species richness was similar in all the plots submitted to livestock activity.
	Pasture prod. and quality	There is not annual monitoring of this variable.
Rainfall simulations		The control plots and managed without livestock plots showed limited hydrological and sedimentological response with no runoff and no sediment except for the plot with the highest level of grazing (D).
Site meteorological conditions		Maximum, minimum temperature and relative humidity are recorded continuously from June 2020.

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 year of monitoring (2021). 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 Changes to be highlighted: (i) higher SOCK stocks are observed after the first monitoring year, except in the control plots, although these changes are not significant; (ii) the higher increase in SOC stocks is observed in A and B plots (low and medium livestock pressure); (iii) all the plots show an increase in N stocks, especially in the B and Control plots; (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 (except in the control plots) and N stocks and Corg/N ratios, after one year 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	In the initial sampling we observed that scrubland clearing had a positive significant effect in pastures because it significantly increased the cover of herbaceous species, being grasses and legumes the most positively affected (very important species for grazing). Species richness was not affected after scrubland clearing. However, in the intermediate sampling (after two years), we observed less legumes cover and less species richness in the cleared area than in the control. Scrubland clearing also increased the bare soil cover, which is not a positive effect on pastures. Regarding livestock activity, plots submitted to grazing (regardless of the intensity) generally showed a positive effect compared to plots not submitted to grazing, which showed the highest bare soil cover and the lowest herbaceous species cover, legumes cover and species richness.
	Pasture prod. and quality	There is not annual monitoring of this variable.
Rainfall simulations		The hydrological and sedimentological responses were higher in the plots under treatment than in the control plot, which showed no runoff nor soil erosion.The hydrological response increased with increasing level of grazing, but interestingly the response was similar in terms of soil erosion.
Site meteorological conditions		Maximum, minimum temperature and relative humidity are recorded continuously from June 2020.

7. References

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